Multidisciplinary Science at the Sanford Underground Research Facility

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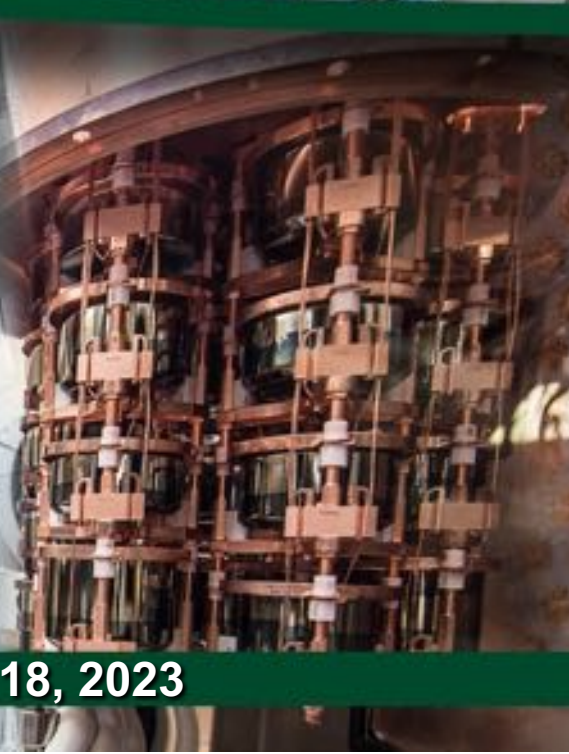
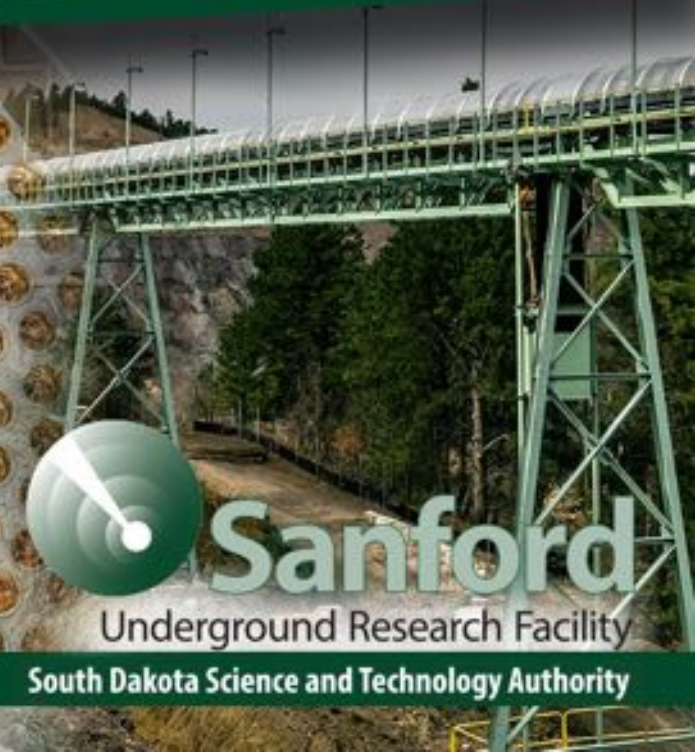


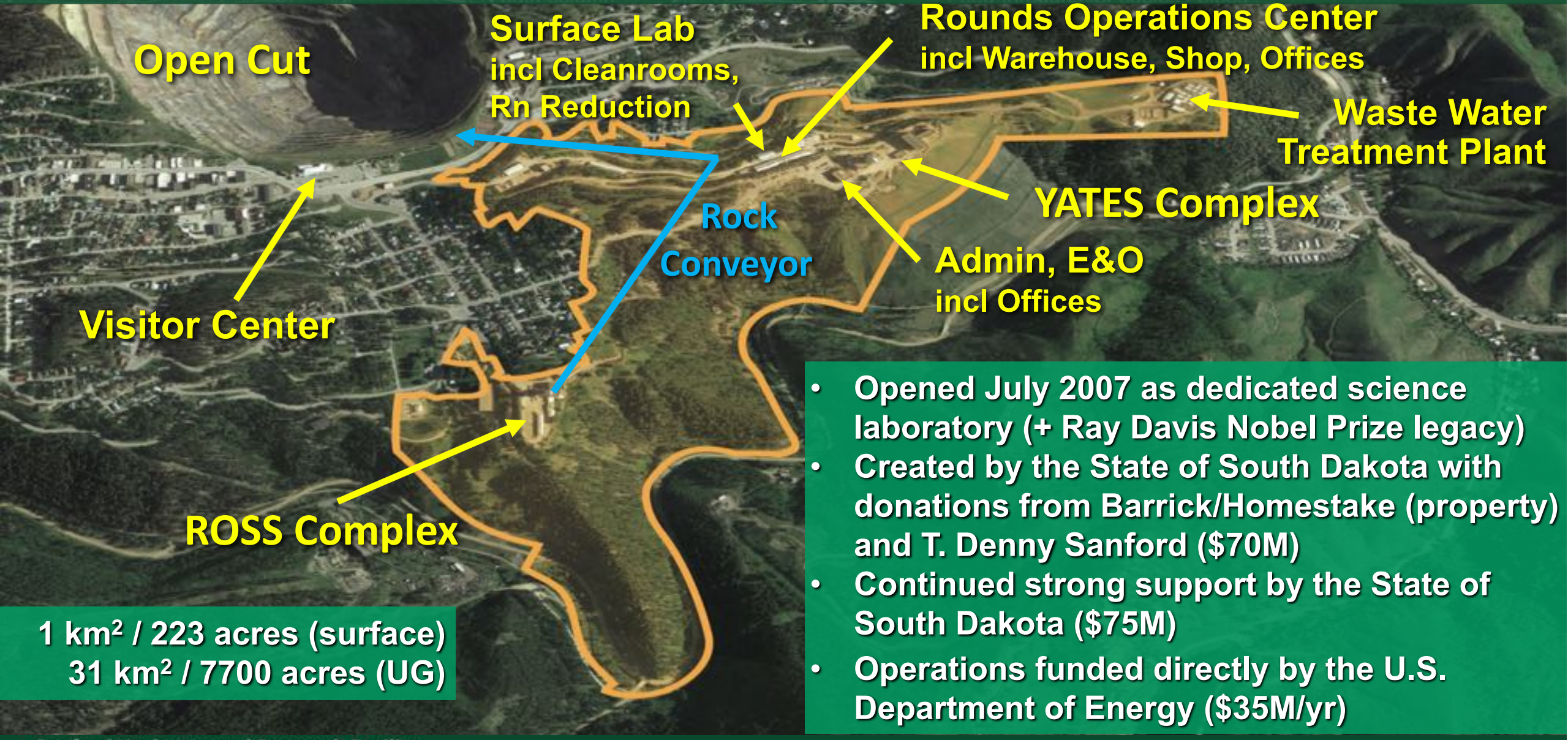


Sanford Underground Research Facility
South Dakota Science and Technology Authority

