The Sanford Underground Research Facility

Mike Headley
SDSTA Executive Director
SURF Laboratory Director

Jaret Heise
SDSTA Science Director

September 28, 2021

Sanford
Underground Research Facility
South Dakota Science and Technology Authority

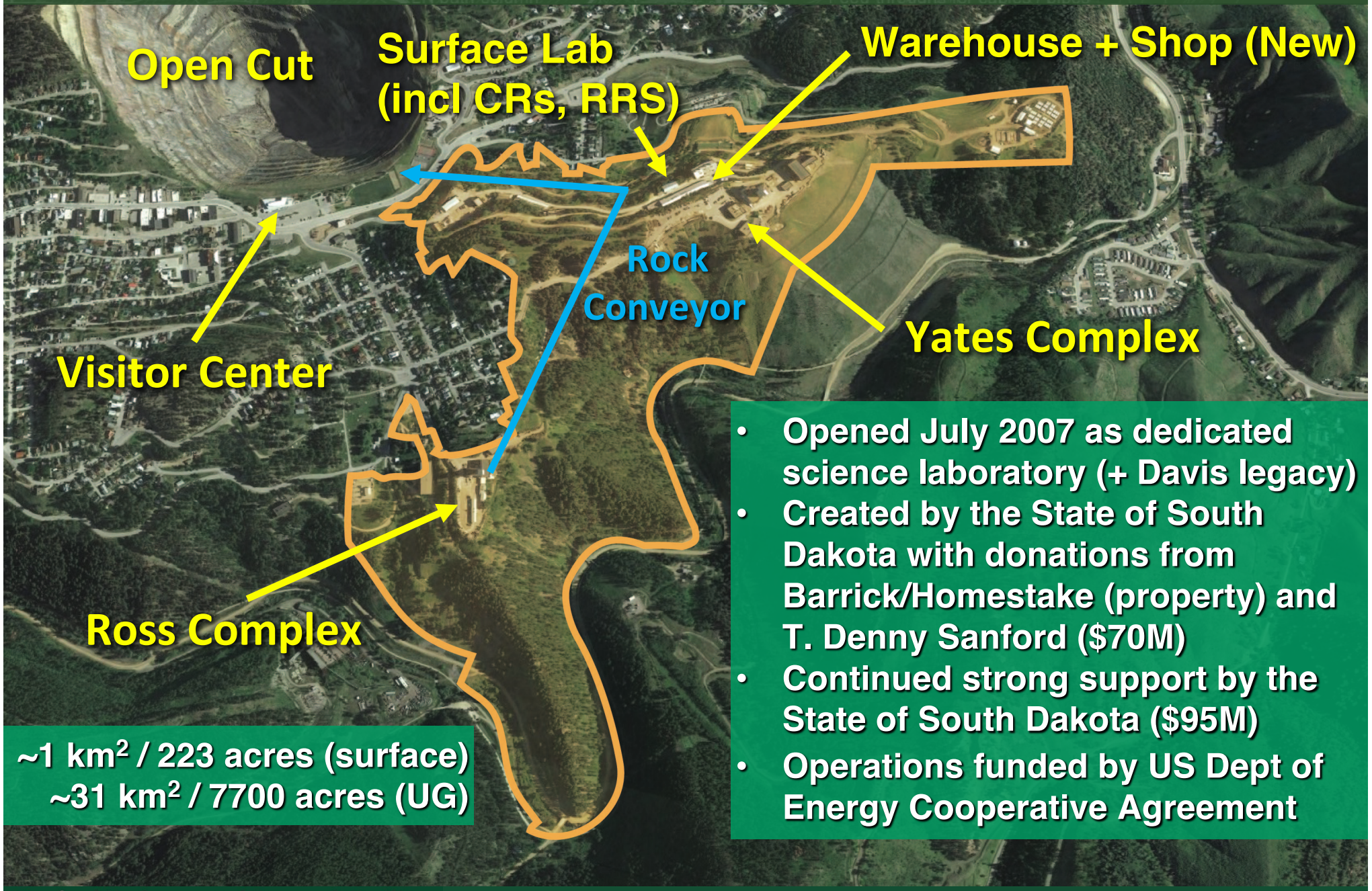
SDSTA Mission and Vision

Mission: *We advance world class science and inspire learning across generations.*

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

Sanford Underground Research Facility

Nation's underground lab to advance multi-disciplinary research



~1 km^2 / 223 acres (surface)
~31 km^2 / 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 ($95M)
- Operations funded by US Dept of Energy Cooperative Agreement

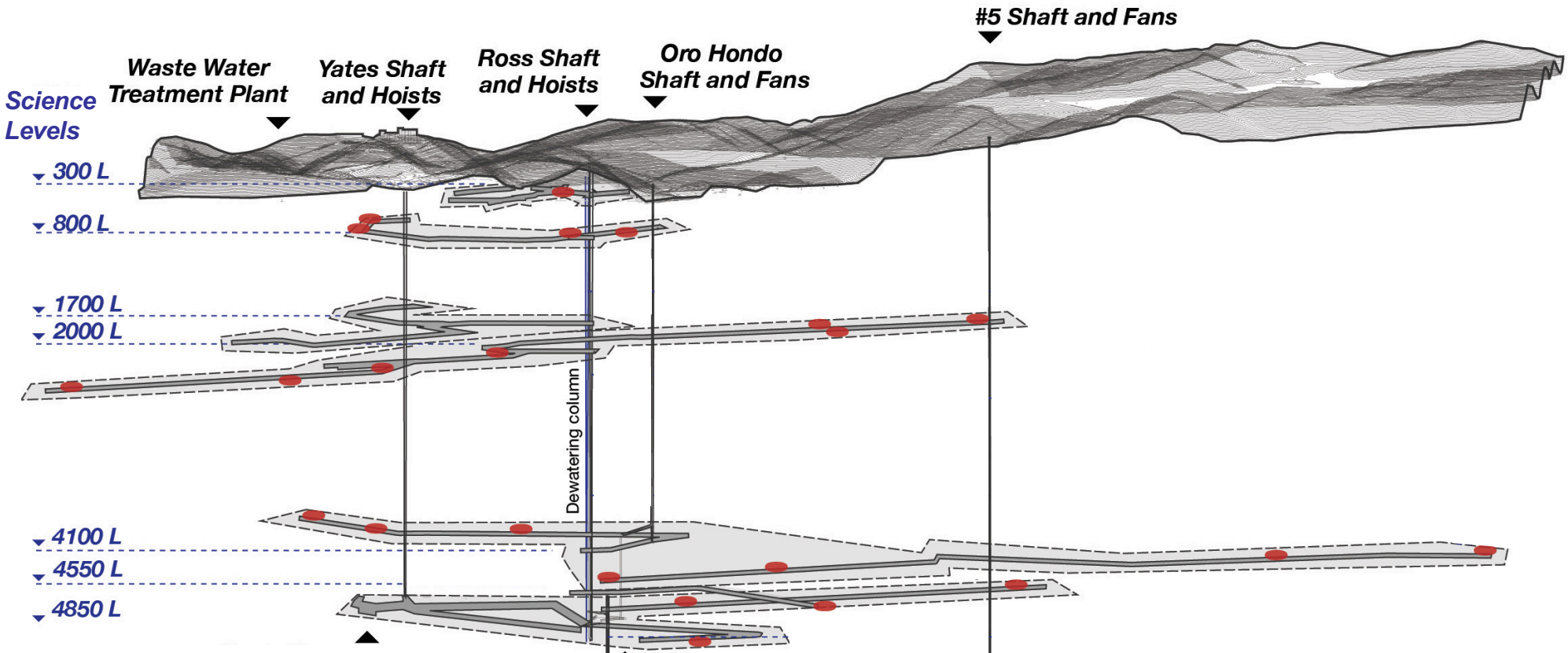
New Rounds Operations Center Completed

$6.5M South Dakota commitment - 26,000 sq. ft. total

ROC Ribbon Cutting – Aug 20

SURF Underground Lab Geography

Yates & Ross + ventilation shafts, multiple levels for science



Davis Campus

LUX-ZEPLIN (LZ)

MAJORANA DEMONSTRATOR (MJD), incl Copper Electroforming

BHSU Underground Campus, incl Low-Background Counting

Ross Campus

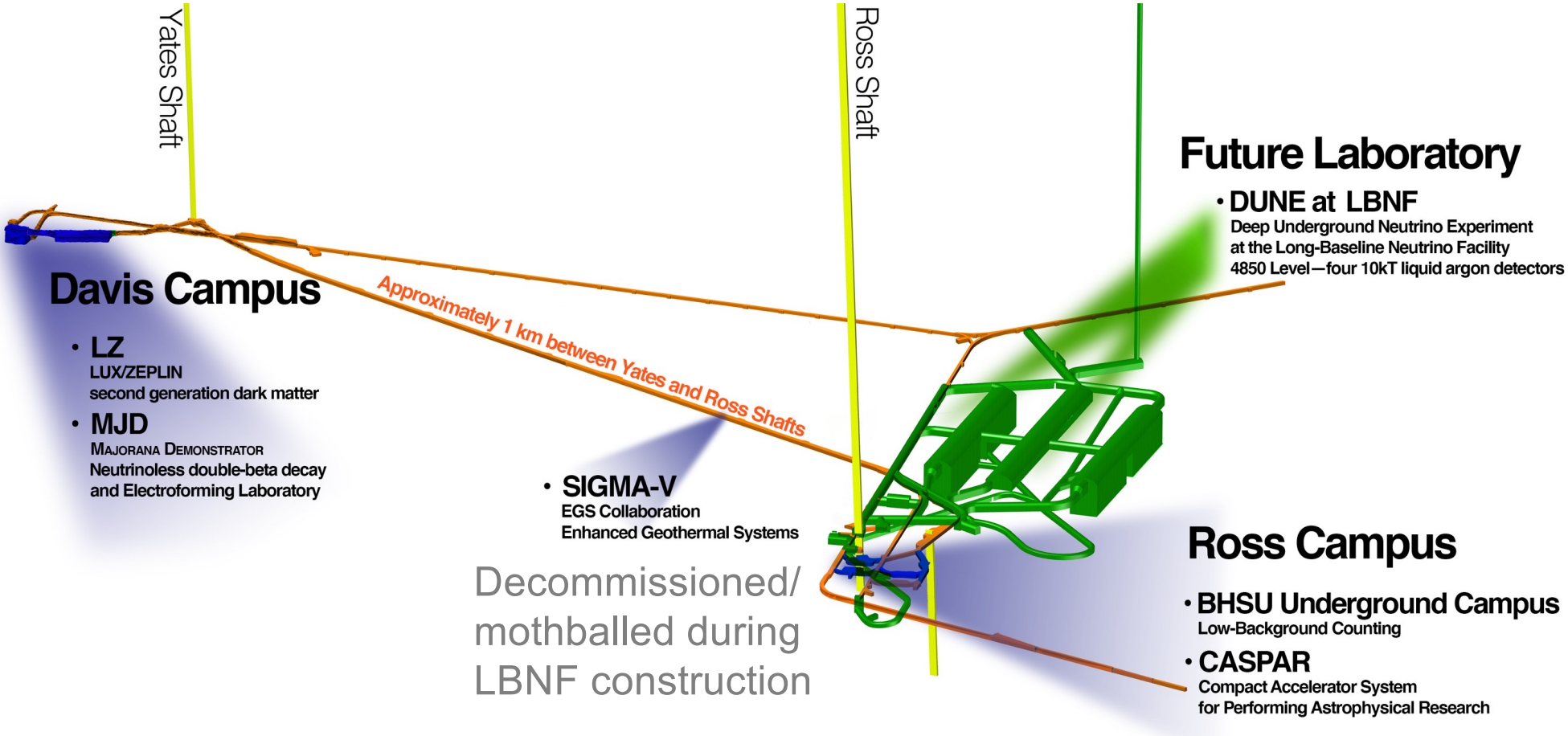
CASPAR (decommissioned Spring 2021)

BHSU Underground Campus (decommissioned Summer 2020)

- ~600 km of tunnels from Surface to 2.4 km (8000 ft) deep
  (63 total elevations, 29 currently accessible)
- ~20 km maintained for science and facility operations

Current & Future Underground Facilities

SURF research through 2050 and beyond

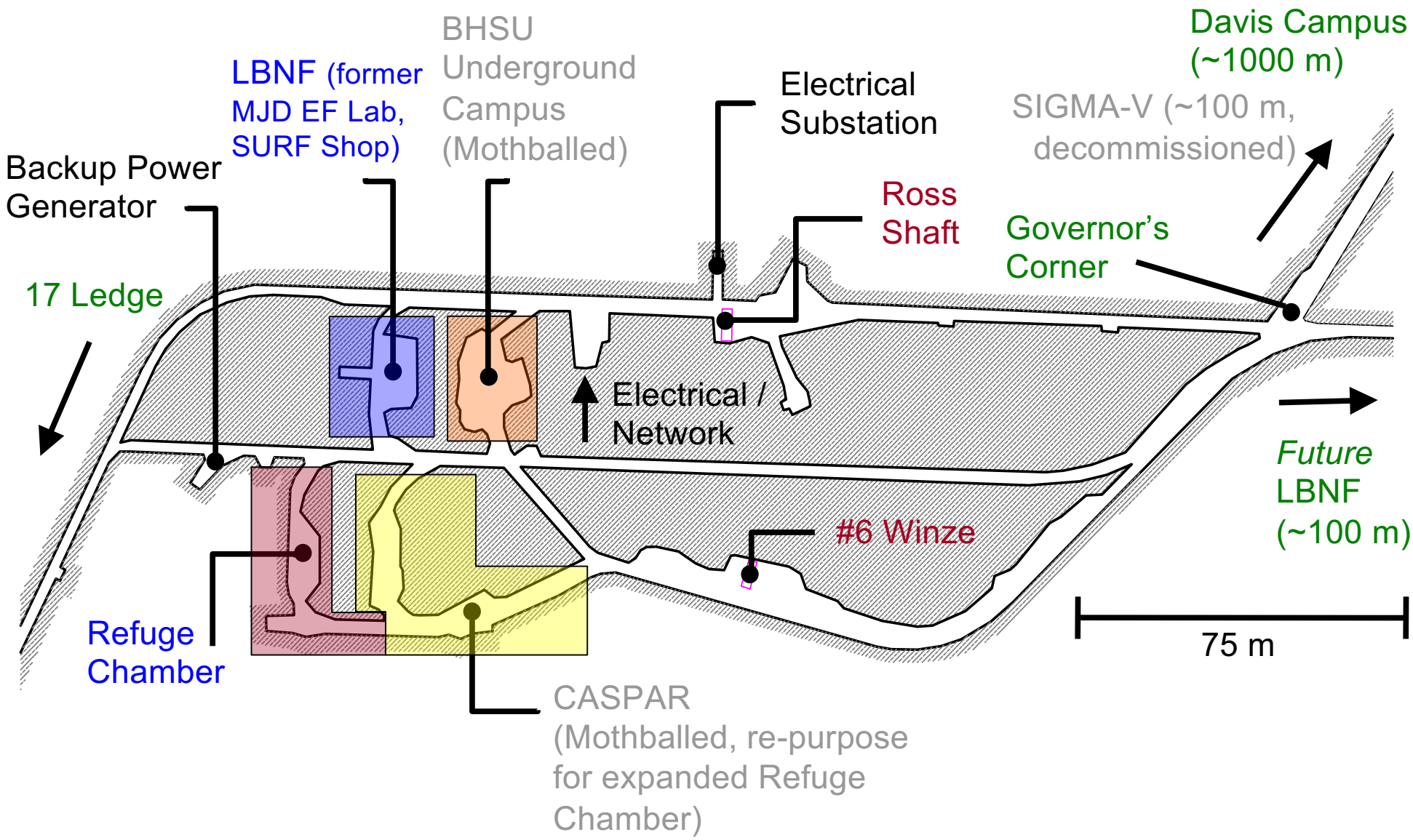


Existing Facilities

Future Facilities

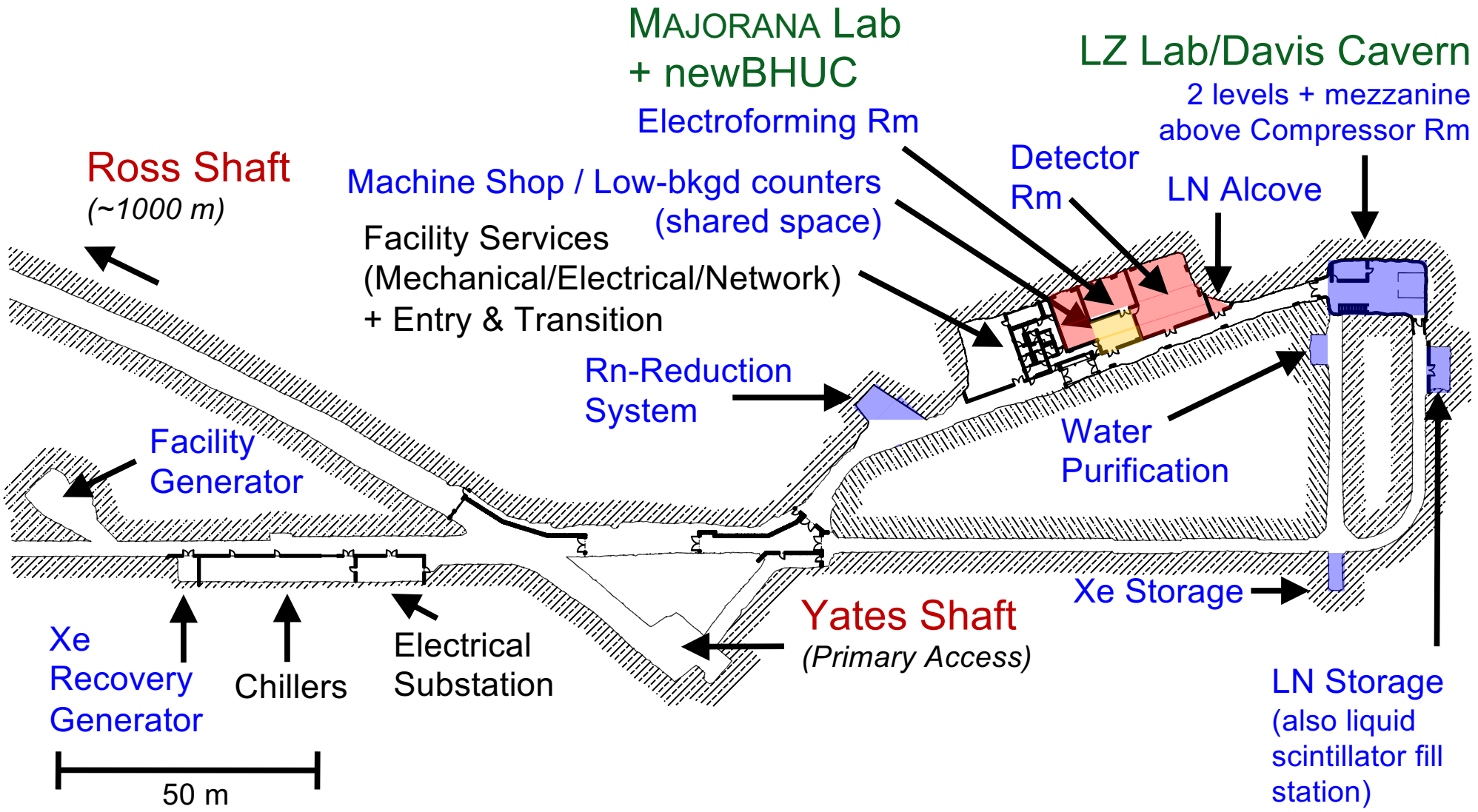
4850L Ross Campus

2,645 m² (Total) / 1,150 m² (Science), Improve Existing Excavations



4850L Davis Campus

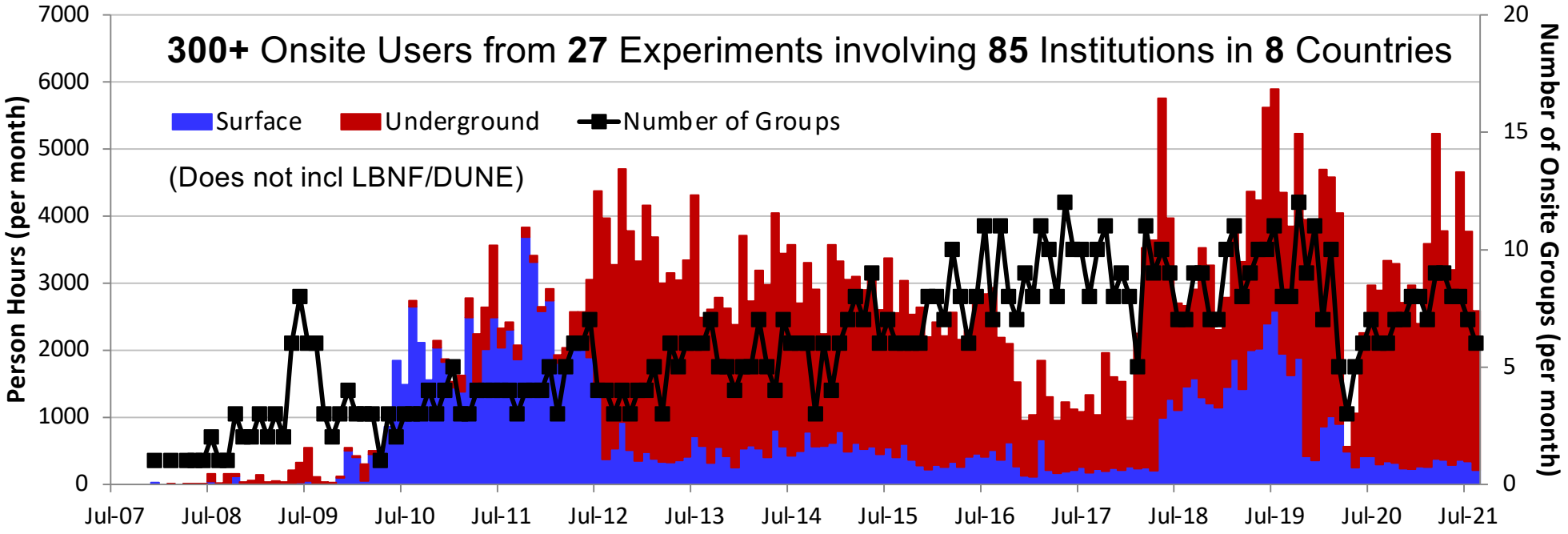
3,015 m² (Total) / 1,015 m² (Science), New Excavation+Davis Cavern



SURF Overview

Serving a diverse community of researchers

- 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: 187 full/part-time staff, 11 departments, ESH (incl nurse, 24-hr emergency response), Engineering, Operations, Science + others
  - **Mature Programs:** Experiment implementation & safety; also monitoring (see backup)
  - **Community:** SURF **User Association** launched in 2020, SURF **Science Program Advisory Cmttee** established in 2021. Both groups support application to become DOE Office of Science **User Facility**



SURF Science Support

Resources for Safe and Efficient 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

David Rynders (CHP, CSP)
Expt Health & Safety
- Health physics, radiation

T. Regan, G. Vandine
Safety, UG Coordination
- Bio/geology (no pic)

J. Connot, Others
UG Operations Eng, UG Maintenance Crew
- Ventilation, prep (no pic)

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

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

Sarah Wortman (+ Service Contracts)
Facilities Technician
- Surface + UG lab system maintenance