LSM Workshop, October 18, 2023

Sanford Underground Research Facility

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



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

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

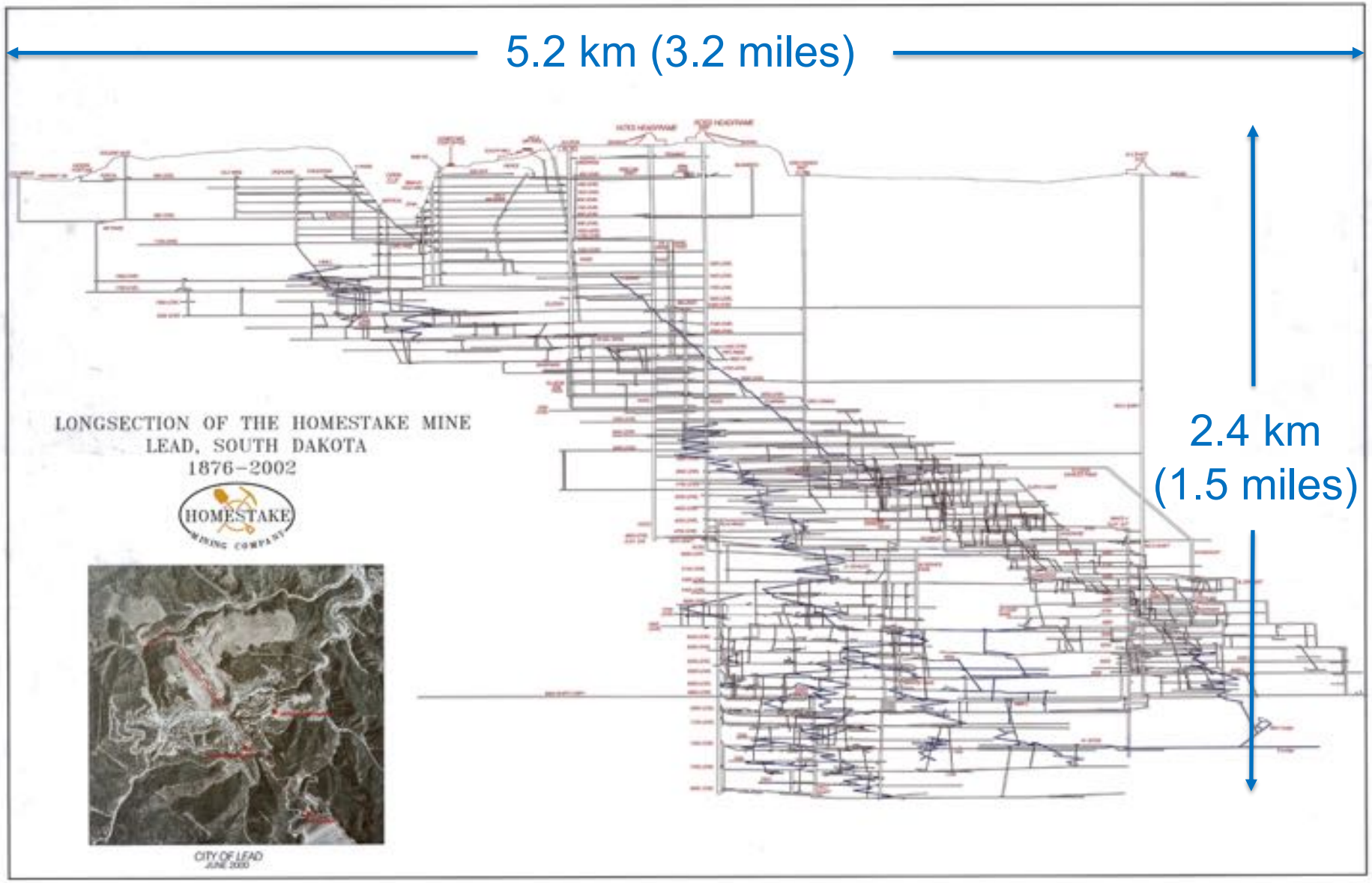
SURF Science Program

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

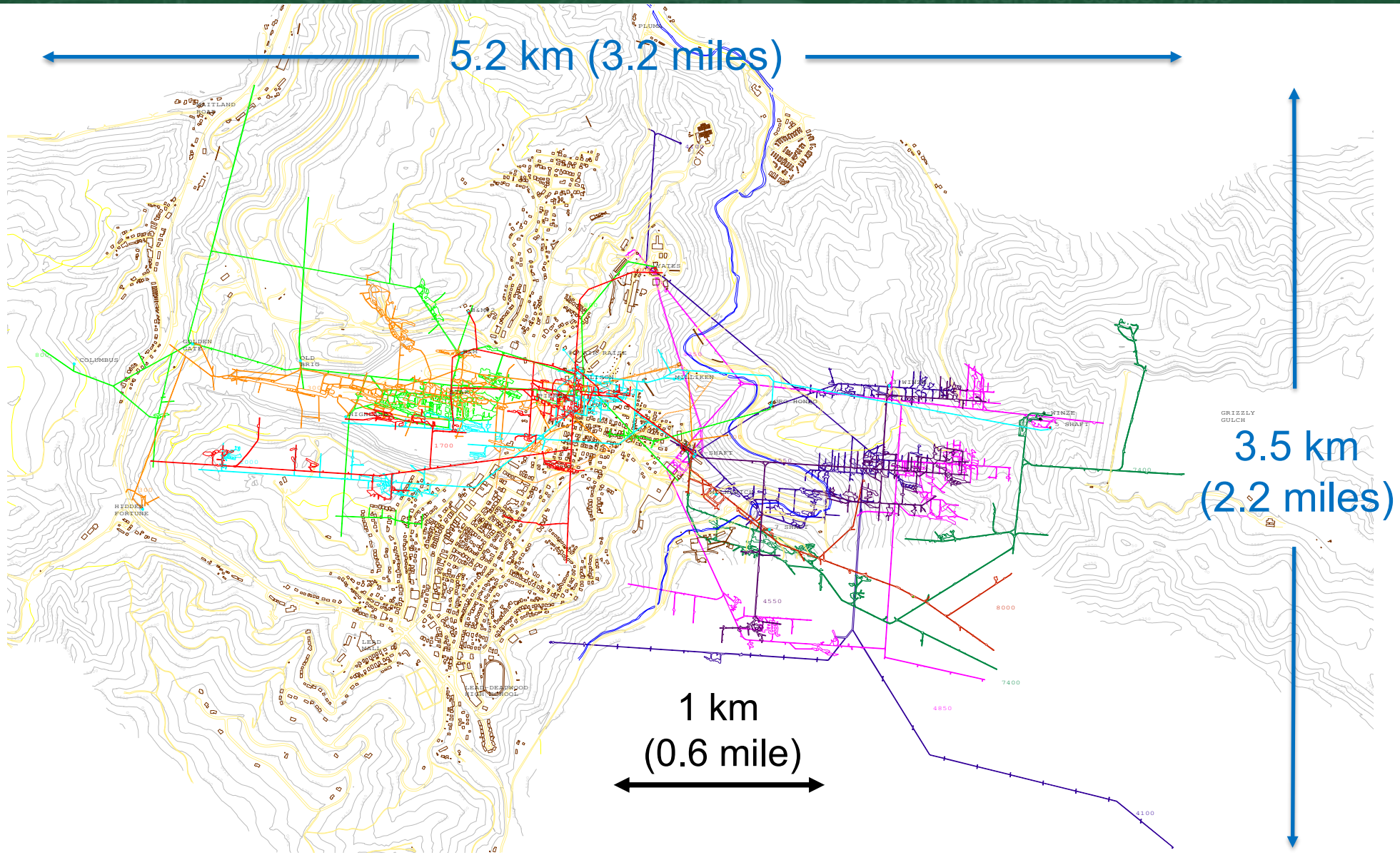
SURF Underground Lab Geography

Significant underground footprint for science



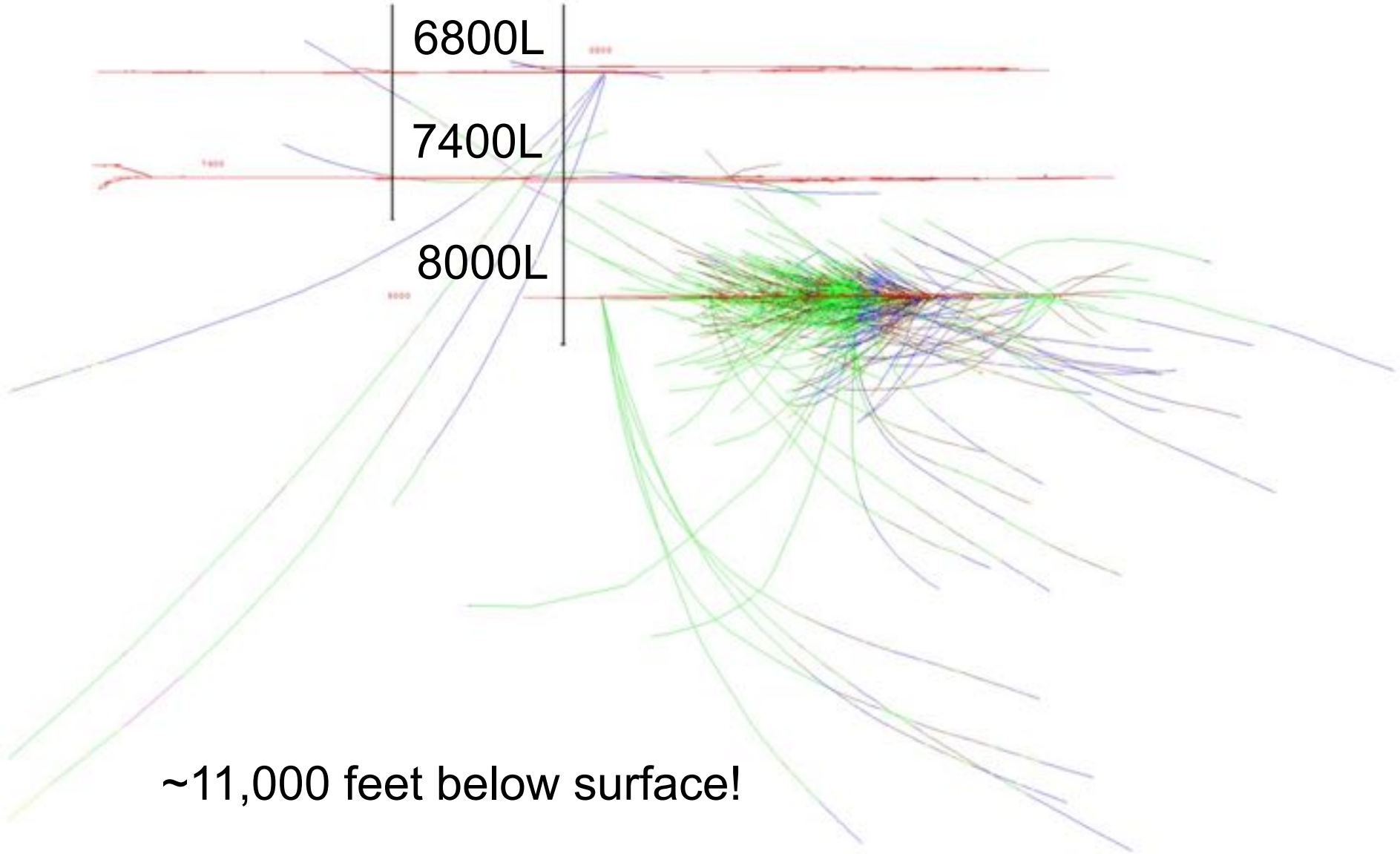
SURF Underground Lab Geography

Significant underground footprint for science



SURF Underground Lab Geography

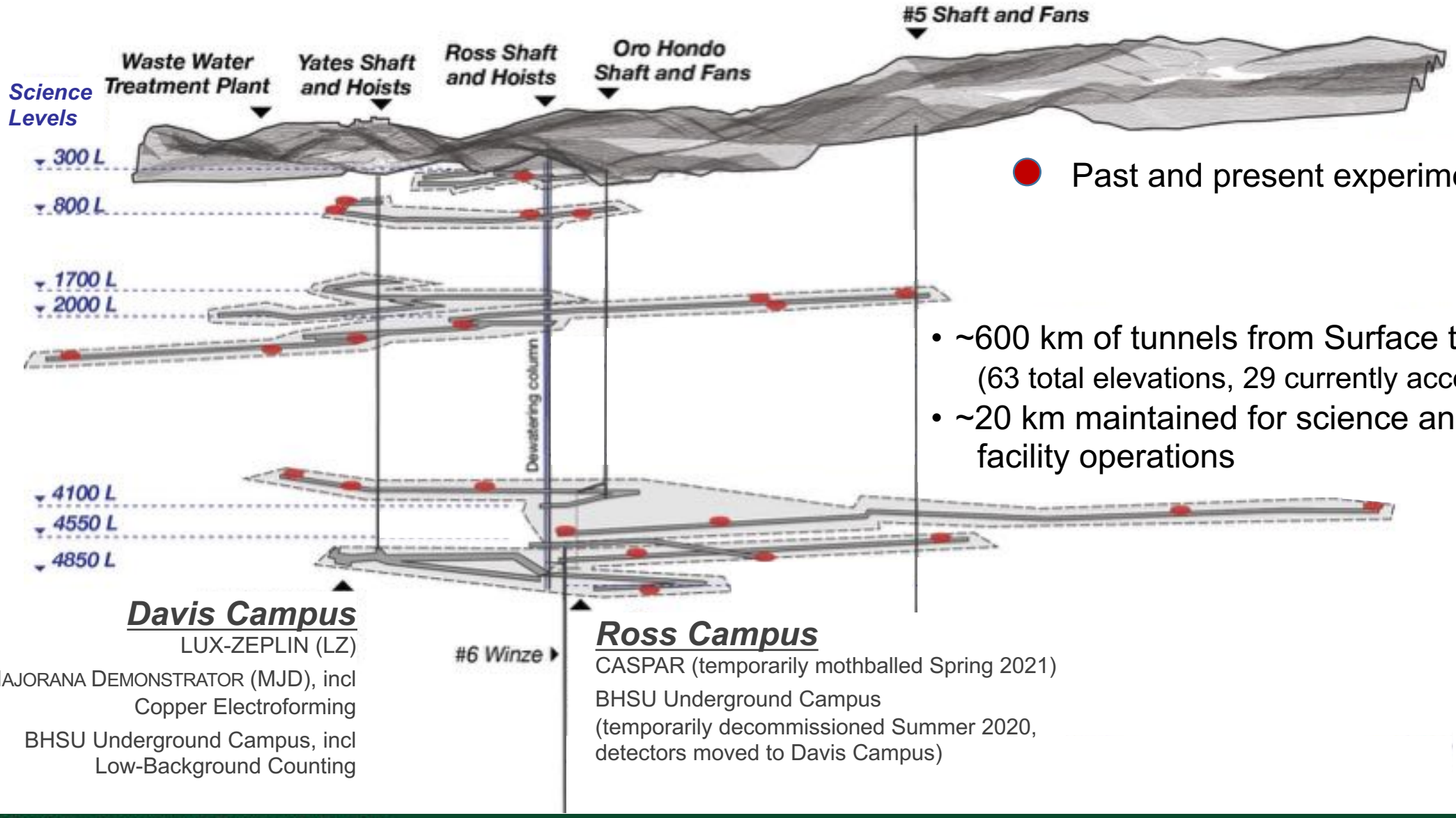
Future Possibilities to Access Existing Deep Holes?



~11,000 feet below surface!

SURF Underground Lab Geography

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



- Past and present experiment sites

- ~600 km of tunnels from Surface to 2.4 km deep
  (63 total elevations, 29 currently accessible)
- ~20 km maintained for science and facility operations

Davis Campus

LUX-ZEPLIN (LZ)

MAJORANA DEMONSTRATOR (MJD), incl Copper Electroforming

BHSU Underground Campus, incl Low-Background Counting

Ross Campus

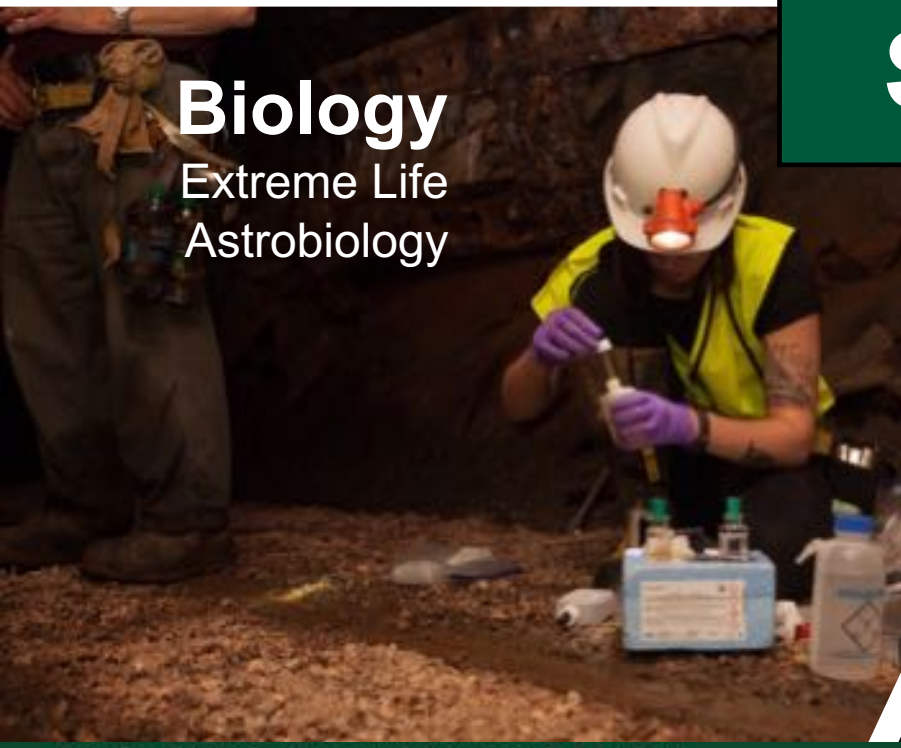
CASPAR (temporarily mothballed Spring 2021)

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

Dark Matter
LUX-ZEPLIN

Neutrinos
MAJORANA DEMONSTRATOR
LBNF /DUNE

Science Program



Biology
Extreme Life
Astrobiology

Geology
Geothermal Energy
Seismic Studies

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*

Total = 31 groups
21 Active Projects
64 Total Groups Since 2007

* Denotes proprietary group

Significant interest from others
(23 groups in 2022)

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

Biology

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

Geology

- DEMO-FTES – *Geothermal*
- 3D DAS – *Seismic monitoring using fiber*
- Core Archive* – *Mainly gold deposits*
- Hydro Gravity – *Gravity for water tables*
- BH Seismic – *Global monitoring*
- BH Geochemistry – *Exobiology*
- Transparent Earth – *Seismic arrays*

Engineering

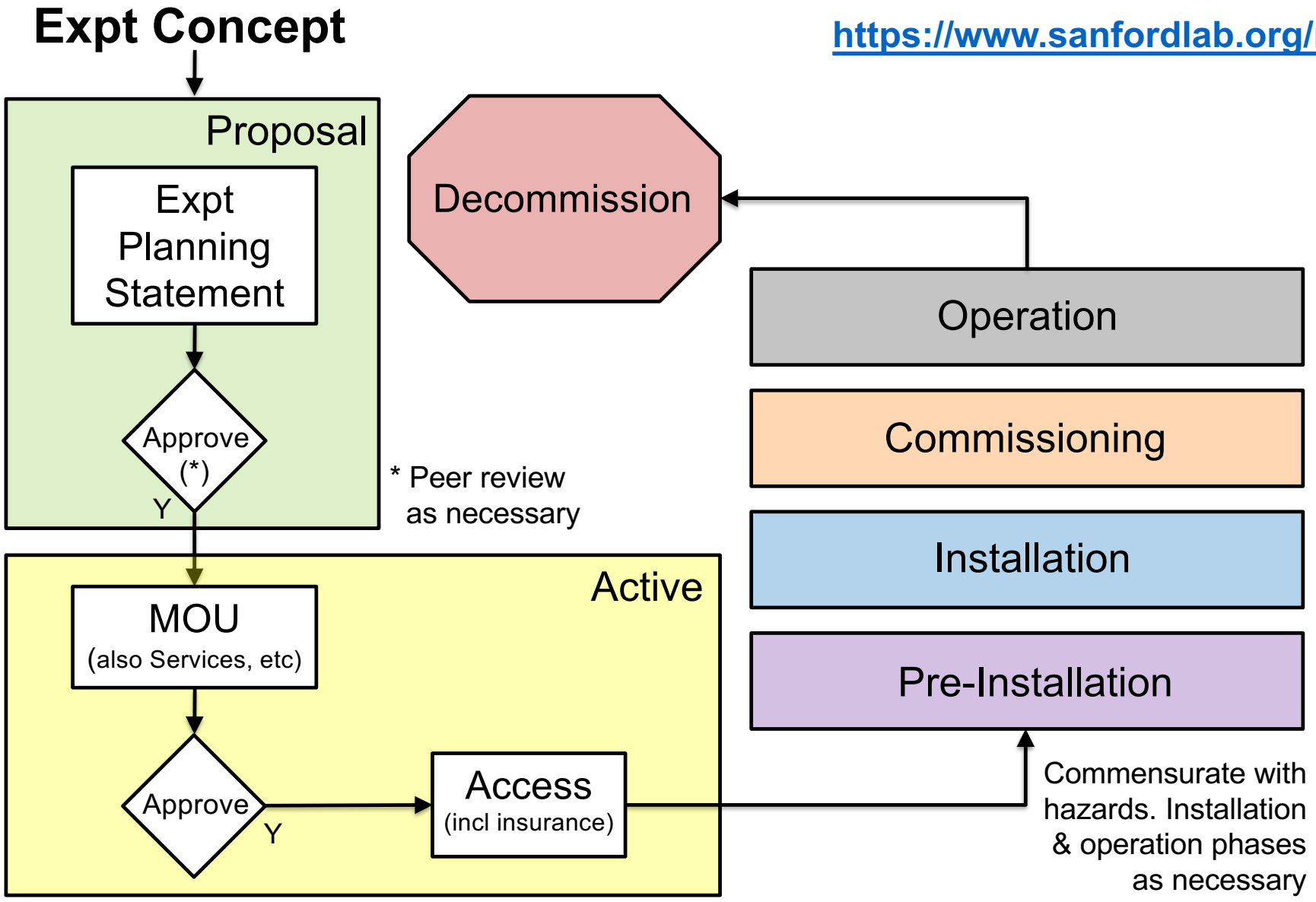
- Xilinx, Inc* – *Chip error testing*
- Thermal Breakout – *In-situ stress*
- Shotcrete – *Mining safety*
- Env Monitoring – *Ventilation airflow*
- Caterpillar* – *Mining processes*
- Blast Monitoring – *LBNF-related*
- PDR – *Sensors*
- NIOSH – *Heat studies*