SURF Current Science Program

Research activities ranging from surface to 1500+ m underground

Physics

- LZ – *Dark matter, 2-phase Xe TPC*
- MAJORANA DEMONSTRATOR / LEGEND – *Neutrinoless double-beta decay Ge-76, also Cu e-forming, planning Ta-180m*
- 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)*
- 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 (SDSMT, USD, SDSU)*
- 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*
- Core Archive* – *Mainly gold deposits*
- Hydro Gravity – *Local gravity for water tables, densities*
- 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*

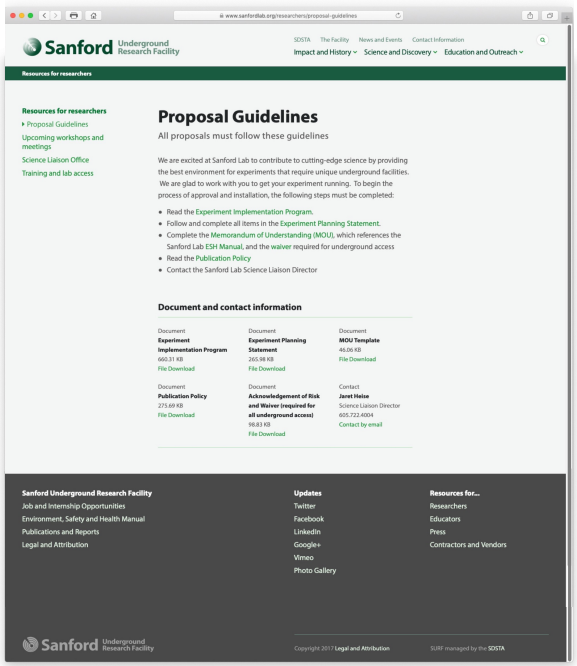
Total = 27 Groups
20 Active Projects
(57 Total Groups Since 2007)

Significant interest from others
(16 groups in 2020)

* Denotes proprietary group

Experiment Implementation Program
Identify Interfaces and Hazards within Approval Framework

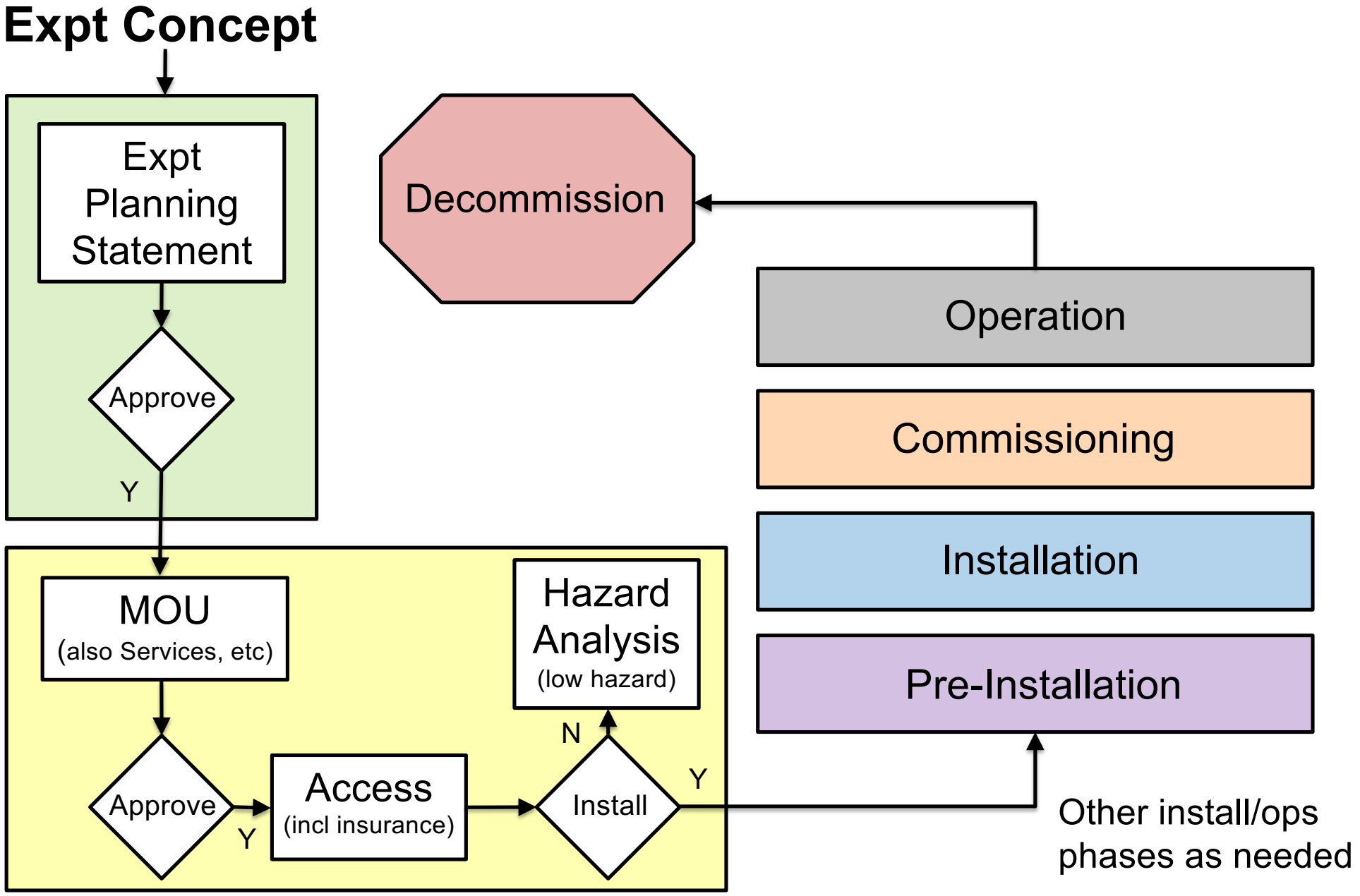
- https://www.sanfordlab.org/researchers/proposal-guidelines
- **Project Documentation**
  - Expression of Interest, incl support letters
  - Experiment Planning Statement
  - Memorandum of Understanding (space commitment)
  - Access: Request form, waiver, insurance
  - Services Agreement(s), if applicable
    - General Services Agreement: Who provides what and who pays
    - Contract(s): Specific expenses, direct use of SURF staff
  - Experiment Decommissioning Statement



- **Environment, Safety & Health**
  - Hazard Analysis: Assessments/analyses (e.g., ODH), procedures, testing/certifications
  - Inventories: Chemical, electrical, hoisting & rigging, pressure vessel, radioactive materials
  - Training: Sanford Lab modules, Expt training plan (incl equivalences), recordkeeping
- **Reviews**
  - Facility, walk-through inspections, monitoring, readiness reviews (safety, operation)
  - Commensurate with hazards
- **Authorization**
  - Work planning & controls (procedure reviews/approvals, release), Science/ESH + SMEs
  - Authorization To Proceed for significant installation and associated significant hazards

Experiment Implementation Program

Process Flow Chart



SURF COVID-19 Response

Effective measures limiting COVID spread at SURF

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)

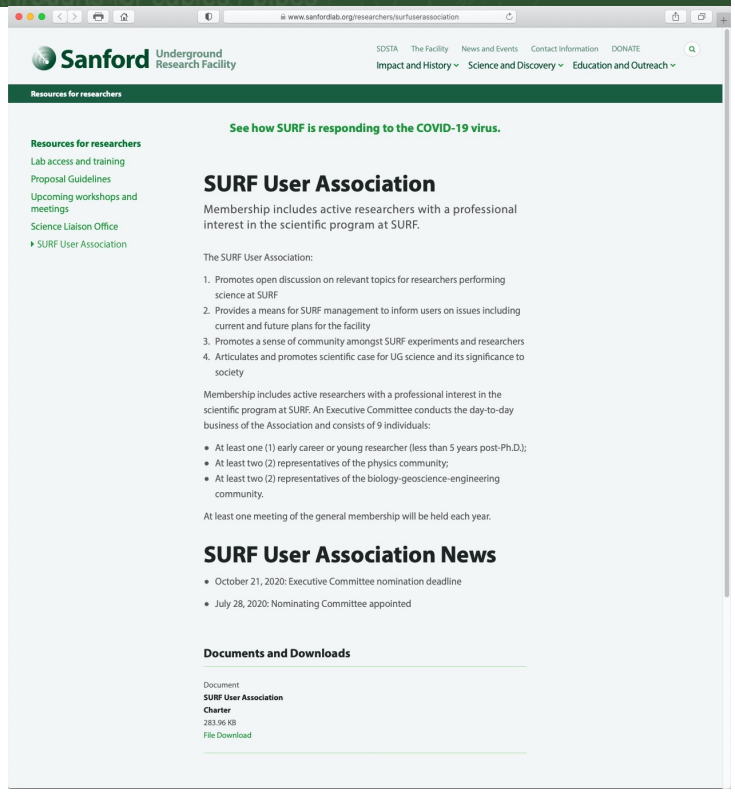
Current:

- Masks required for personnel in buildings/labs and conveyances per CDC based on elevated county virus transmission metrics (cases, positivity)
- Restricted occupancy in some areas, limited in-person events

SURF User Association

Purpose

- Promotes **open discussion on relevant topics for researchers** performing science at SURF
- Provides a means for **SURF management to inform users** on issues including current and future plans for the facility
- 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**



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

Organization

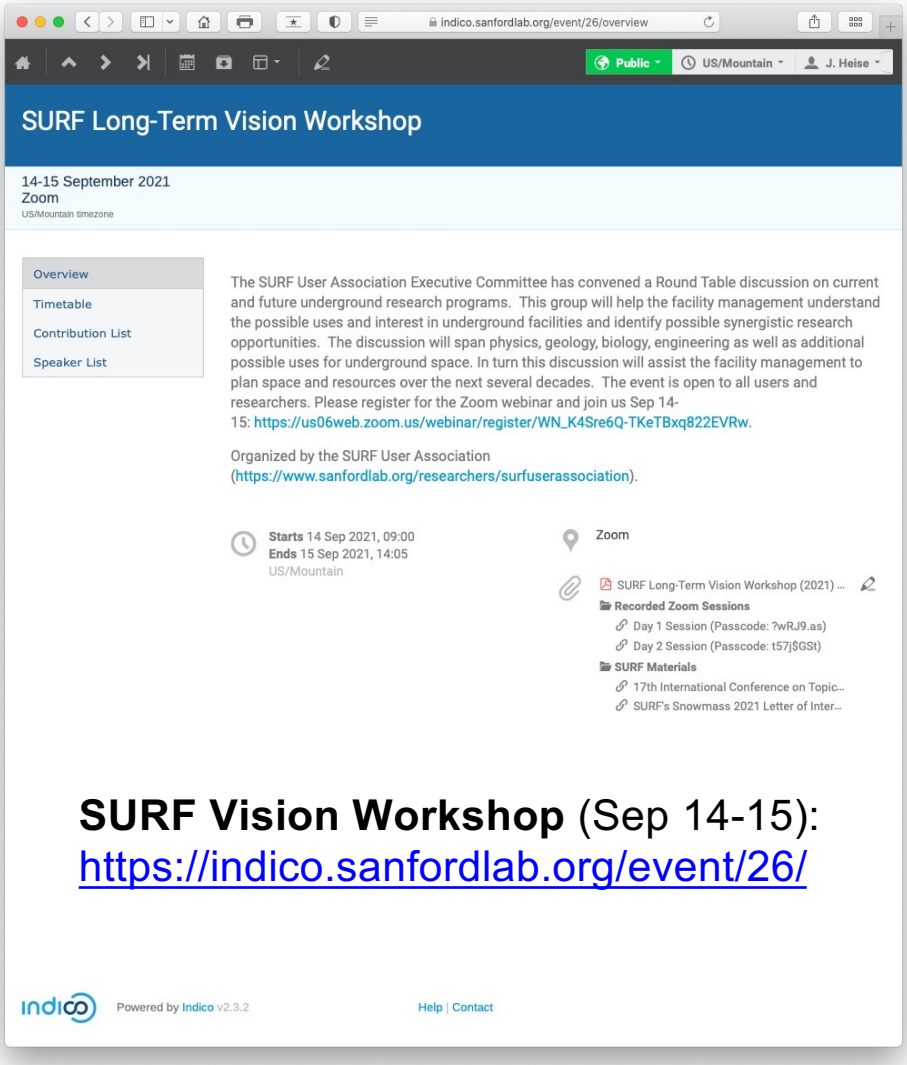
- **Membership** open to Underground Science Community (initially was active SURF researchers). Annual meeting
- **Executive Committee** consists of 9 individuals across scientific disciplines, incl early career. Two-year terms (except first year in order to provide overlap), limits per experiment and institution. Quarterly meetings