SURF High-Impact Science

- Characterization of thermostable cellulases produced by *Bacillus* and *Geobacillus* strains, G. Rastogi, A. Bhalla, A. Adhikari, K. M. Bischoff, S. R. Hughes, L. P. Christopher, R. K. Sani *Bioresource Technology* **101**, 8798 (2010) doi: 10.1016/j.biortech.2010.06.001.
- Improved Lignocellulose Conversion to Biofuels with Thermophilic Bacteria and Thermostable Enzymes, A. Bhalla, N. Bansal, S. Kumar, K. M. Bischoff, R. K. Sani *Bioresource Technology* **128**, 751 (2013) doi: 10.1016/j.biortech.2012.10.145.
- Insights into the phylogeny and coding potential of microbial dark matter, Rinke C, Schwientek P, Sczyrba A, Ivanova NN, Anderson IJ, Cheng JF, Darling A, Malfatti S, Swan BK, Gies EA, Dodsworth JA, Hedlund BP, Tsiamis G, Sievert SM, Liu WT, Eisen JA, Hallam SJ, Kyrpides NC, Stepanauskas R, Rubin EM, Hugenholtz P, Woyke T. *Nature* **499**:431-437 (2013) doi: 10.1038/nature12352.
- Obtaining genomes from uncultivated environmental microorganisms using FACS-based single-cell genomics, Rinke C, Lee J, Nath N, Goudeau D, Thompson B, Poulton N, Dmitrieff E, Malmstrom R, Stepanauskas R, Woyke T. *Nature Protocols* **9**:1038-1048 (2014) doi: 10.1038/nprot.2014.067.
- First Results from the LUX Dark Matter Experiment at the Sanford Underground Research Facility, D. S. Akerib *et al*. (LUX Collaboration) *Phys. Rev. Lett.* **112**, 091303 (2014) doi: 10.1103/PhysRevLett.112.091303.
- Results on the Spin-Dependent Scattering of Weakly Interacting Massive Particles on Nucleons from the Run 3 Data of the LUX Experiment, D. S. Akerib *et al.* (LUX Collaboration) *Phys. Rev. Lett.* **116**, 161302 (2016) doi: 10.1103/PhysRevLett.116.161302.
- Results from a Search for Dark Matter in the Complete LUX Exposure, D.S. Akerib *et al*. (LUX Collaboration) *Phys. Rev. Lett.* **118**, 021303 (2017) doi: 10.1103/PhysRevLett.118.021303.
- New limits on Bosonic Dark Matter, Solar Axions, Pauli Exclusion Principle Violation, and Electron Decay from the MAJORANA DEMONSTRATOR, N. Abgrall *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **118**, 161801 (2017) doi: 10.1103/PhysRevLett.118.161801.
- First Searches for Axions and Axionlike Particles with the LUX Experiment, D. S. Akerib *et al*. (LUX Collaboration) *Phys. Rev. Lett.* **118**, 261301 (2017) doi: 10.1103/PhysRevLett.118.261301.
- Search for Neutrinoless Double-ß Decay in ^{76}Ge with the MAJORANA DEMONSTRATOR, C. E. Aalseth *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **120**, 132502 (2018) doi: 10.1103/PhysRevLett.120.132502.
- First Limit on the Direct Detection of Lightly Ionizing Particles for Electric Charge as Low as e/1000 with the MAJORANA DEMONSTRATOR, S. I. Alvis *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **120**, 211804 (2018) doi: 10.1103/PhysRevLett.120.211804.
- Measurement of Low-Energy Resonance Strengths in the ^{18}O(α,γ)^{22}Ne Reaction, A.C. Dombos *et al*. (CASPAR Collaboration) *Phys. Rev. Lett.* **128**, 162701 (2022) doi: 10.1103/PhysRevLett.128.162701.
- Search for Spontaneous Radiation from Wave Function Collapse in the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **129**, 080401 (2022) doi: 10.1103/PhysRevLett.129.080401.
- Search for Solar Axions via Axion-Photon Coupling with the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **129**, 081803 (2022) doi: 10.1103/PhysRevLett.129.081803.
- Final Result of the MAJORANA DEMONSTRATOR's Search for Neutrinoless Double-β Decay in ^{76}Ge, I. J. Arnquist *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **130**, 062501 (2023) doi: 10.1103/PhysRevLett.130.062501.
- First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment, J. Aalbers *et al*. (LZ Collaboration) *Phys. Rev. Lett.* **131**, 041002 (2023) doi: 10.1103/PhysRevLett.131.041002.
- Constraints on the Decay of ^{180m}Ta, I. J. Arnquist *et al*. (MAJORANA Collaboration), *Phys. Rev. Lett.* **131**, 152501 (2023) doi: 10.1103/PhysRevLett.131.152501.
- Exotic dark matter search with the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration) submitted to *Phys. Rev. Lett.*

SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework



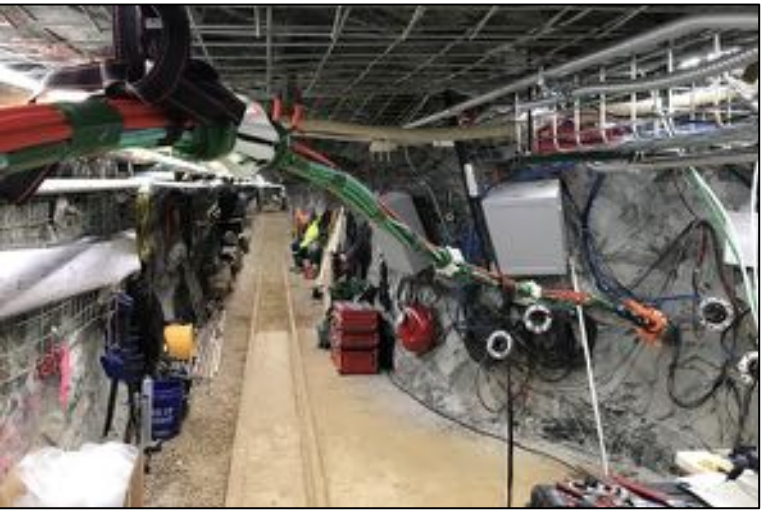
https://www.sanfordlab.org/researchers/proposal-guidelines

SURF Science Program

Biology / Geology / Engineering (Multiple Levels)

Life Science:

- Explorations into the diversity and extent of life, practical applications such as biofuels. Testing equipment for Mars mission.
- **Status:** 800L, 1700L, 2000L, 4100L, 4850L.



Earth Science:

- Topics include seismic studies, UG monitoring, geothermal testing, mineral deposit studies
- **Status:** Surface, 800L, 1700L, 2000L, 4100L, 4850L.

Engineering:

- Topics include soft error rate chip testing, thermal applications, UG hazard monitoring, reinforced shotcrete, technology R&D
- **Status:** Surface, 1700L, 4100L, 4850L.

Biology: DeMMO
Deep Mine Microbial Observatory

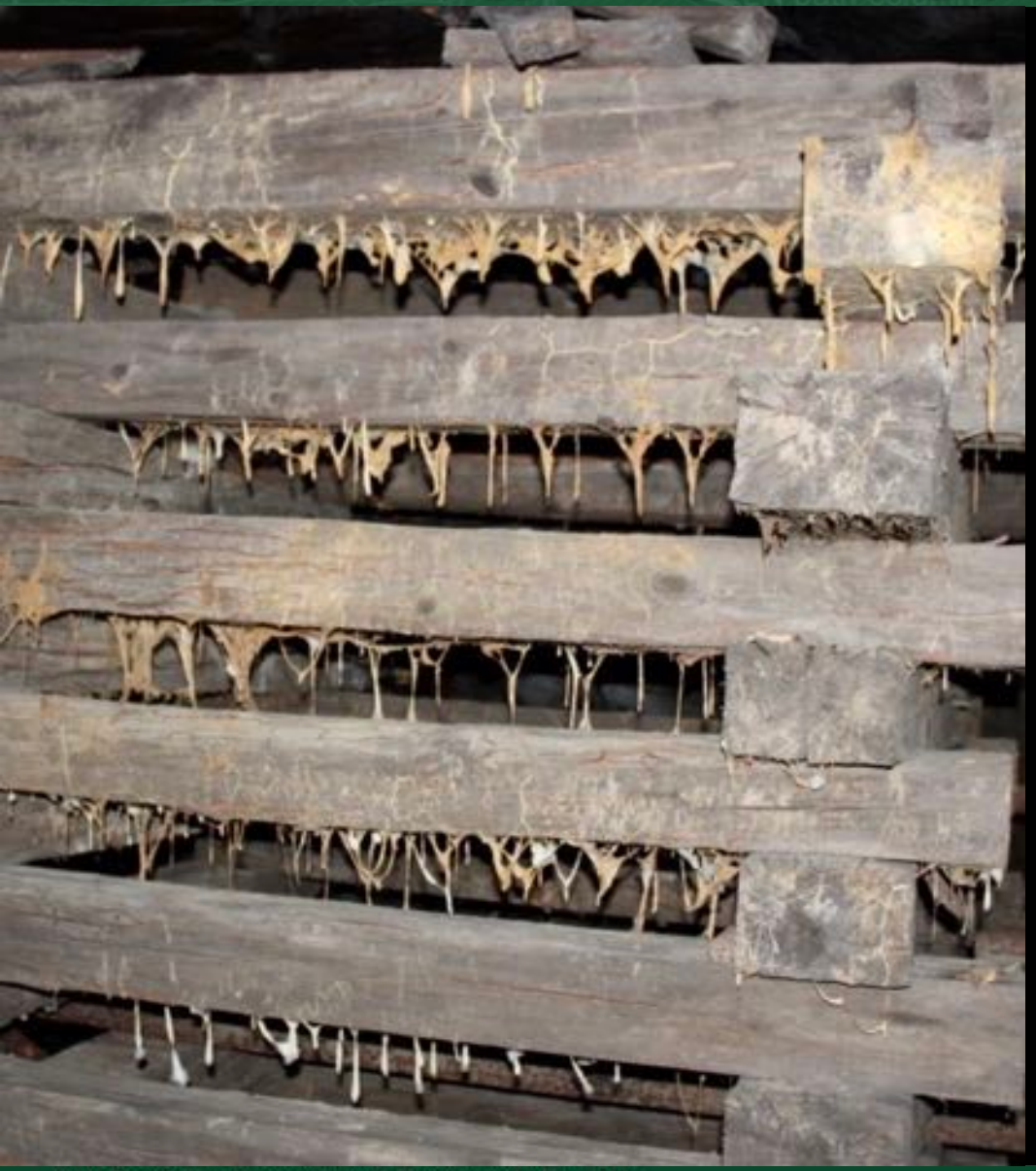
- **Science Goal:** Explore and understand rock-hosted microbial ecosystems by performing long-term water sampling from drill core holes (new and legacy), testing for life in drill core (new); also test various substrates, incl electrode-assisted cultivation (bioreactor).
- **Collaboration:** DeMMO (7 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 from 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

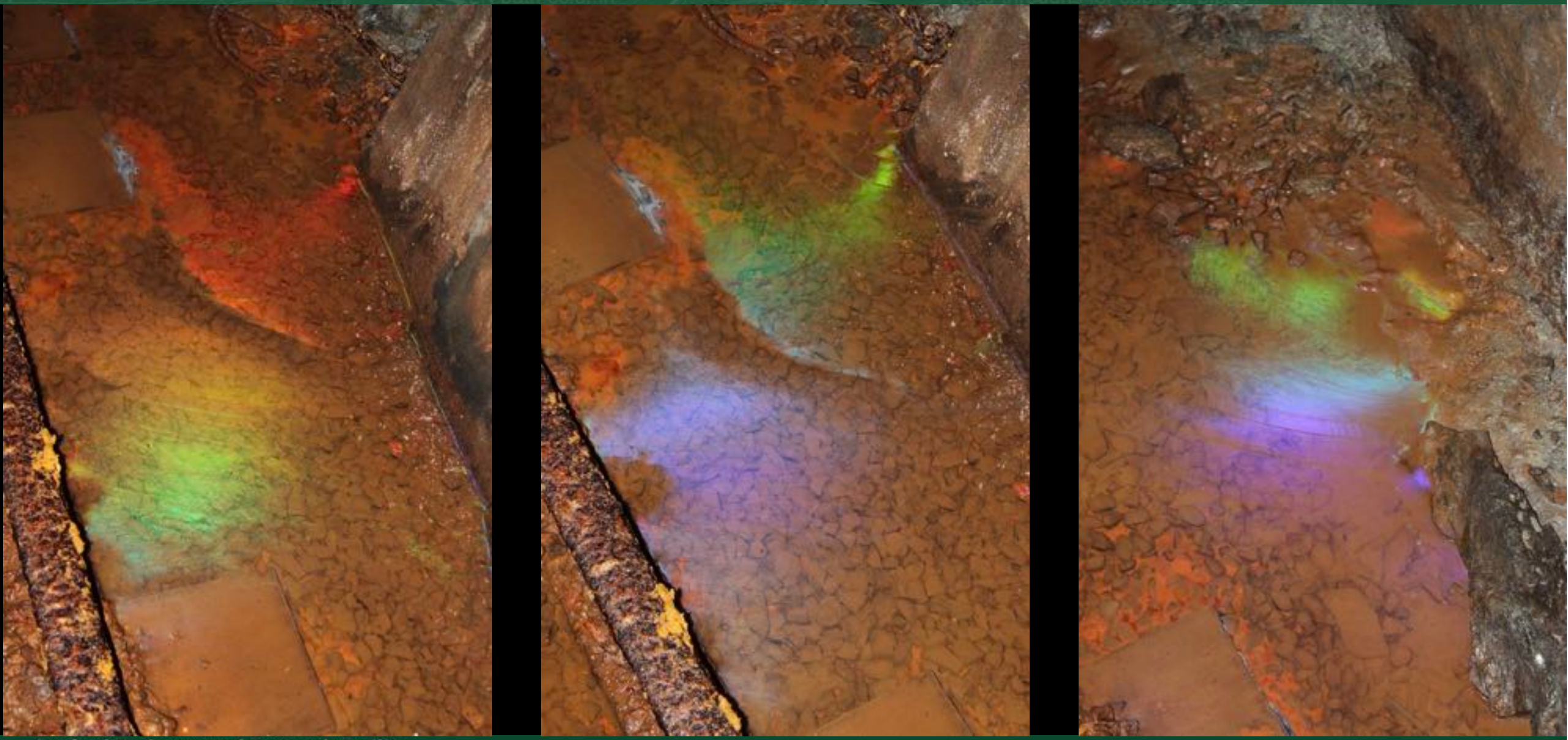
SURF Biology in Action

Biology / Geology / Engineering (Multiple Levels)



SURF Biology in Action

Biology / Geology / Engineering (Multiple Levels)



BHSU Biologists in Action

Biology / Geology / Engineering (Multiple Levels)

Geology: 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:**
  - Expected onsite starting Oct/Nov 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 to upgrade electrical infrastructure for water heaters.
- **Future:**
  - SURF activities for ~1 year (Oct/Nov 2023 – Dec 2024).
  - Interest from community, incl DOE-SC Basic Energy Sciences (e.g., CUSSP ~2024 through 2027) and ARPA-E (e.g., Eden).