Status

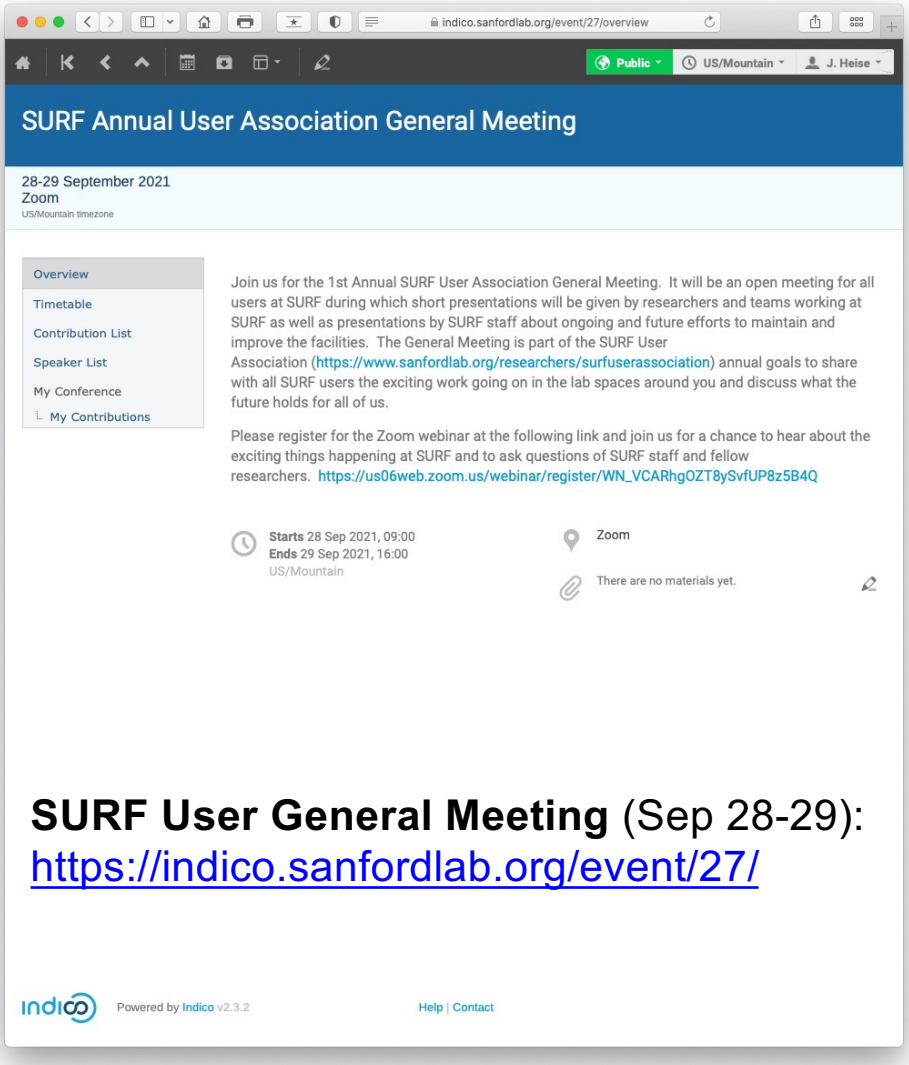
- **Charter** initially approved in Feb 2020, updated in Aug 2021 to broaden membership (need to formalize registration process)
- **Executive Committee** elections conducted in Oct 2020, members announced Dec 2020, officers selected Jan 2021 (chair and secretary). Next election soon!
- Association organized SURF **Vision Workshop** Sep 14-15; also **General Meeting** Sep 28-29 (now!)

SURF User Association

Recent (and Current) Events



SURF Vision Workshop (Sep 14-15): https://indico.sanfordlab.org/event/26/

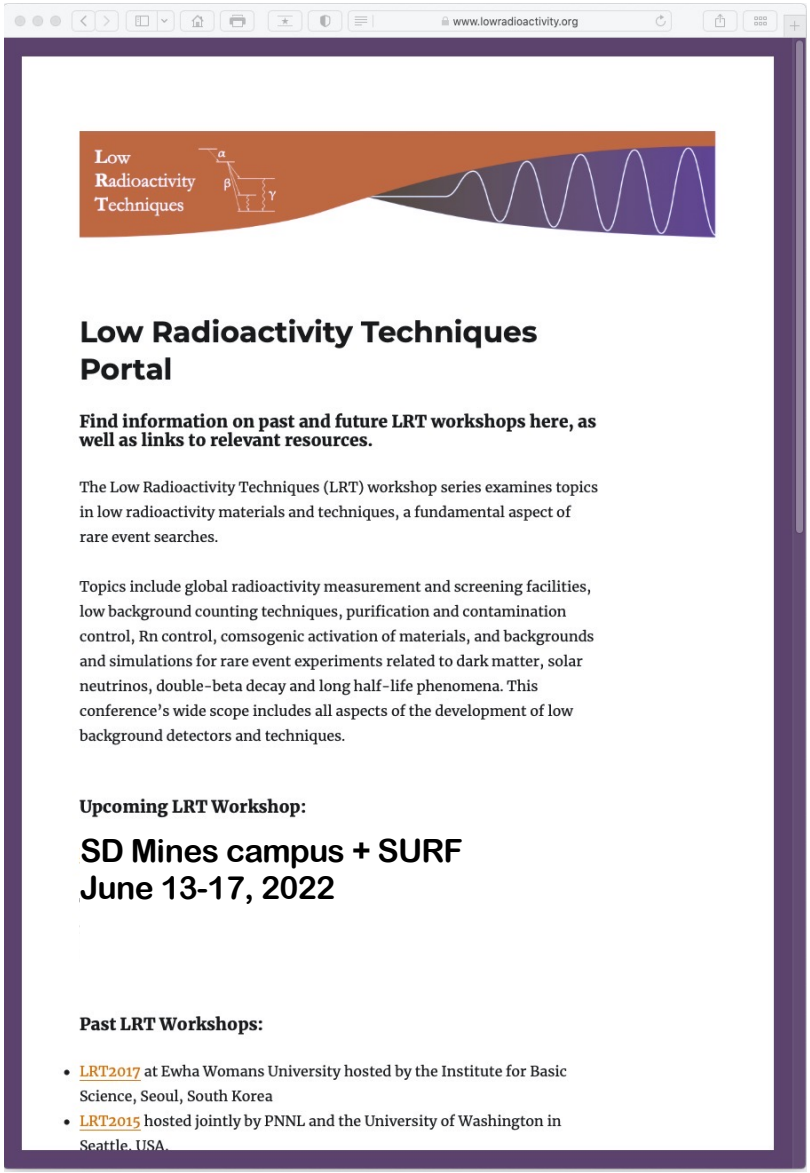


SURF User General Meeting (Sep 28-29): https://indico.sanfordlab.org/event/27/

SURF Conferences

Upcoming Events

Stay Tuned for More Details!



May 11-13, 2022:
Conference on Science at SURF (SD Mines)

Jun 13-17, 2022:
Low Radioactivity Techniques (SD Mines + SURF)

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
- **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

Committee Membership

- 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

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

Status

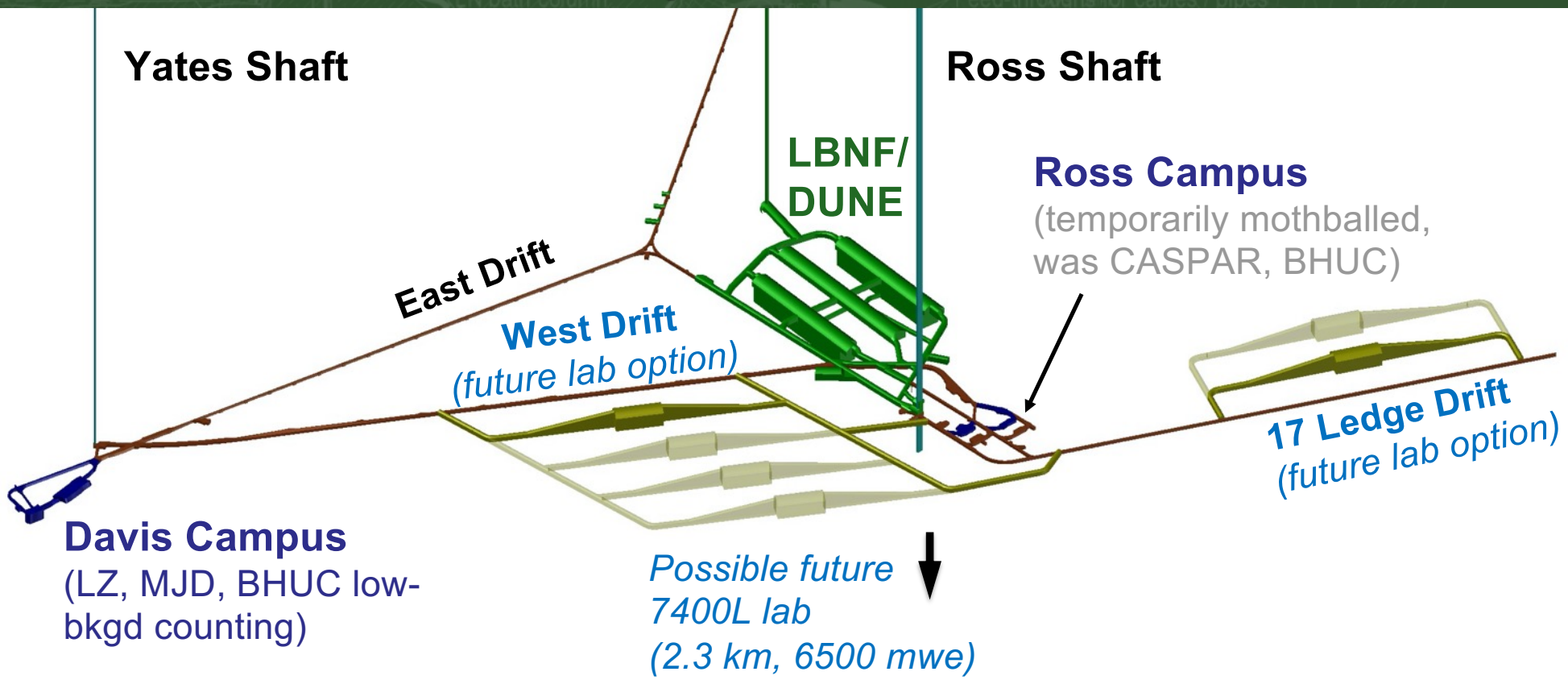
- SPAC charter formalized in May 2021, committee members finalized in Sep 2021
- Planning first meeting in 2021, incl engage on SURF strategic items such as additional UG lab space, Snowmass, etc

SURF 15-Year Horizon Goals

- LBNF and DUNE have been constructed and are fully operational.
- Two additional large lab modules on the 4850L have been constructed and are operational.
- Construction is underway on two 7400L lab modules including the required underground access infrastructure for experiments with increased shielding requirements.
- Provide broader underground access to a range of science disciplines including below the 5000L.
- SURF Institute has been constructed and is fully operational with compelling, vibrant science and education programs.
- Foster commercial partnerships to advance technology development in the region, increase facility ops efficiency and safety, and expand workforce development opportunities.