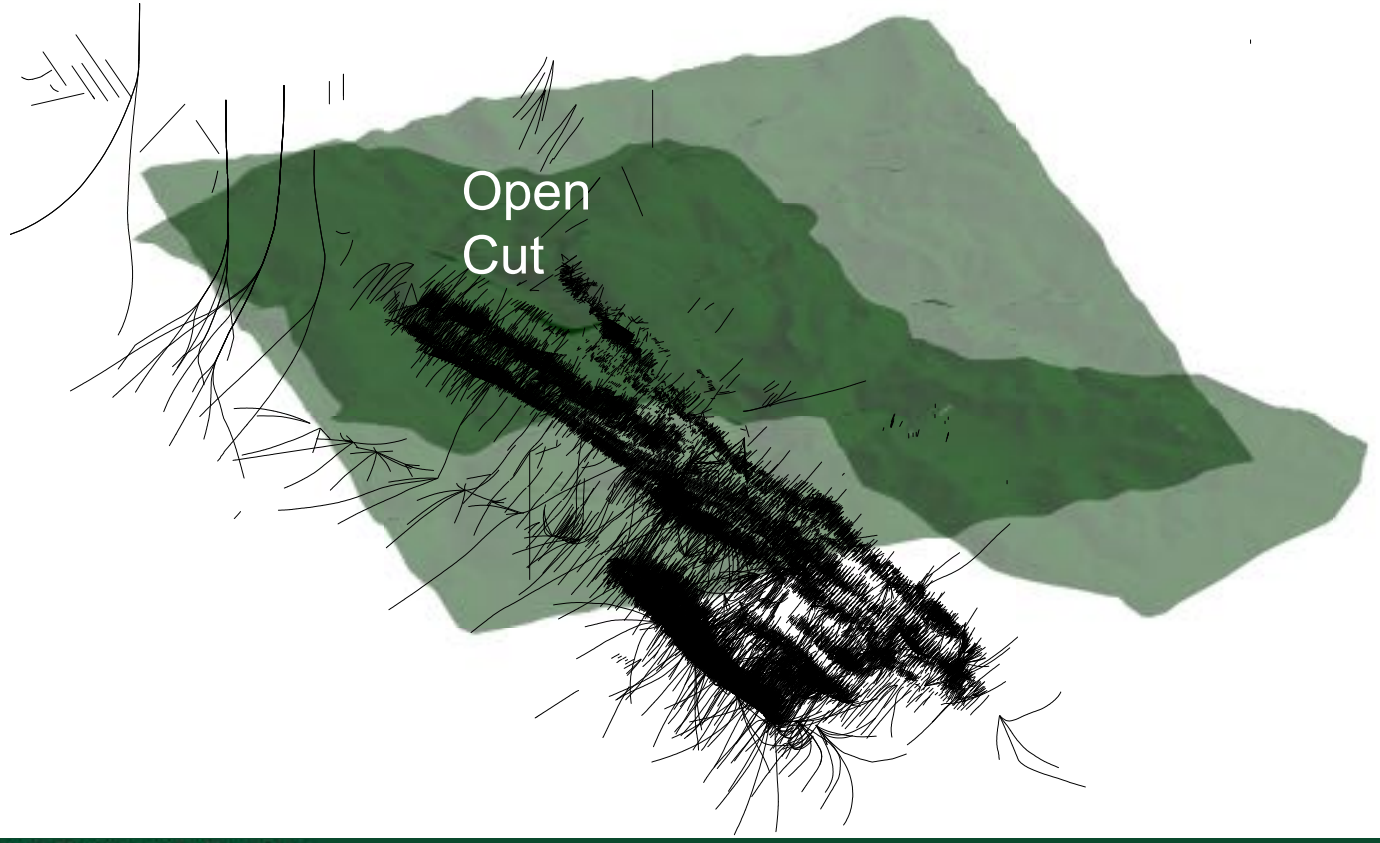
SIMFIP tool installed for EGS/SIGMA-V

DOE-SC BES program manager visit

SURF Science Opportunities – Drill Core

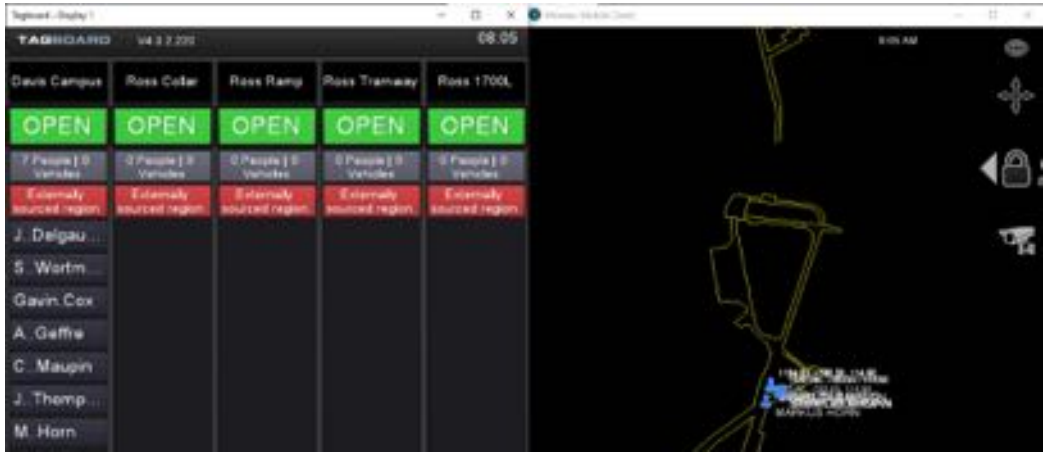
Core repository

- 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/



Engineering: 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 234, incl customer groups), 38 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^2), ~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.



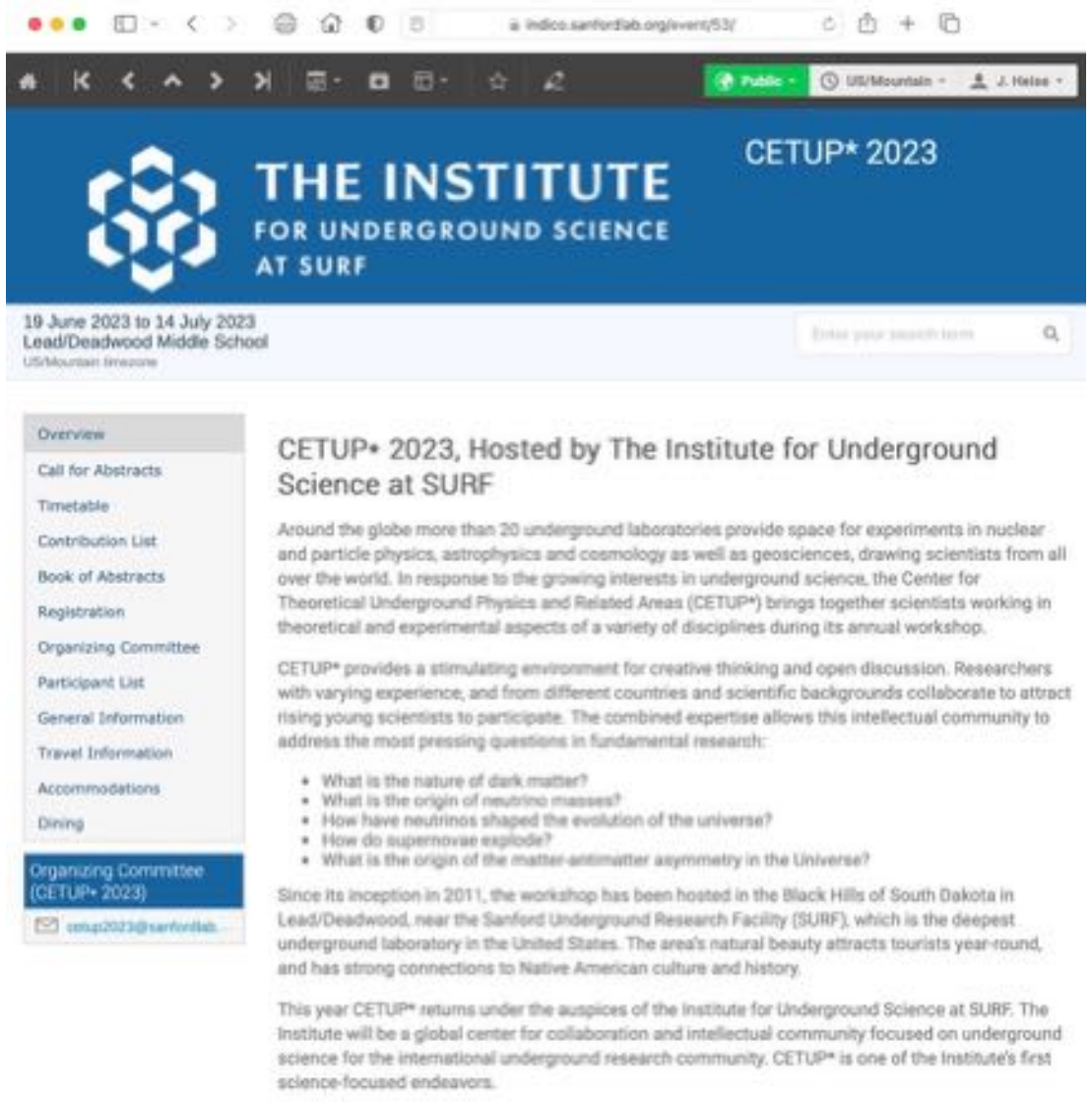
SURF's Road to Multi-Disciplinary Science

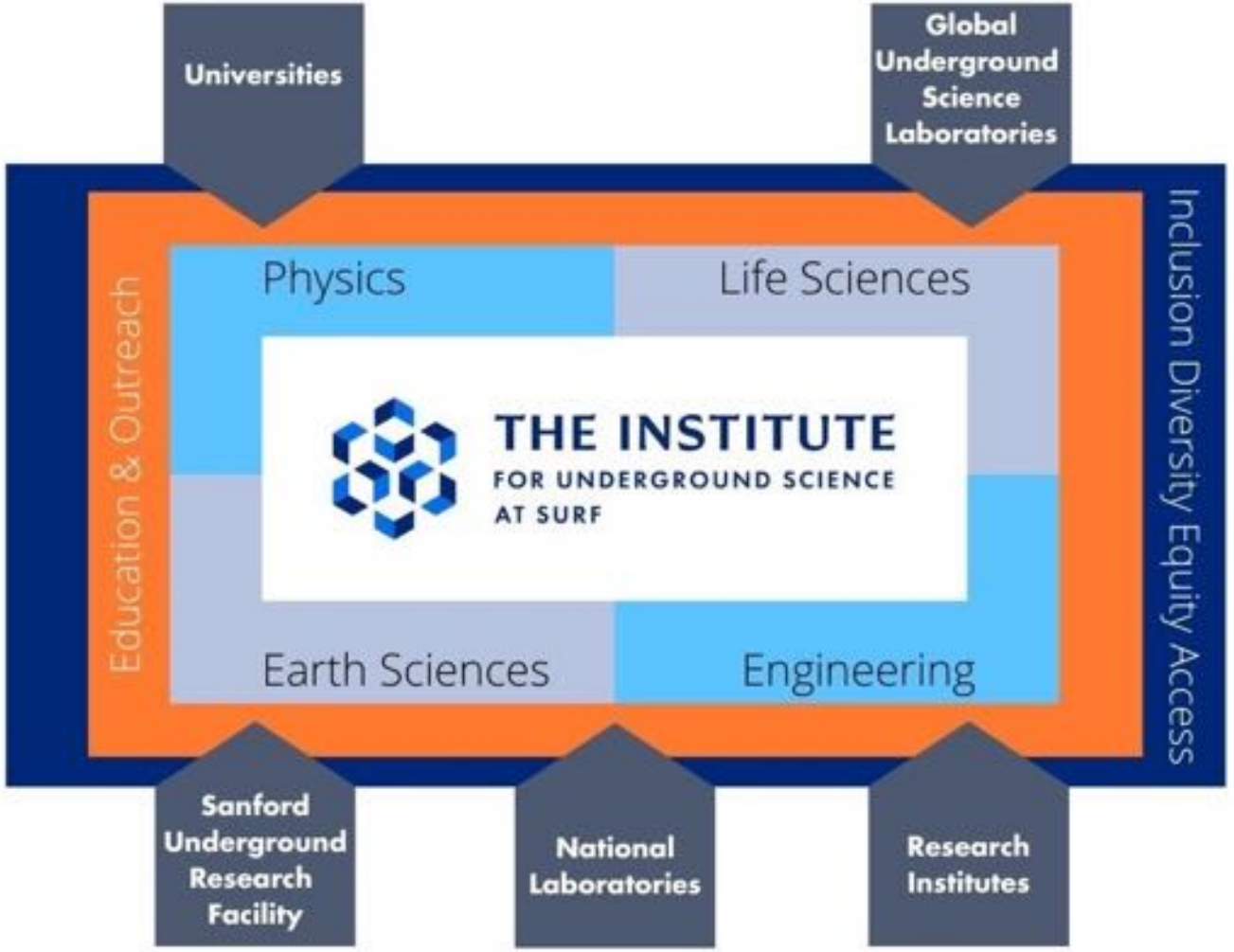
Broad science program right from the start

- 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 (current 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!**

Underground Science Community Engagement

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





Sanford Underground Research Facility

Thank You!

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 (^{180m}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 >80% complete, science starts early 2029)
- **4850L Expansion:** Up to 2x caverns (100m L x 20m W x 24m H), develop in 2 phases (funding for first phase in-hand), excavation complete by ~2030
- **7400L Expansion:** One or more caverns (75m L x 15m W x 15m H), funding/schedule TBD

Sanford Underground Research Facility
Physical characteristics

- **Property:** 1 km^2 (surface) with ~1600 m^2 storage (incl drill core) and 355 m^2 staging/assembly space. 31 km^2 (underground) with ~600 km of tunnels extending to over 2450 m below ground.
- **Access:** Vertical; personnel and materials via one of two main shafts (Yates Shaft currently undergoing extensive maintenance). Facility dedicated to science.
  - Yates Shaft: 1.39 × 3.77 × 2.58 m, 4.8 tonnes (lengths up to 7.3 m possible at reduced payload mass)
  - Ross Shaft: 1.40 × 3.70 × 3.62 m, 6.1 tonnes (lengths up to 8.2 m possible at reduced payload mass)
- **Depth:** Deepest lab in U.S. Main UG level = 4850L (1490 m, 4300 mwe), muon flux = 5.31×10^{-5} $\mu/m^2/s$. Several other UG elevations for science: 300L, 800L, 1700L, 2000L, 4100L, 4550L.
- **Space:**
  - Surface (science space, as low as class 10-100): 210 m^2 (cleanrooms = 92 m^2 / 914 m^3)
  - 4850L (science space, as low as class 100): Davis Campus (1018 m^2 / 4633 m^3), Ross Campus (920 m^2 /3144 m^3)
  - Radon-reduction: Surface = 2200x reduction @ 300 m^3/h (Ateko), Davis = 700x reduction @ 150 m^3/h (SD Mines)
- **Bkgds** (4850L): Radon = 300 Bq/m^3, gamma = 1.9 $\gamma/cm^2/s$, neutron = 1.7×10^{-2} $n/m^2/s$.
- **Utilities:**
  - Power = 24,000 kW capacity (20,000 kW available now, 15,000 kW in FY27); Standby = 3 diesel generators (390 kW)
  - Chilled water (2x 246 kW), purified water (37.8 lpm), compressed air (up to 1100 scfm, 140 scfm at Davis Campus)
  - Network = 20 Gbps internally, 10 Gbps externally (100 Gbps planned). WiFi available surface + underground.