SURF Underground Facility Expansion

Current facilities and future possibilities

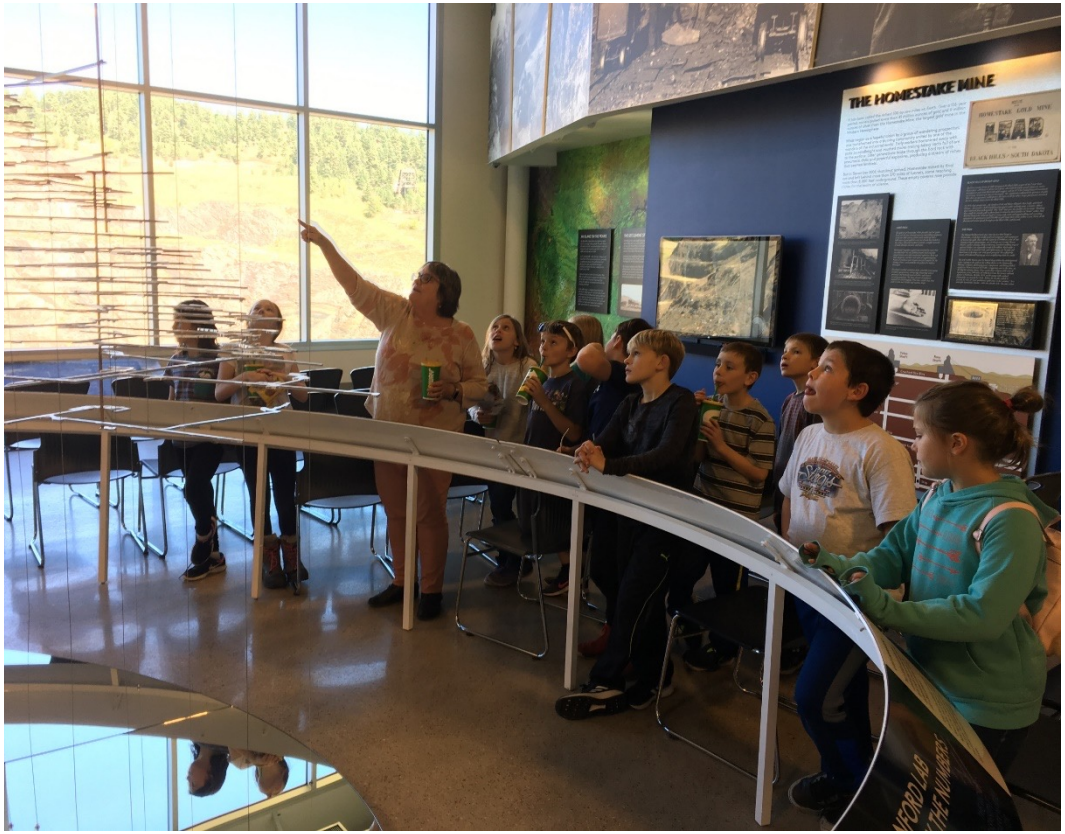


- **LBNF construction** at SURF **started Jan 2019**; excavation and concrete underway, complete by **Nov 2023;** outfitting complete **Jul 2025,** cryostat #1 complete **Apr 2026**
- **Expansion possibilities:** 4850L (as indicated), possible 7400L (2300 m, 6500 mwe)
  - Engaging design firm to conduct 4850L feasibility study in 2021
- Future space development must be responsive to **community's needs**:
  - SURF participating in Snowmass, SURF LOI submitted for Underground Facilities Frontier: https://www.snowmass21.org/docs/files/?dir=summaries/UF/
  - Planning Snowmass whitepaper to document SURF capabilities and future plans

Education and Outreach "Why"

Every student deserves:

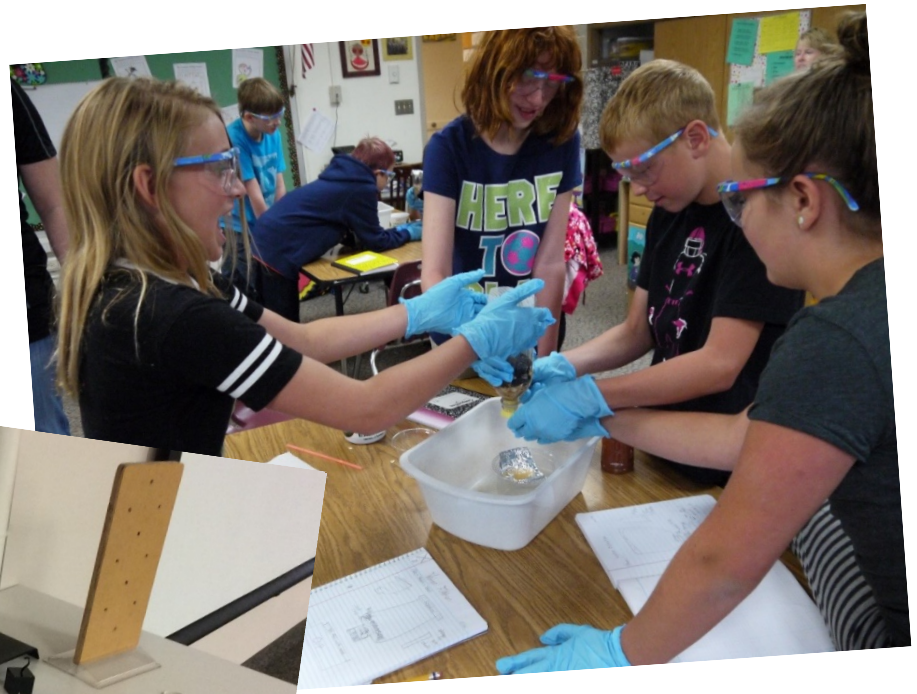
- High Quality
- Engaging
- Relevant
- Equitable
- Rigorous



science learning opportunities.

Defining the E&O "How"

Create experiences, resources and supports that move classroom experiences from **"Learning About" to "Figuring Out"** – and leverage the engineering and unsettled science of Sanford Lab.



Describing the E&O "What"

1. Field Trips
2. School Presentations
3. Curriculum Units
4. Teacher Professional Development & Support

E&O – Next Steps

Building Relationships

- Expanding the number of schools and students impacted annually
- Increasing the percentage of rural and tribal partner districts

Bridging to Post-Secondary and Career

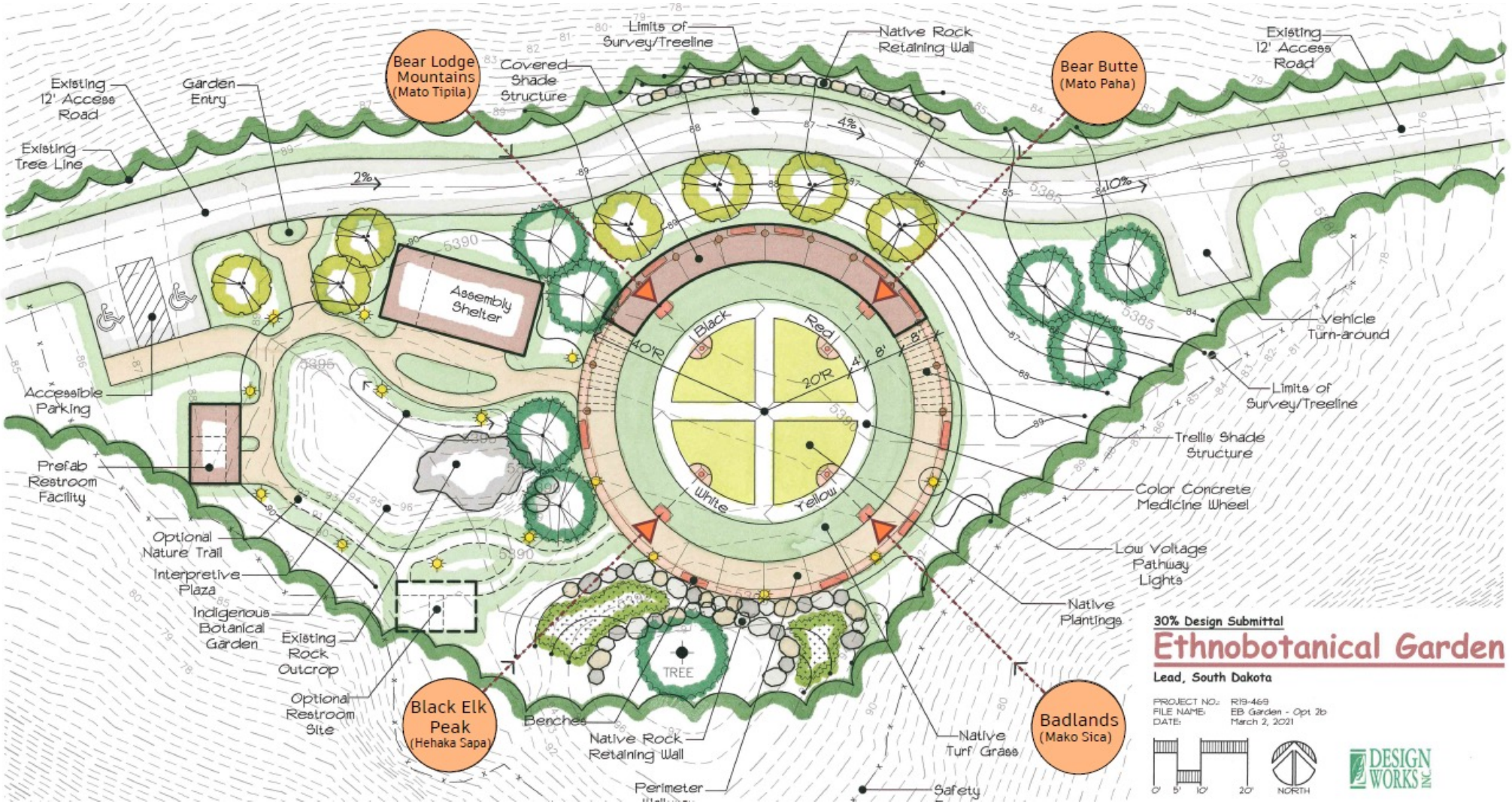
- Expanding partnerships with post-secondary institutions
- Offering unique supports & resources to K-12 pre-service teachers in science
- Increasing outreach to a diverse audience for internships and the Davis-Bahcall Scholars Program

Working toward a Global Reach

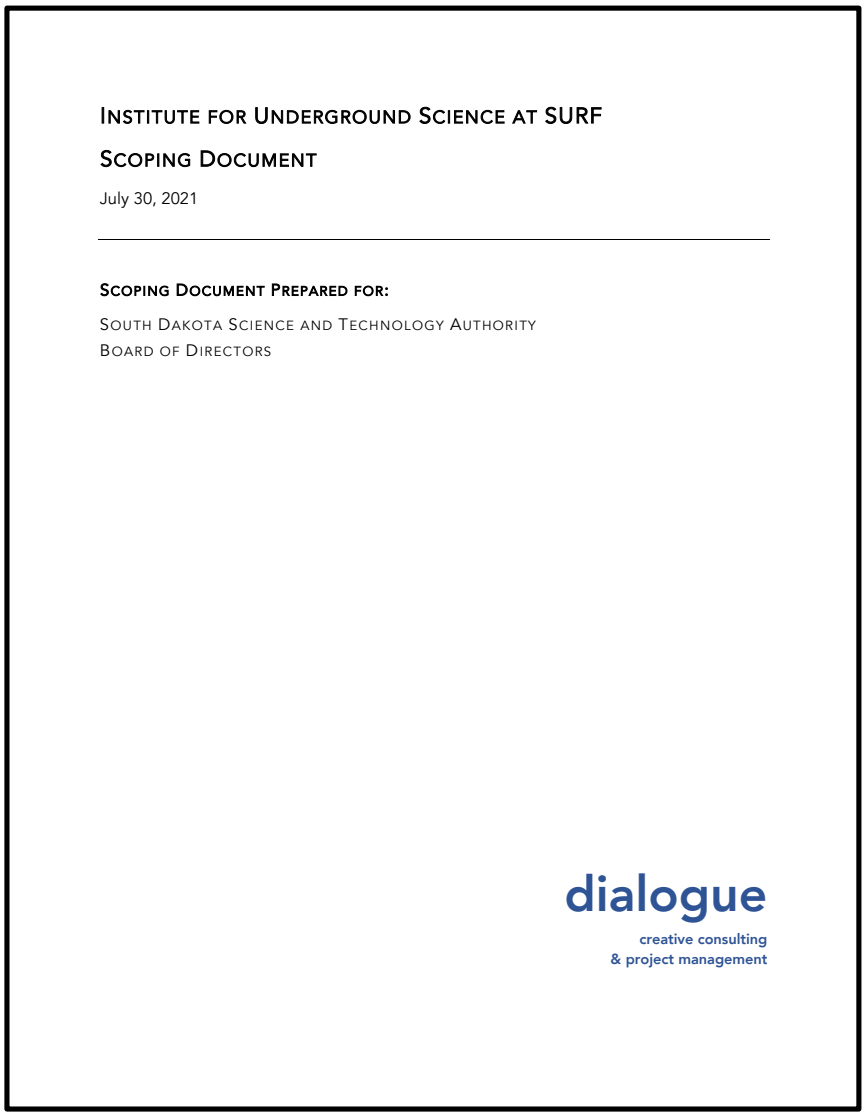
- Building on lessons learned during the pandemic to offer engaging virtual options anywhere.