The Road to SURF

Laying the (under)ground work for a dedicated U.S. underground laboratory

1876 - 2003 **Mining**

- Homestake Mining Company: 41M oz (1275 metric tonnes) gold
- Mining ceased Dec 2001, decommissioned by 2002, pumps off 2003

1965 - 2001 **Early Science**

- Ray Davis: World's first solar neutrino detector
- "Solar Neutrino Problem" lasted 30 years, resolved in 2001 (SNO)
- Nobel Prize awarded to Davis in 2002 (SNO award in 2015)

2000 - 2007 **Dedicated Underground Science Laboratory**

- NUSEL site at Homestake proposed by scientific community 2000/2001
- NSF refined selection process, candidate sites incl: Cascades/WA, Henderson/CO, Kimbalton/VA, San Jacinto/CA, Soudan/MN, WIPP/NM
- Barrick Gold donates Homestake Mine to South Dakota in April 2006
- T. Denny Sanford donates $70M in June 2006
- Homestake selected by NSF as Deep Underground Science & Engineering Lab (DUSEL) in July 2007

The Road to SURF

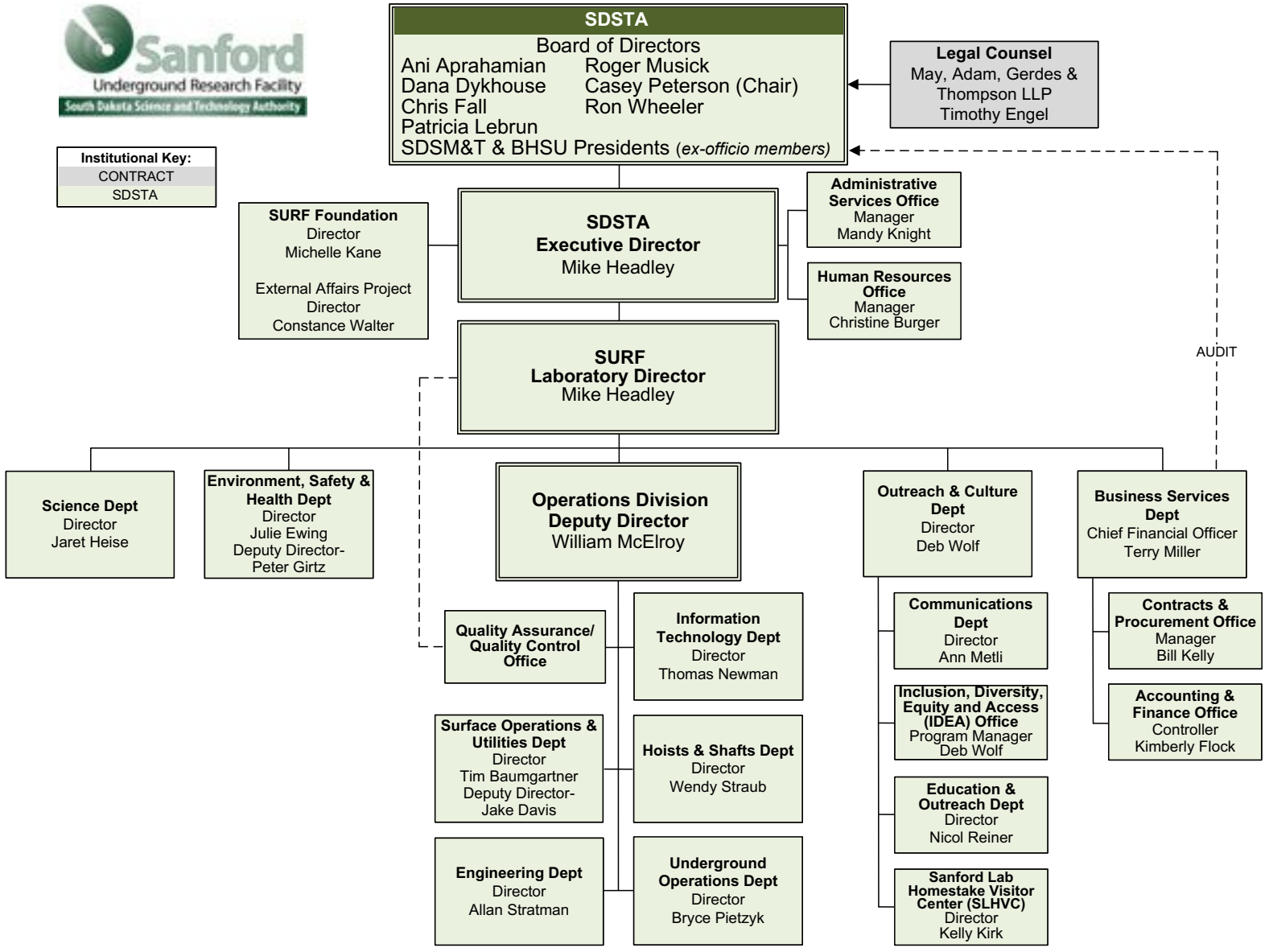
Laying the (under)ground work for a dedicated U.S. underground laboratory

2007	Homestake selected. Ross Shaft re-entry begins, science begins (resumes!)
2008	Underground dewatering begins, high-water mark 4530 feet below surface.
2009	Yates Shaft re-entry and construction on 4850 Level begins.
2010	Davis Campus excavation completed (17 ktonnes excavated), Surface Laboratory renovation complete. National Science Board terminates DUSEL NSF funding.
2011	First UG physics lab begins operation (MJD Cu e-forming). DOE funds operation.
2012	Experiments deploy at 4850L Davis Campus. Ross Shaft refurb begins.
2013	First major results from SURF science (LUX dark matter search).
2014	Ross Campus renovations begin.
2015	Experiments deploy at 4850L Ross Campus.
2016	More major results from SURF science, first major experiment completes data.
2017	UG accelerator starts ops, LBNF/DUNE groundbreaking. Surface Lab refurb.
2018	Davis Campus refurb (incl Rn-reduction system), LBNF construction starts.
2019	DOE 5-Yr Cooperative Agreement (operations funding increase + infrastructure).

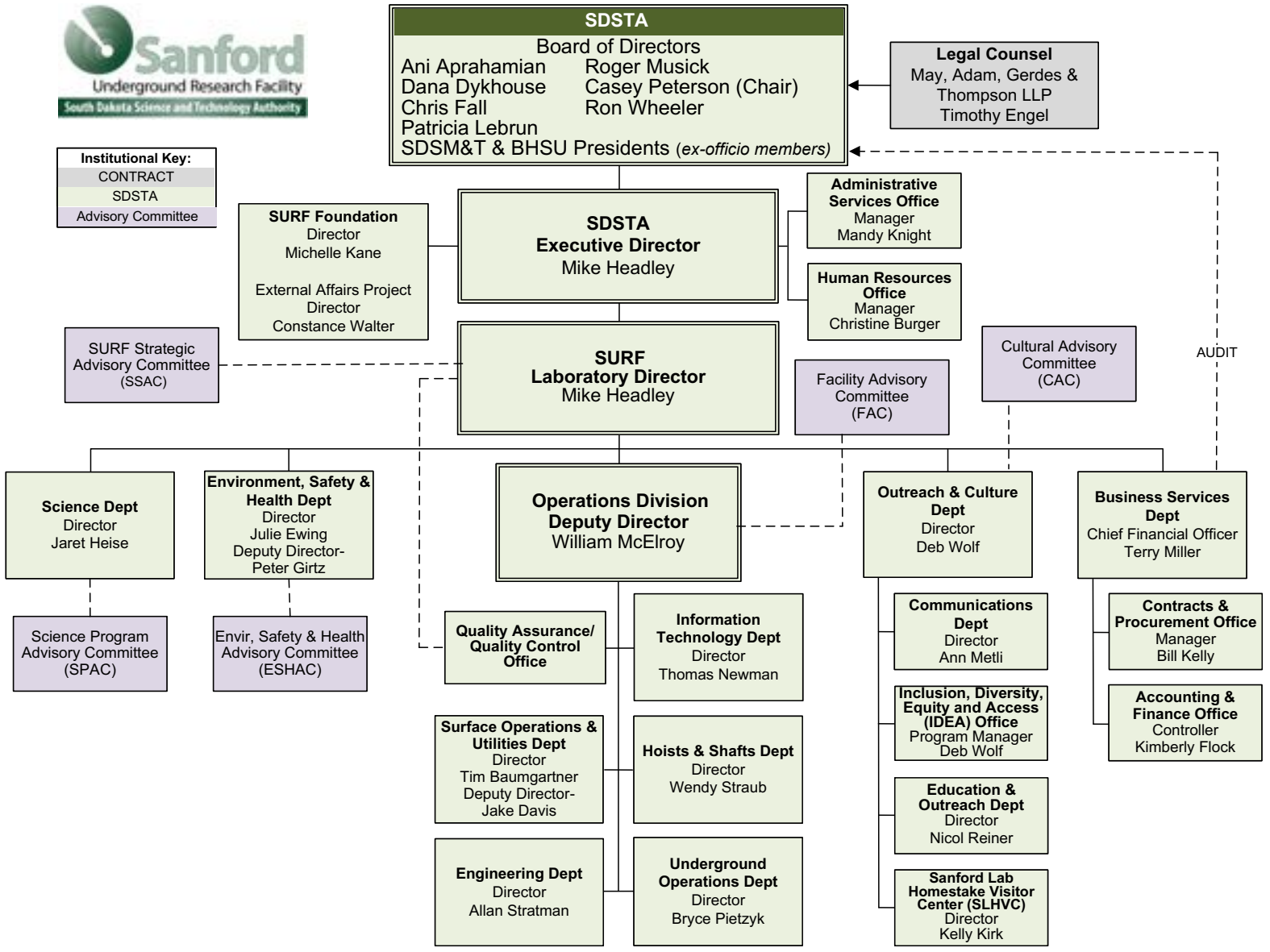
Sanford Underground Research Facility

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

SDSTA Organization Structure



SDSTA Organization Structure



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*

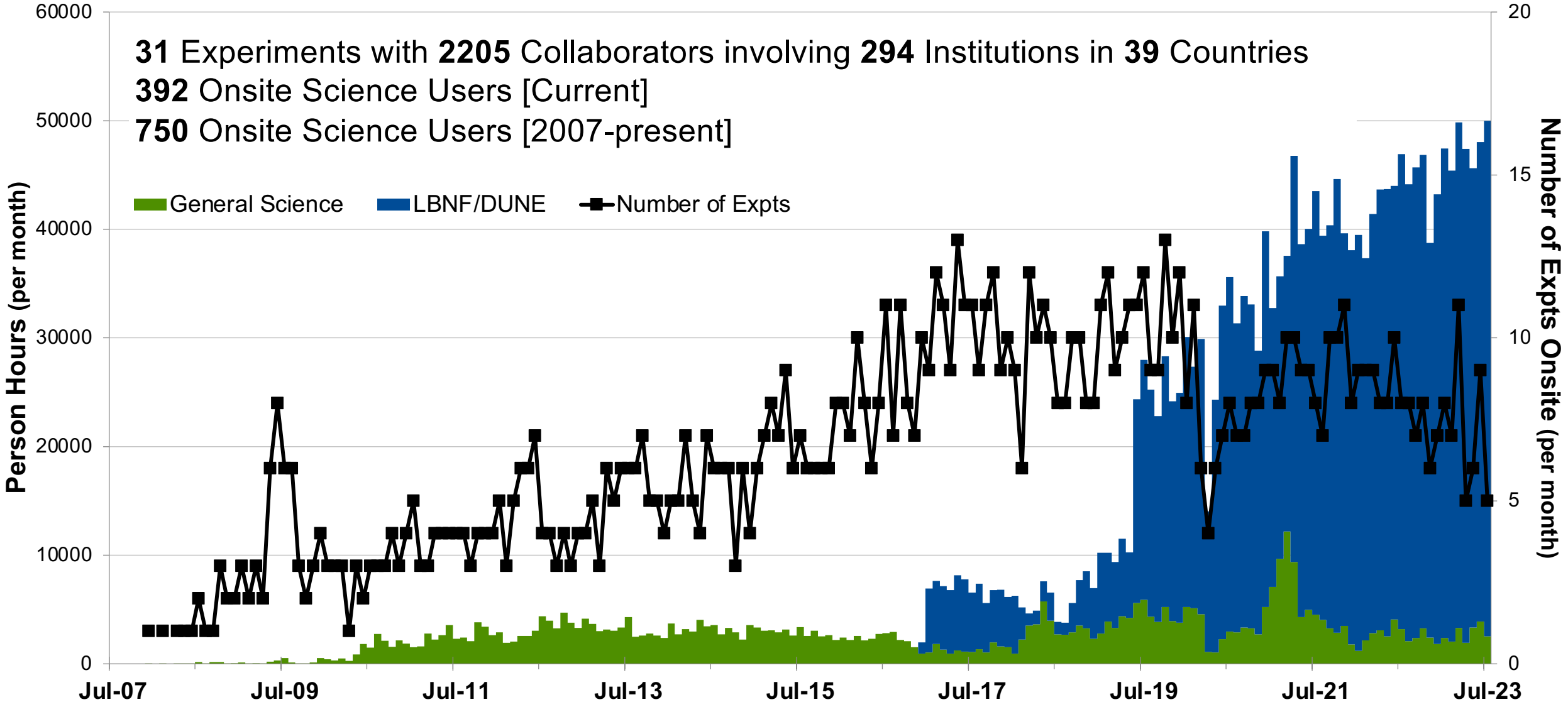
SURF Experiment Implementation Program

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

SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



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 ~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.

1. Brittany Kruger (DRI/**Chair**)
2. Jared Thompson (SD Mines/**Secretary**)
3. Mark Hanhardt (SDSTA)
4. Sarah Keenan (SD Mines)
5. Samuel Meijer (LANL)
6. Brianna Mount (BHSU)
7. Megan Smith (LLNL)
8. Frank Streider (SD Mines)
9. David Woodward (LBNL)

Status

- **Established** Dec 2020, operating well. **Executive Committee** elections conducted successfully (2020, 2021, 2022)
- **Charter** updates to broaden membership to **global underground science community**, adopt new **registration** process, increase **minimum representation** from various disciplines (SPAC recommendation), clarify aspects relating to **elections and meeting logistics**, meetings **"typically"** held annually
- **User regsistration form** linked on SURF website and advertised to community. Expanded membership will increase SURF's prominence and leadership in global UG science community.
- Association organized SURF **Vision Workshop** Sep 2021 and **General Meetings** Sep 2021, Oct 2022. Next meetings 2024.
- Looking to increase engagement with underground science community – **please join us!**

SURF plans to become DOE User Facility

Benefits:

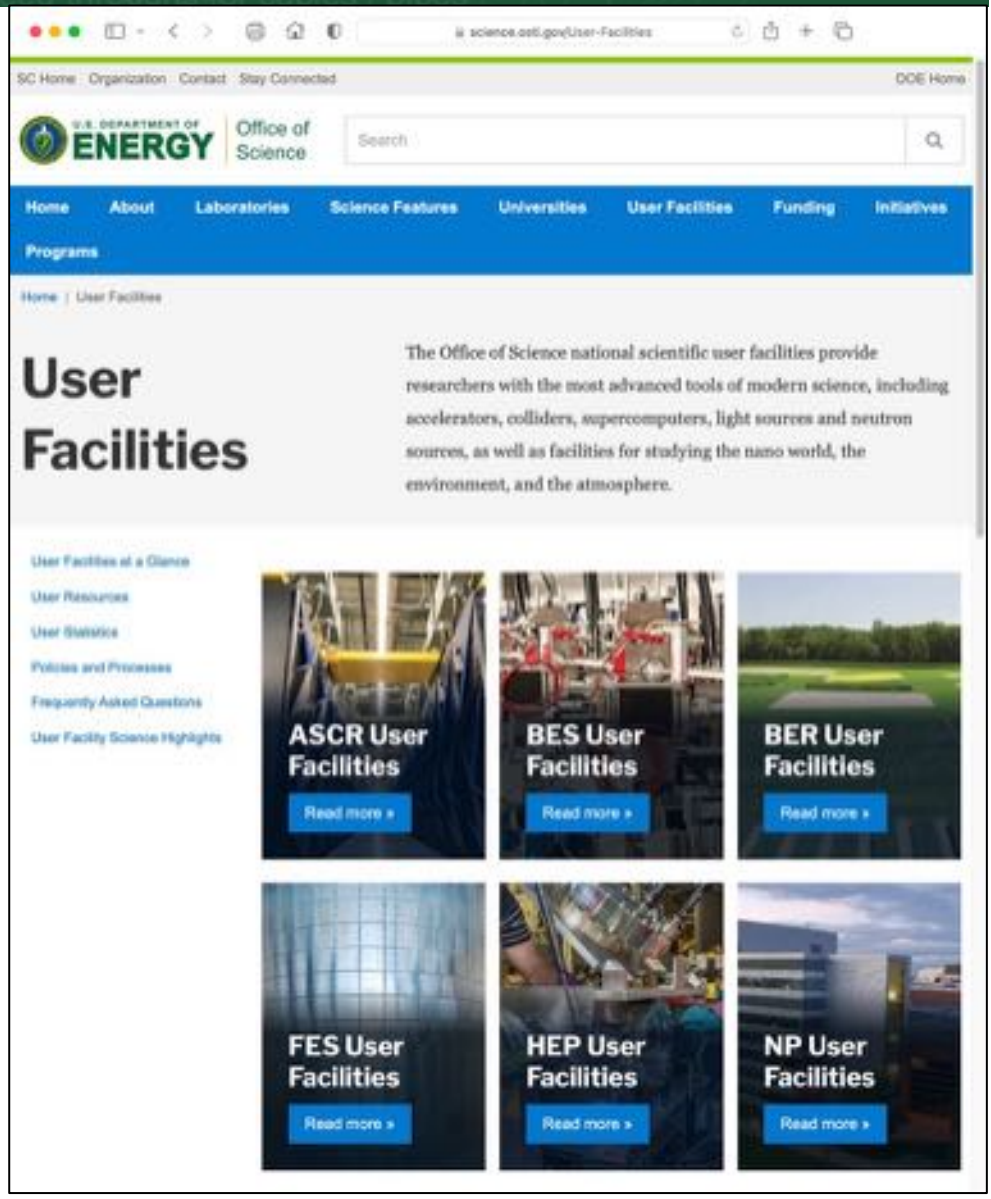
- Expands DOE User Facility portfolio to incl underground lab, raises SURF's stature within DOE community.
- Promotes underground science in U.S., increases funding opportunities.
- Enhances SURF's role in global science community.
- Communicates SURF is open to broad range of science and users, with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

Main Requirements:

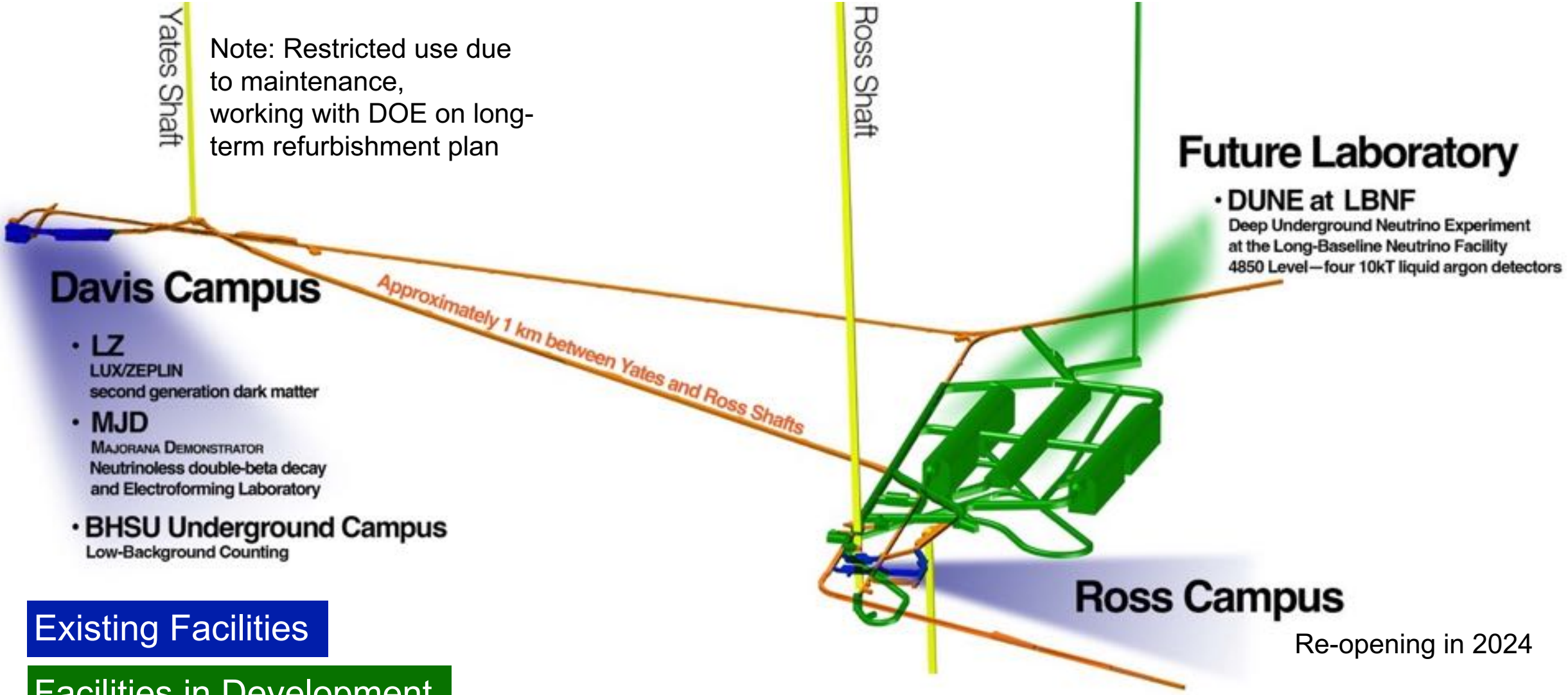
- Facility open to users regardless of nationality or institution.
- Allocation of facility resources determined by merit review.
- Facility resources for users to conduct work safely and efficiently.
- The facility supports a formal user organization.

Status:

- User Association and Science Program Advisory Cttee established.
- Application draft near final; anticipate DOE invitation to submit in coming years.



4850L Science Facilities

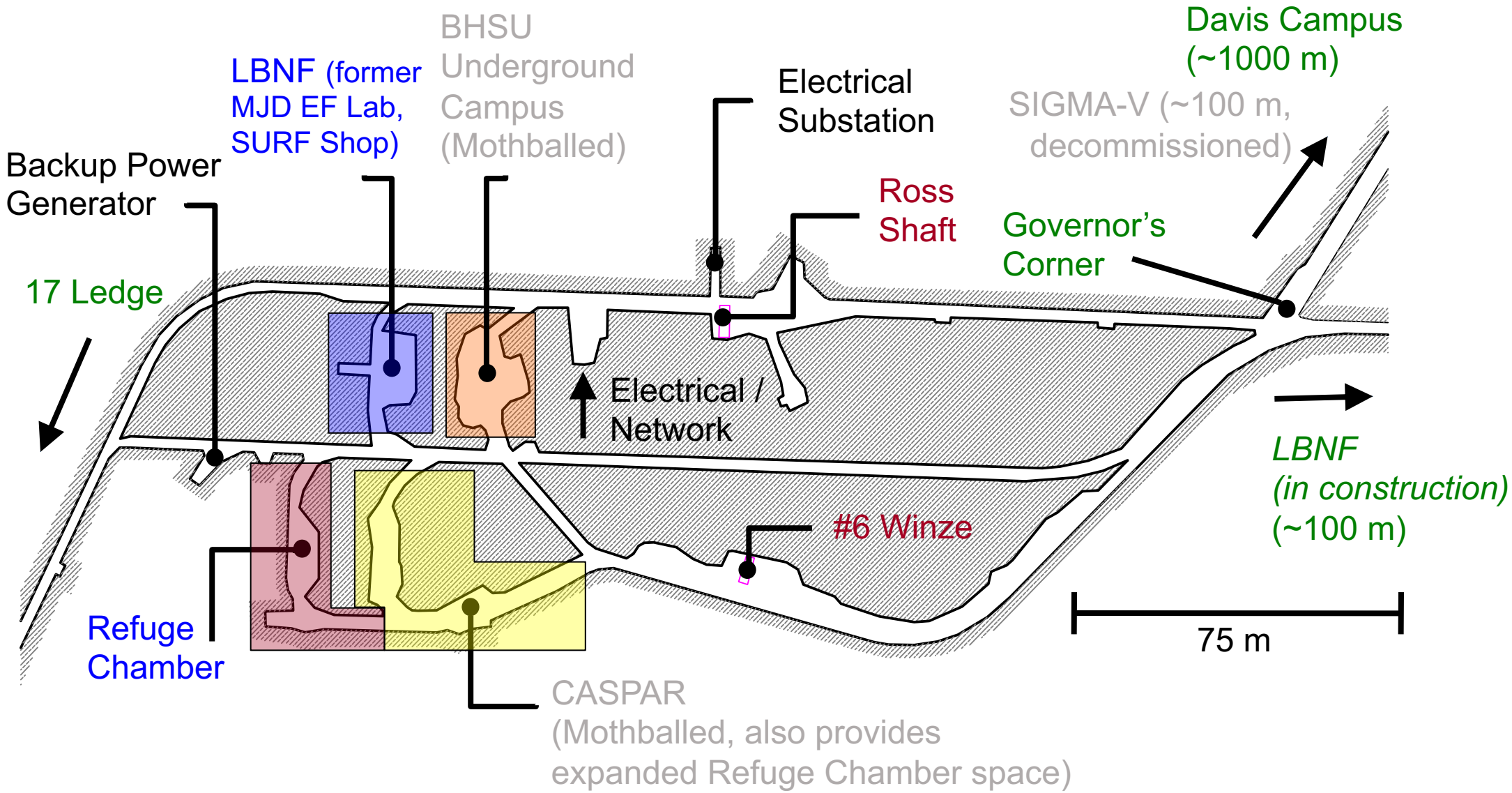


Existing Facilities

Facilities in Development

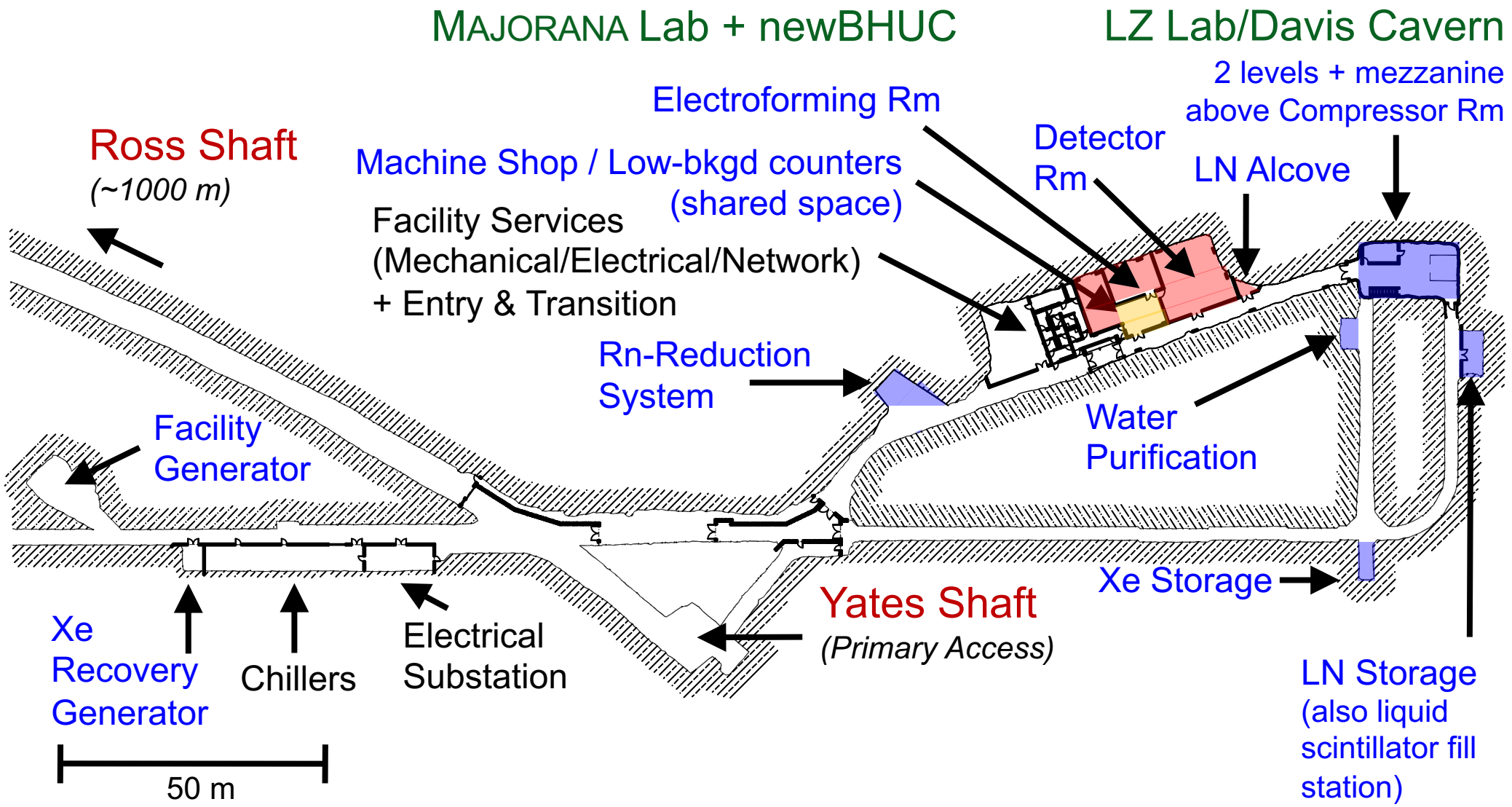
4850L Ross Campus

2,653 m² (Total) / 920 m² (Science)



4850L Davis Campus

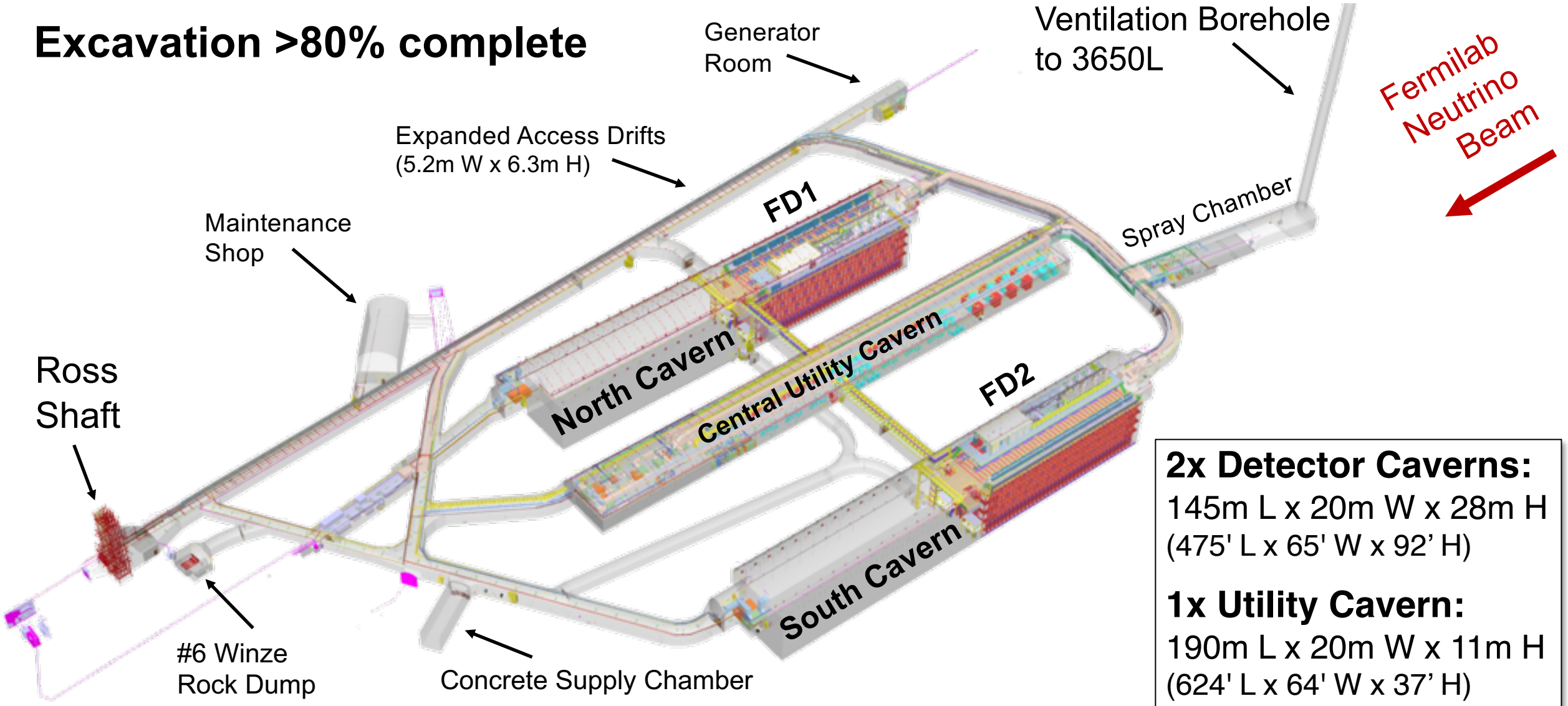
3,017 m² (Total) / 1,018 m² (Science)



Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

Excavation >80% complete



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

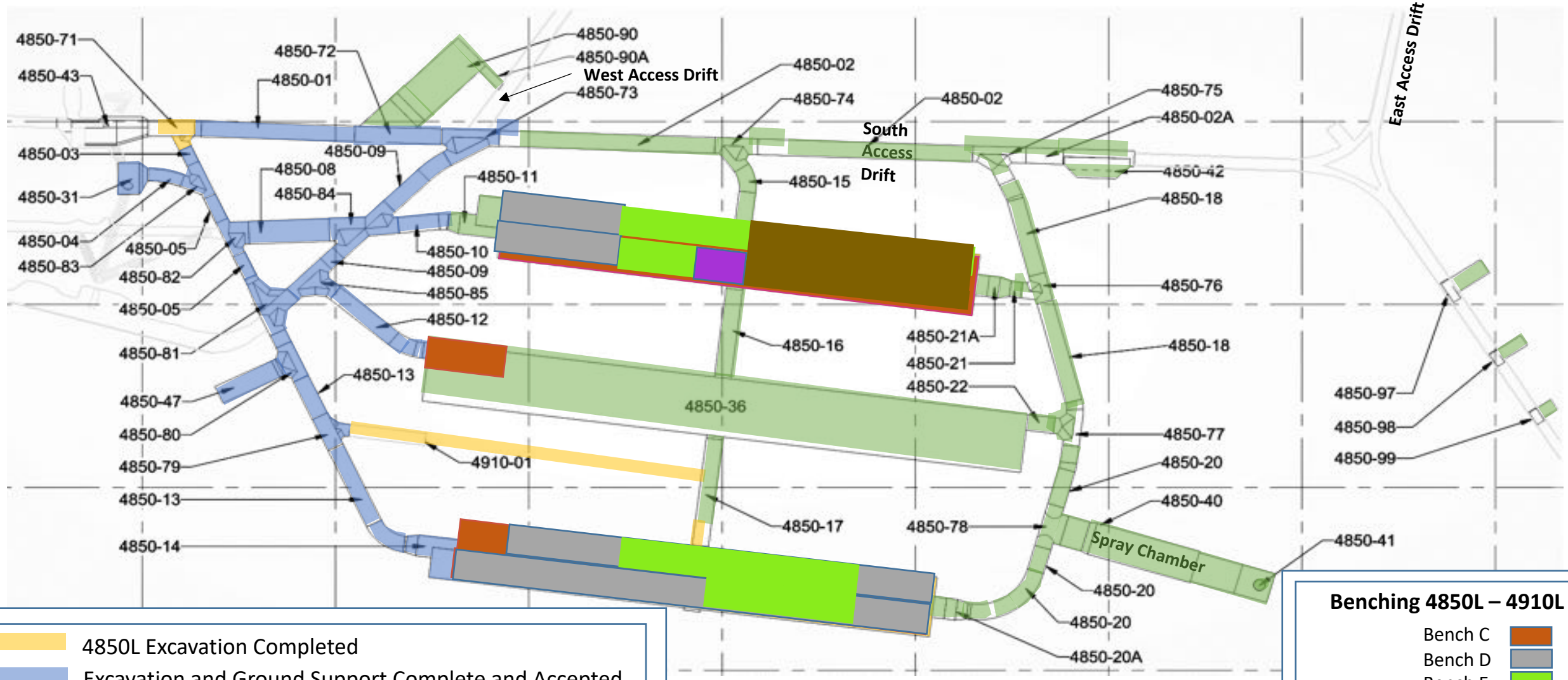
1x Utility Cavern:
190m L x 20m W x 11m H
(624' L x 64' W x 37' H)

LBNF Excavation Progress

>80% completed by volume. Excavation phase continues through mid-2024.

LBNF Excavation Progress

>80% completed by volume. Excavation phase continues through mid-2024.



4850L Excavation Completed

Excavation and Ground Support Complete and Accepted

Concrete Complete

September 18, 2023

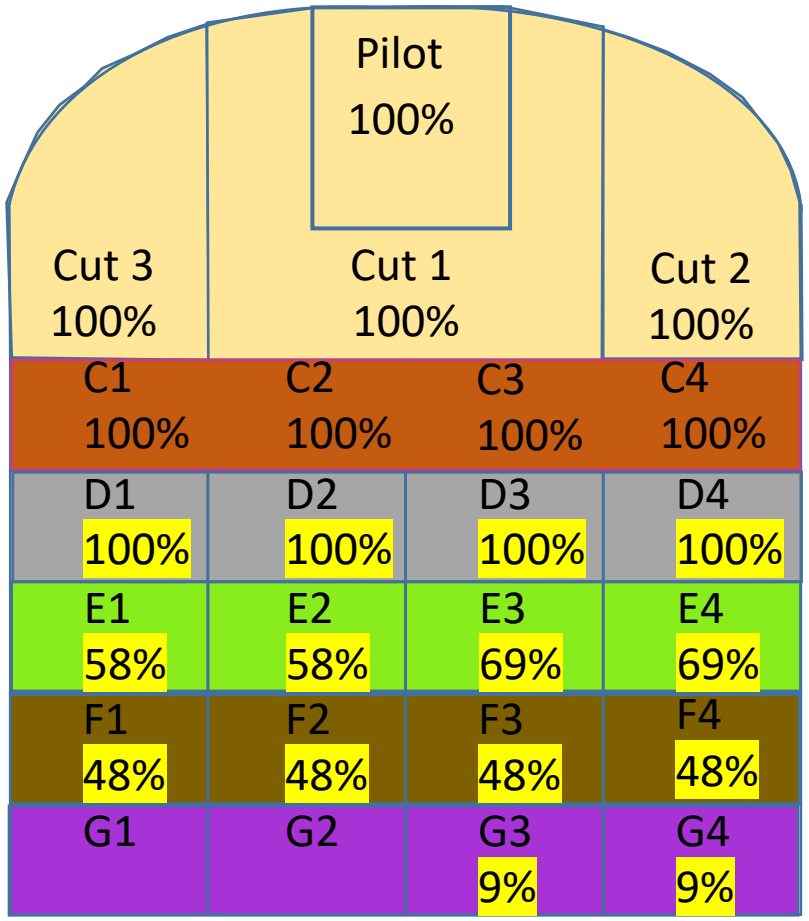
Benching 4850L – 4910L

- Bench C
- Bench D
- Bench E
- Bench F
- Bench G

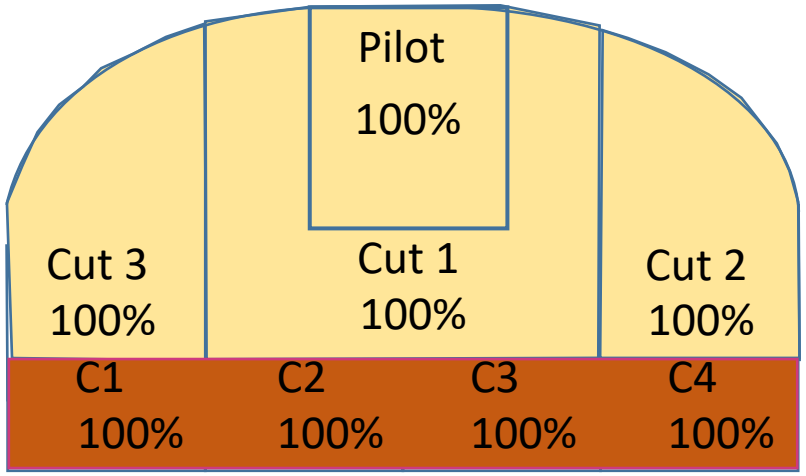
LBNF Excavation Progress

>80% completed by volume. Excavation phase continues through mid-2024.

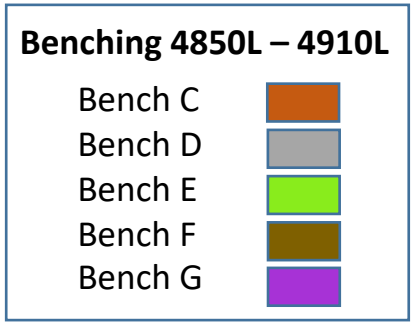
September 18, 2023

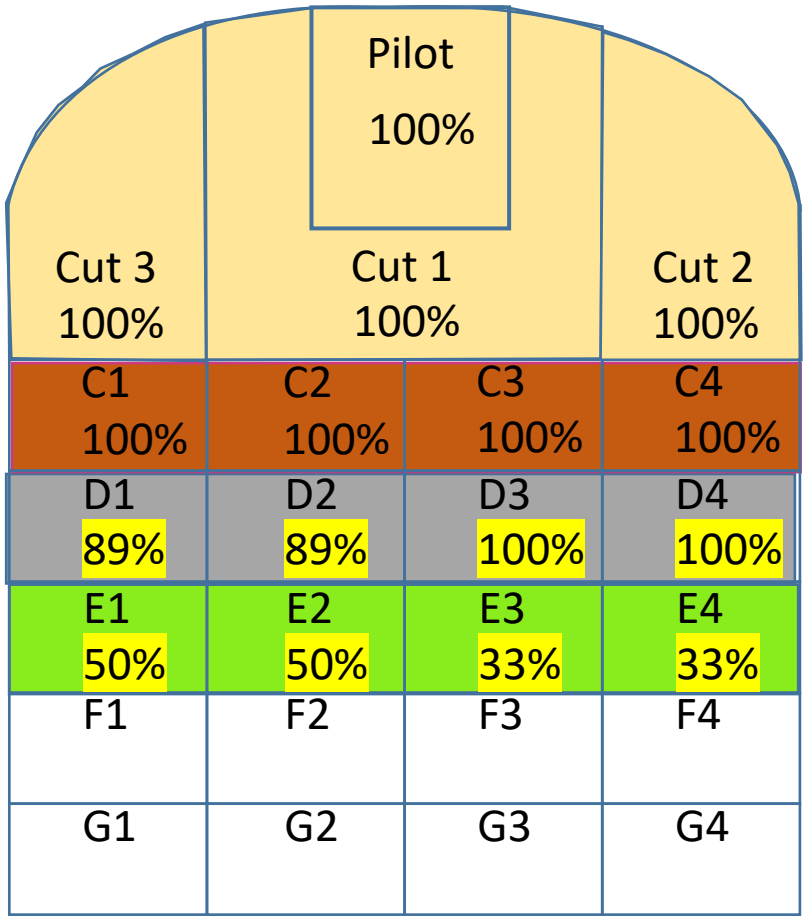


North Cavern



CUC Cavern





South Cavern

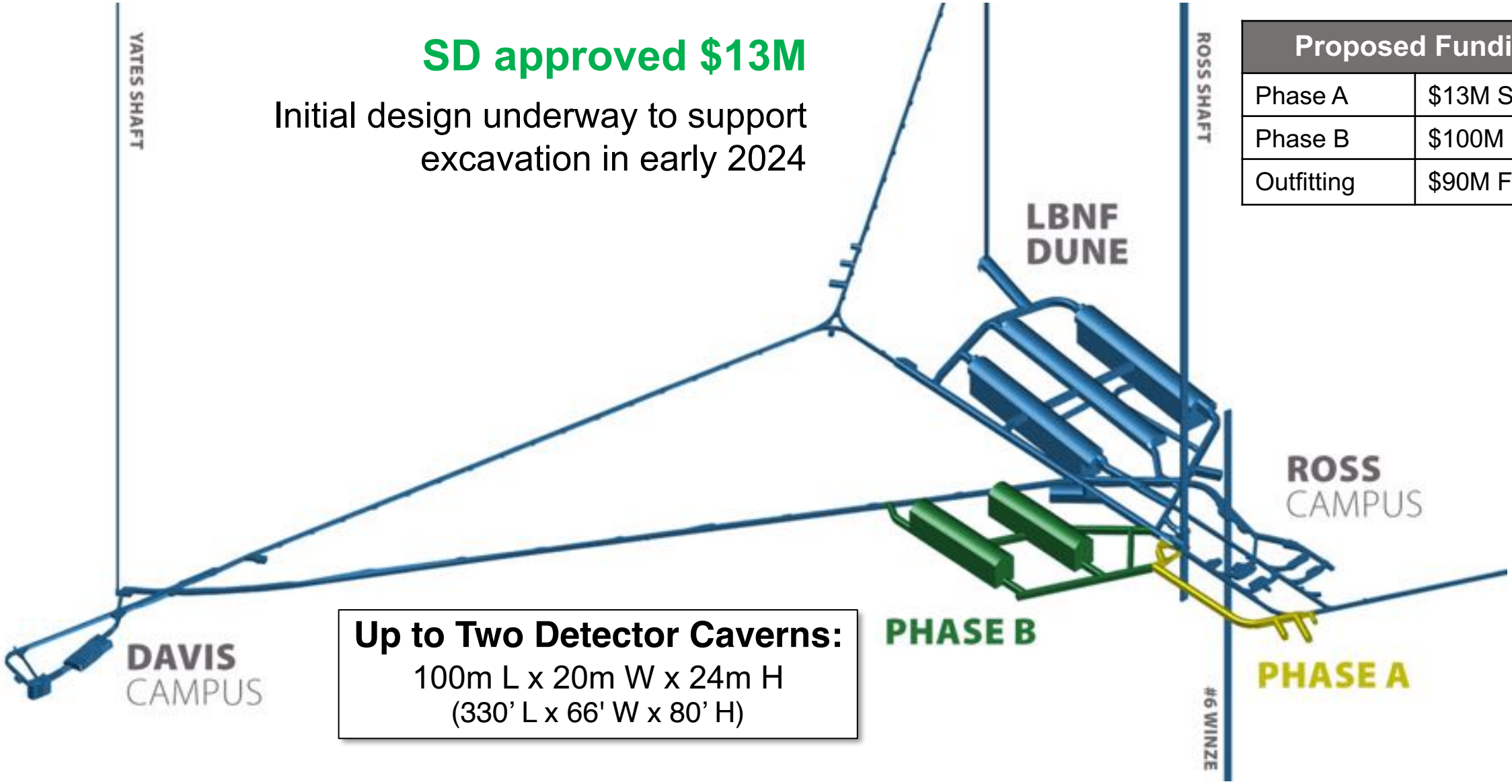
4850L Space Needed for Future Experiments