Cangleska Wakan (Sacred Circle) Garden

https://www.sanfordlab.org/garden



Institute for Underground Science at SURF


INSTITUTE FOR UNDERGROUND SCIENCE AT SURF

SCOPING DOCUMENT

July 30, 2021

SCOPING DOCUMENT PREPARED FOR:

SOUTH DAKOTA SCIENCE AND TECHNOLOGY AUTHORITY
BOARD OF DIRECTORS

dialogue
creative consulting
& project management

Institute scoping document released on July 30. Many thanks to our working group for their contributions!

We've since held a building visioning workshop with Arup on Aug 27. Discussed functional requirements, sizing, pros/cons of potential locations on-site and in Lead overall.

Arup developing report to capture items from above and initial costing for main structure and guest house.

We're also working with Elizabeth Freer and SDSTA CFO & HR to refine staffing plan and develop annual budget.

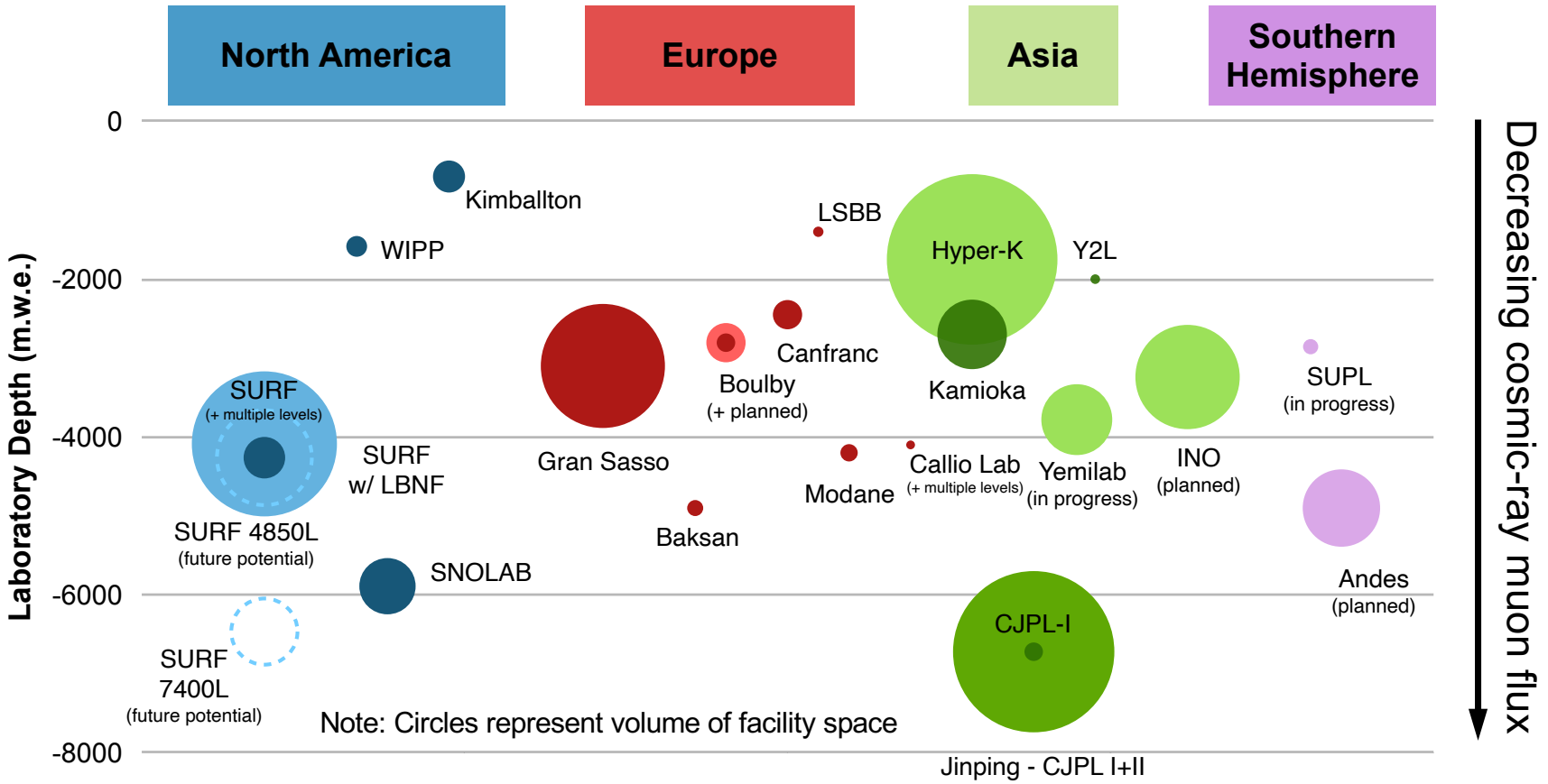
We expect to provide presentation on the above to SDSTA and SURFF Boards no later than Dec 2021 meetings.

Sanford Underground Research Facility

Thank you!

Underground Facilities

Underground Facilities



World-class UG Facilities provide:

- Overburden protection from cosmic-ray muons
- UG material production or purification
- Implementation and operations support
- Local radiation shielding, environmental controls
- Material screening

Underground Facilities

World-class 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
  - Variety of rock conditions (stress, temperature, etc)
- Engineering
  - Real-world environments for technology development, mining, etc

SURF Science Program

Researchers from 85 institutions (Pre-DUNE), active in bold (56)

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**
- **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**
- 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
- **University at Albany/SUNY, Albany, NY**

US – continued

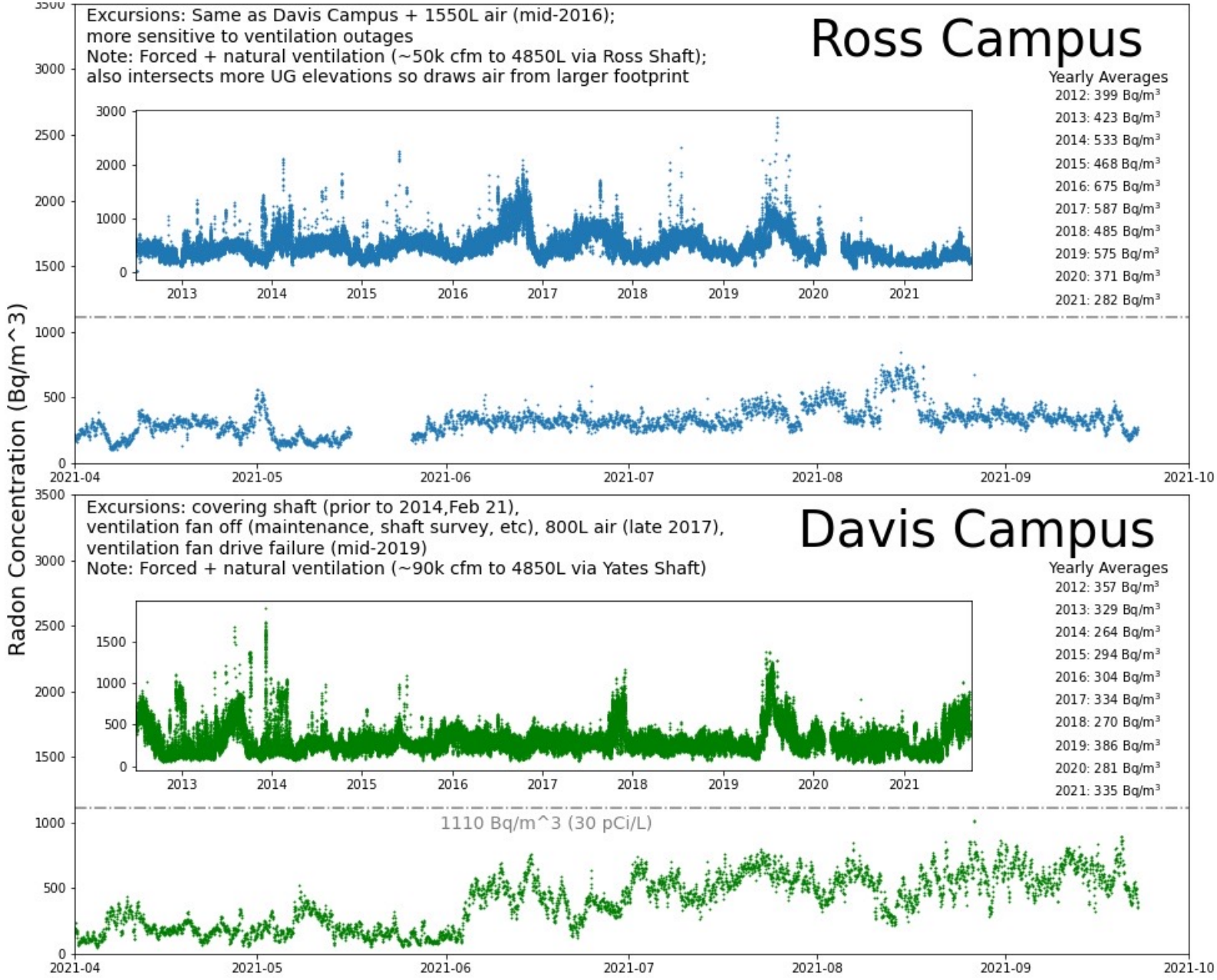
- **University of Alabama, Tuscaloosa, AL**
- **University of California Berkeley, Berkeley, CA**
- **University of California Davis, Davis, CA**
- **University of California Santa Barbara, Santa Barbara, CA**
- **University of Kentucky, Lexington, KY**
- **University of Maryland, College Park, MD**
- **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
- William's 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**
- MEPhI, Moscow, Russia
- 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 Universitat Munchen / 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**

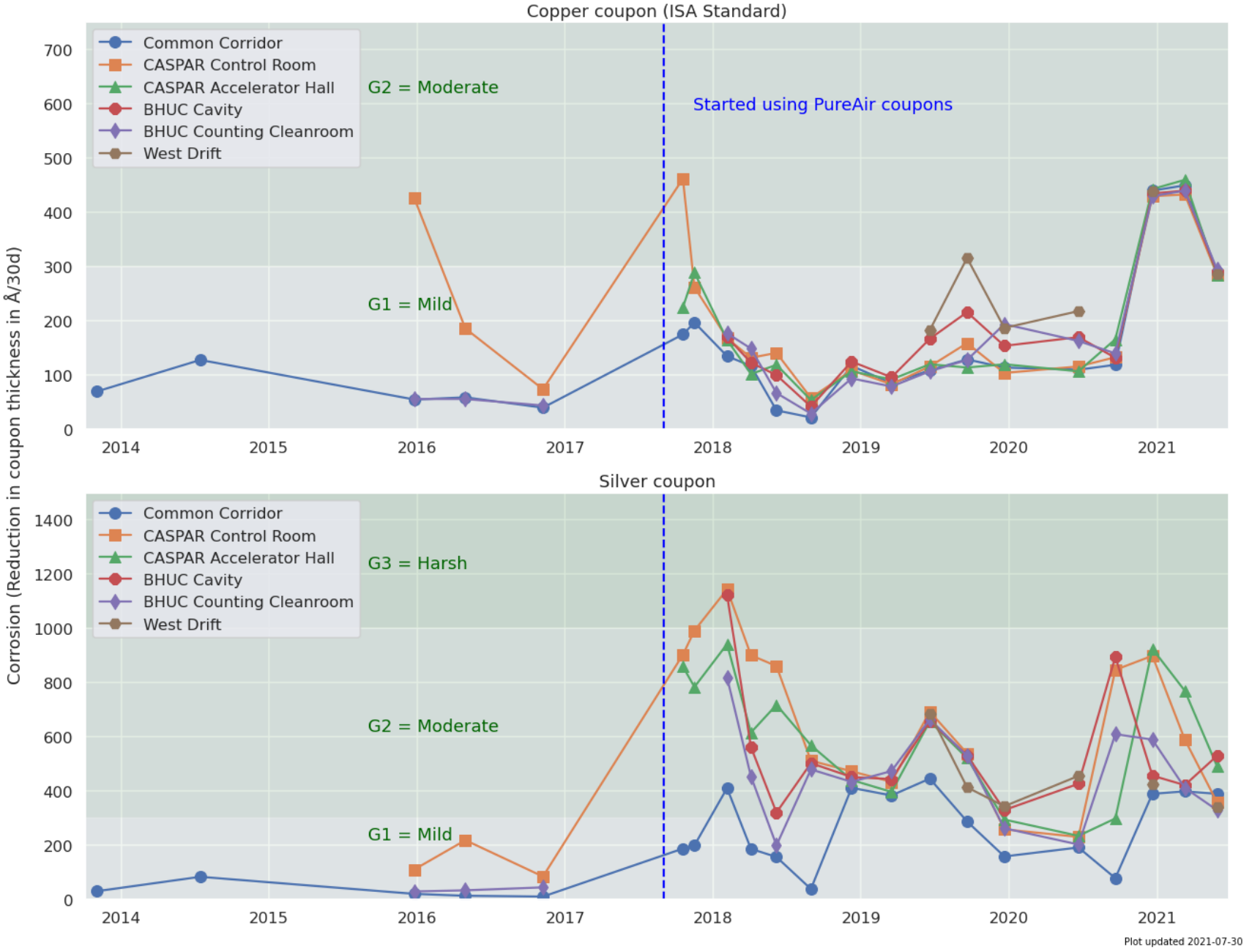
SURF Science Support – Monitoring

Radon concentrations in 4850L laboratories since 2012



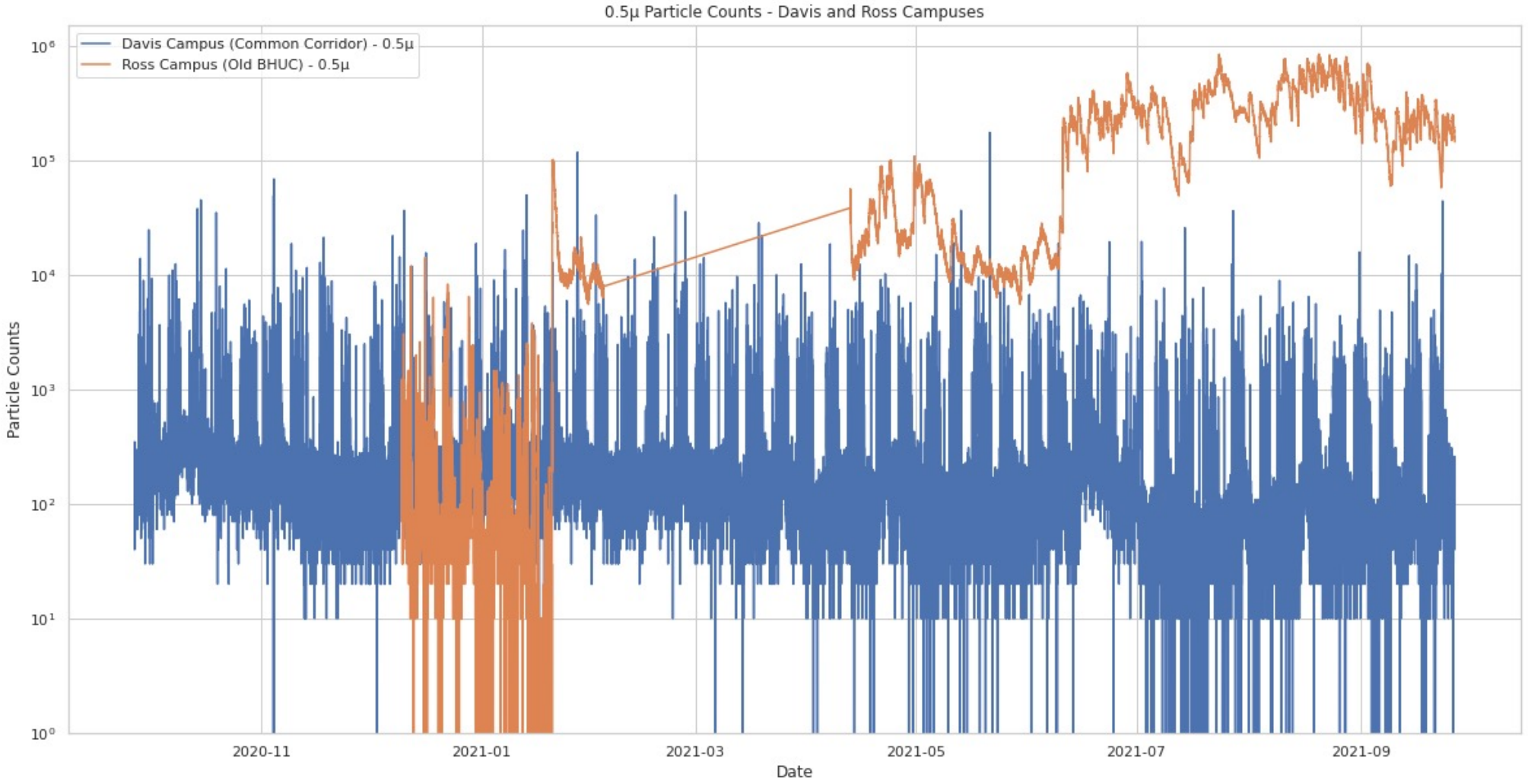
SURF Science Support – Monitoring

Corrosion/reactivity testing in 4850L laboratories since 2013



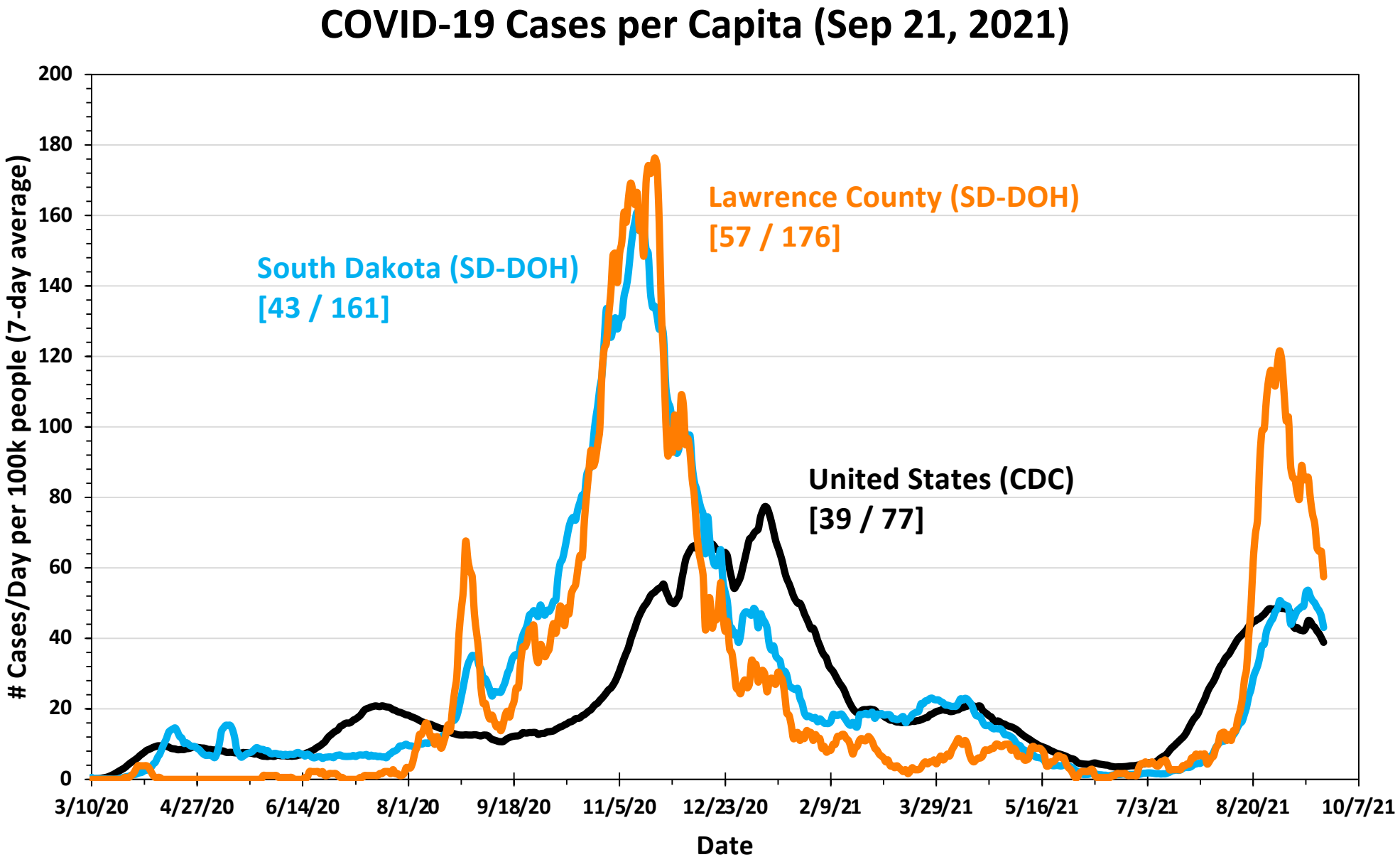
SURF Science Support – Monitoring

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



SURF COVID-19 Data Monitoring

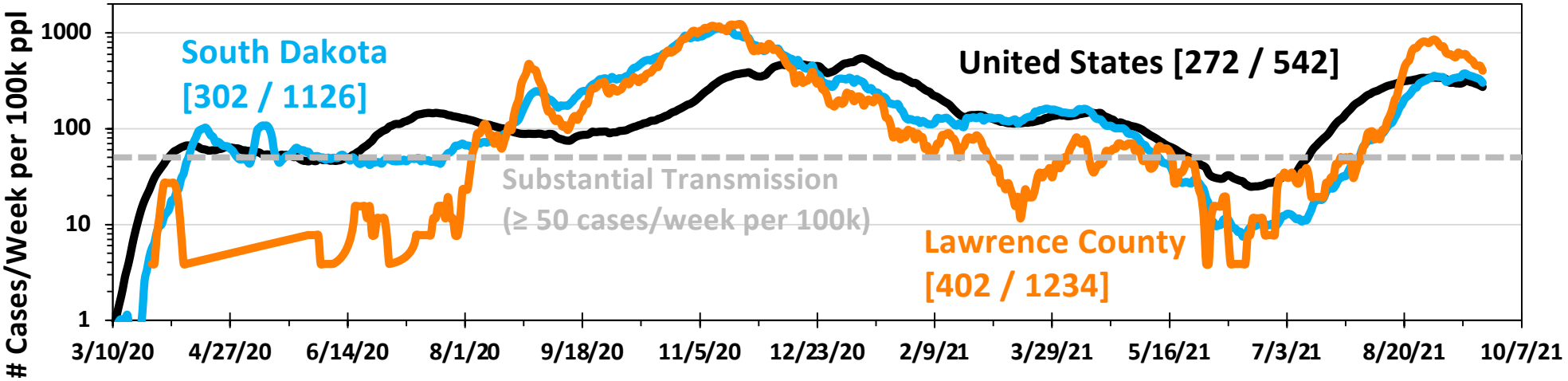
Cases (current / max 7-day per capita average values indicated)