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

SD approved $13M

Initial design underway to support excavation in early 2024

Proposed Funding Model	
Phase A	$13M State of SD ✓
Phase B	$100M Private
Outfitting	$90M Federal



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

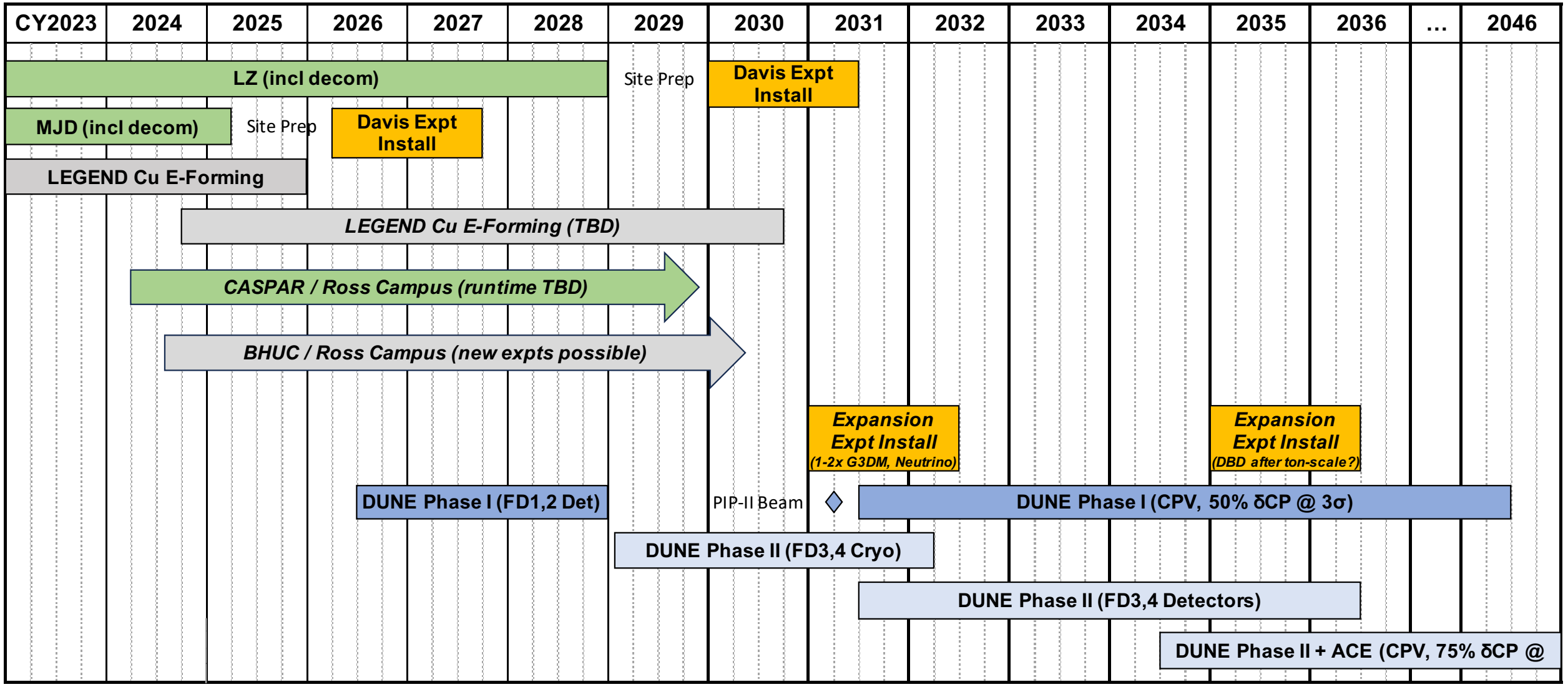
SURF Current & Future Facilities

Summary for various science campuses, including timelines

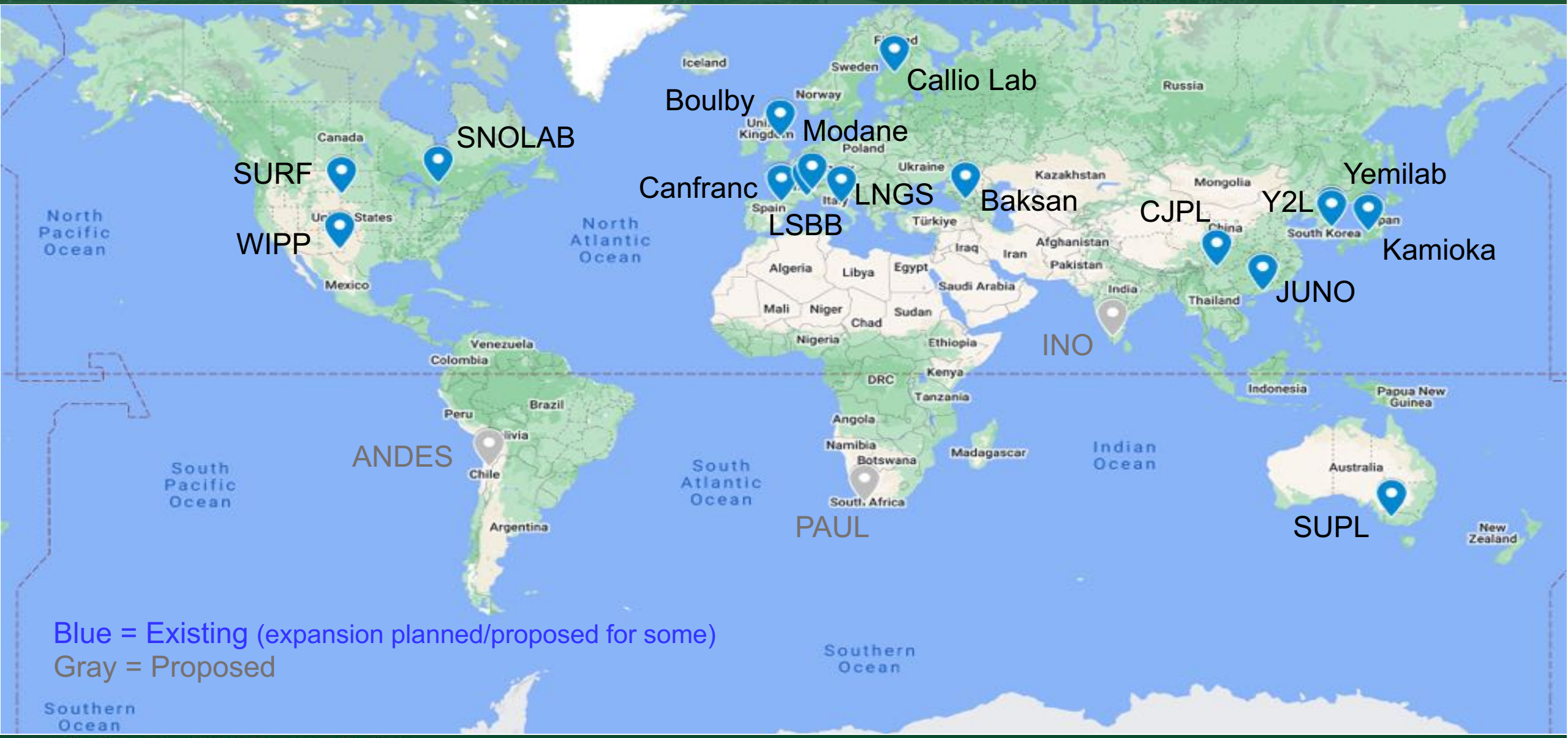
Location	Laboratory	Existing/*Planned* Space		Available (CY)	Comments
		Area (m^2)	Vol (m^3)		
Surface	Surface Lab (+ RRS)	210	600	2021	LZ use ~complete, allowing use by others
Davis Campus (4850L)	LZ Lab – Davis Cavern (2 levels)	372	1,956	~2028	LZ data complete in ~2027 + decommissioning
	MJD Lab – 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 FY24 after LBNF excavation
	CASPAR	395	1,130	2029-2031?	Mothballed, equip remains, re-occupy FY24 after LBNF excavation. (Also expanded Refuge Chamber)
	Refuge Chamber	258	866	?	Long-term use TBD
LBNF (4850L)	*LBNF*	*9,445*	*191,863*	*?*	*Excavation complete in 2023*
4100L	Geoscience Lab	334	11 drill holes	2025	DEMO-FTES use 2023-2024
4850L	*New Labs (2 proposed)*	*4,022*	*94,608*	*Earliest new: excavation 2027, complete ~2030*	*Each 20m (W) x 24m (H) x 100m (L)*
7400L	*New Labs (2 proposed)*	*4,178*	*42,440*		*Each 15m (W) x 15m (H) x 75m (L) + other supporting*

SURF Science Strategic Planning

Timeline



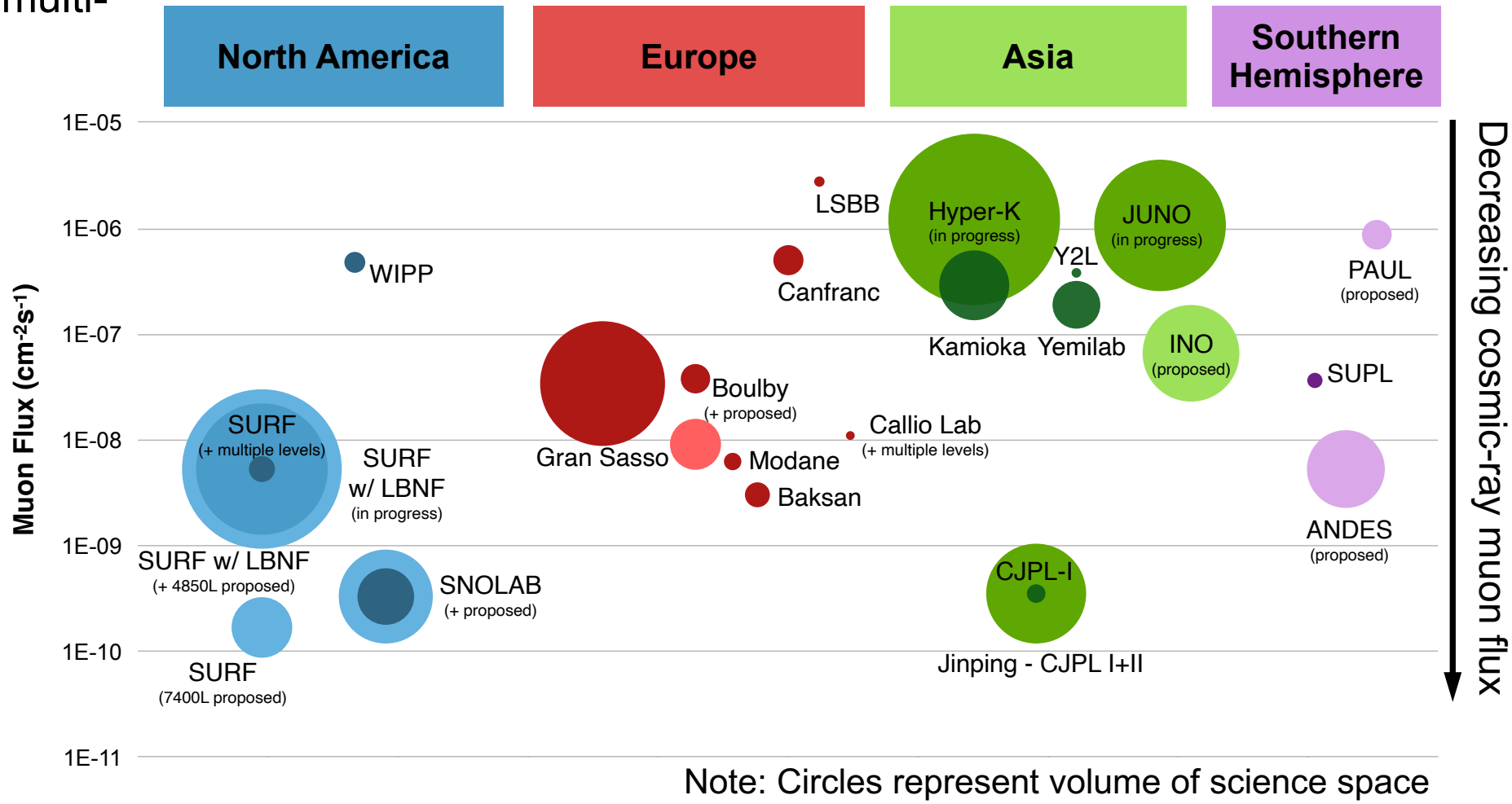
World-wide Underground Facilities



SURF in the Global Context

SURF provides:

- 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



Underground Facilities – SURF

SURF provides:

- **Unique environments for multi-disciplinary research:** SURF has attracted world-leading experiments and scientists from diverse scientific communities.
  - **Overburden protection from cosmic-ray muons:** SURF is the deepest underground lab in U.S., one of deepest in the world (1500 m, 4300 mwe). SURF has sufficient depth for next-generation experiments, but needs additional space – SURF is exploring options for more 4850L lab space as well as greater depth for the future (2300 m, 6500 mwe)
- **Local radiation shielding:** Water tank and corresponding water purification system, steel shielding; also selection of low-activity facility construction materials (e.g., concrete, shotcrete)
- **Assay capabilities:** Low-background counting serving national & international community
- **Material production/purification:** One of only a few labs where UG Cu electroforming is performed
- **Environmental control:** Cleanrooms with HEPA filtration, dehumidifier and Rn-reduction systems
- **Implementation and operations support:** Robust organization with support for planning, execution and coordination of science program activities both planned and ongoing at facility. SURF has proven track record of delivering successful science.
- **Community catalyst:** User Association, incl Vision Workshop 2021. Science Program Advisory Cmttee. Both groups support upcoming SURF application to become **DOE Office of Science User Facility**

SURF Overall 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.
  - **SURF existing science program and LBNF/DUNE remain top priorities**.
- SURF wants to host other future world-leading experiments:
  - Call for proposals in early 2024 for space available in 2025 (Davis & Ross Campus), 2028 (Davis Campus).
  - SURF is preparing to **increase underground laboratory space**, plans advancing for new large caverns on 4850L (1500 m, 4200 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).
  - Anticipating strong recognition and support for SURF in upcoming **P5 report for U.S. strategic planning** (SURF expansion recognized in nuclear science Long Range Plan in context of beyond-ton-scale DBD).

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.