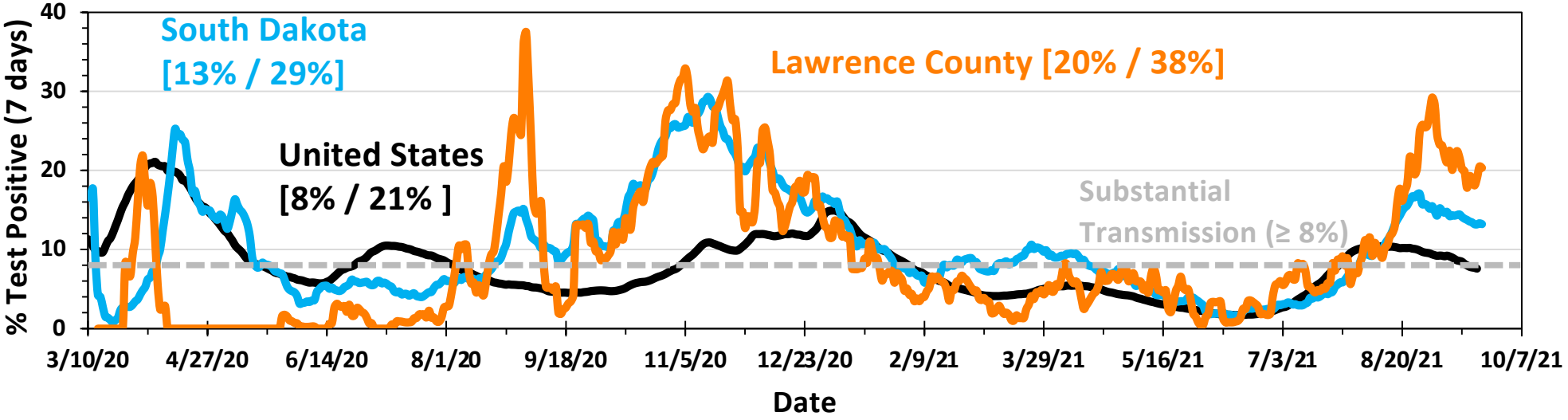
SURF COVID-19 Data Monitoring

Transmission: Cases & Positivity (current / max values indicated)

COVID-19 Cases per Capita (Sep 21, 2021)

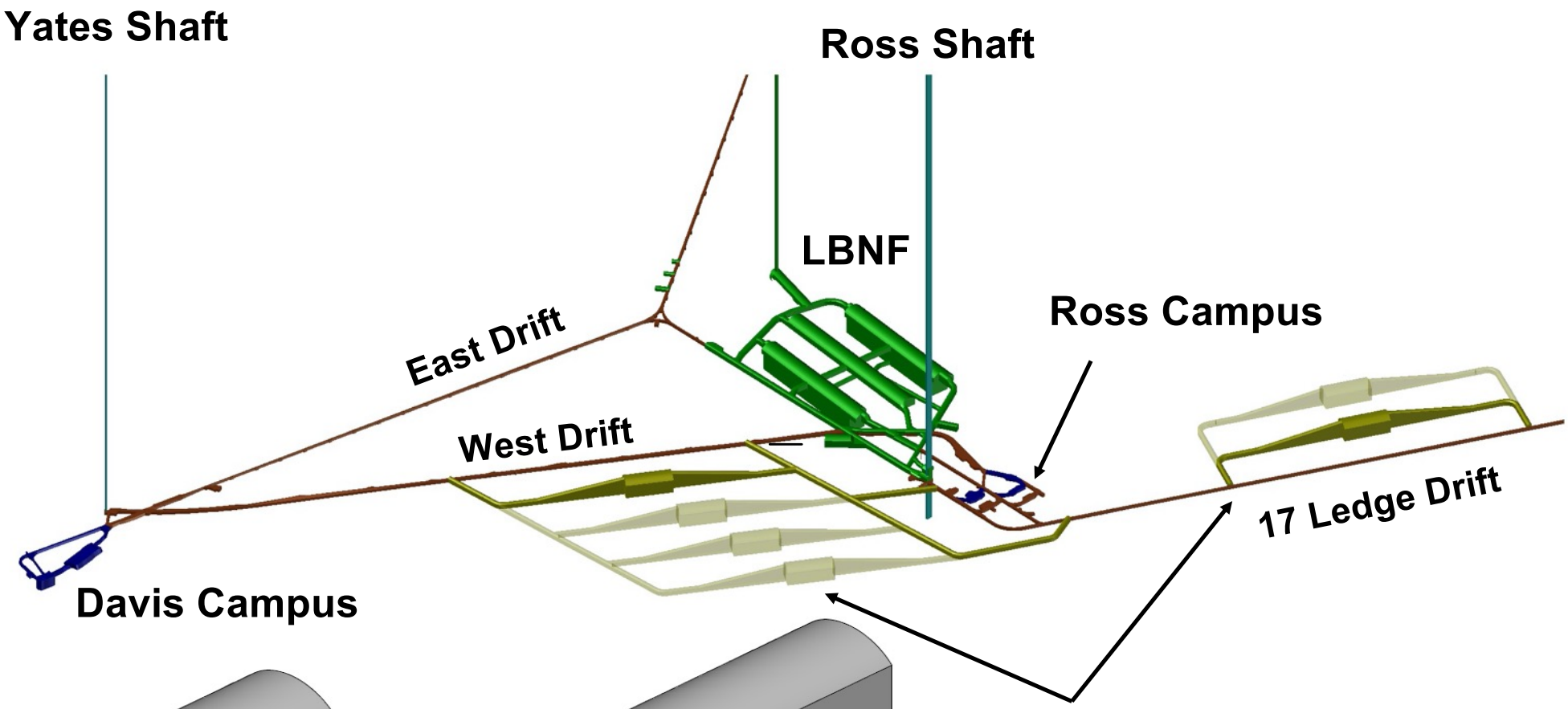


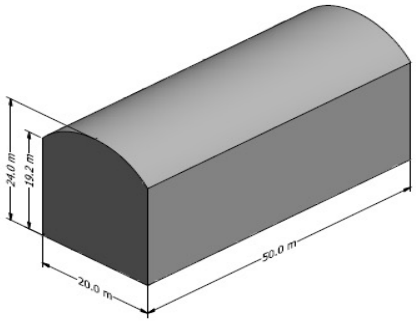
COVID-19 Positivity (Sep 21, 2021)



SURF Underground Facility Expansion

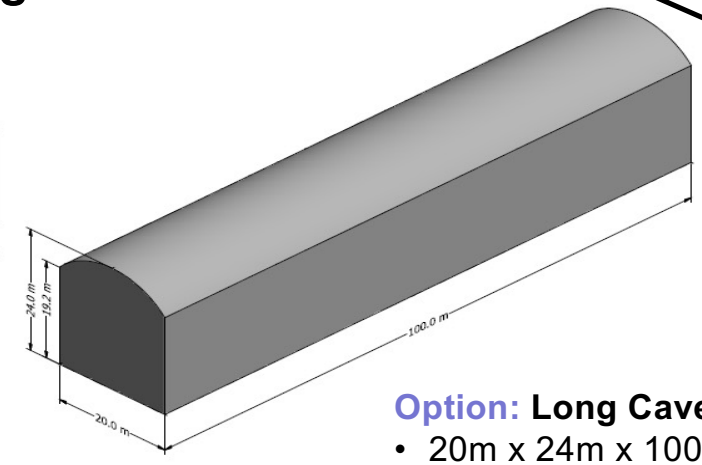
4850L Future Expansion Planning





Option: Medium Cavern

- 20m x 24m x 50m



Option: Long Cavern

- 20m x 24m x 100m

Lab Module Expansion Sites

- Utilizes LBNF rock handling system
- Dimensions scalable to meet experiment needs

SURF Laboratory Space

Summary for various science campuses, including timelines

Location	Laboratory	Existing/*Planned* Space		Available (CY)	Comments
		Area (m^2)	Vol (m^3)		
Surface	Surface Lab (served by 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 operations beginning 2021, complete by ~2026 + decommissioning
	MJD Lab – 2 Rms + BHUC share	300	1,279	~2024/2026	Initial scope complete by end of 2021, Ta-180m data to ~mid-2023 + decommissioning; e-form Cu through 2025
	Cutout Rms (4)	100	412	~2027	LZ timeframe for most spaces
Ross Campus (4850L)	Former E-forming	228	742	?	LBNF use + SURF UG WWTP
	BHUC (BHSU owns cleanroom)	266	773	~2025	Mothballed, most equipment and systems relocated to Davis Campus; re-occupy after LBNF construction
	CASPAR	395	1,130	~2024/2027	Mothballed, equip remains, re-occupy after LBNF construction? Use to expand Refuge Chamber during DUNE install
	Refuge Chamber	258	866	?	Long-term use TBD
LBNF (4850L)	*LBNF*	*9,445*	*191,863*	*~2024*	*Excavation started 2020, lasts ~3 yrs*
4100L	*Multiple labs*	*TBD*	*TBD*	*TBD*	*SIGMA-V in progress, also RESPEC*
4850L	*Propose 2 labs*	*2 x 2,300*	*2 x ~46,738*	*Responsive to community need*	*Each 20m (W) x 24m (H) x 115m (L)*
7400L	*Propose 2 labs*	*2 x 1,125*	*2 x 14,288*		*Each 15m (W) x 15m (H) x 75m (L)*

SURF Supports Science

Variety of Resources to Ensure Safe and Successful Science

Science

- Main point of contact for researchers, coordinate and marshall 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 63 science users per day

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)

Experiment Implementation Program

SDSTA Publication Policy

A. Purpose

The purpose of this policy is twofold:

1. To establish high standards of excellence for publications by encouraging appropriate review for all scientific, technical and engineering publications related to Sanford Underground Research Facility ("Sanford Lab") research and technical activities prior to publication; and

2. To ensure Sanford Lab is notified of all publications that are based on work performed in whole, or in part, at Sanford Lab.

B. Applicability

This policy concerns collaborating partners ("Users"), employees, contractors and visitors working at or with the Sanford Lab.

This policy applies to all publications that are based on work performed in whole, or in part, at Sanford Lab. For the purposes of this policy, the term "Publication" means any document (in whatever form) such as abstracts, manuscripts and technical papers printed in a professional journal, popular periodical, published as a book or portion of a book (including electronic versions) and made available to the public. The term includes materials subject to patents or copyrights.

C. Responsibilities

The SDSTA is not responsible for the validity, opinions, findings, conclusions or methods of the research performed by Users at the Sanford Lab.

Prior to the publication of any work resulting from the research performed at the Sanford Lab, it is the responsibility of the author(s), or other person(s)

Publication Policy

South Dakota Science and Technology Authority

responsible for the content of the publication and/or those who originated or developed the content, to ensure that:

1. All requirements of any relevant investigator institution's review processes are met.

2. Findings adhere to scientific community standards of ethics and values.

3. All requirements of any applicable funding agencies are met.

4. The publication contains the appropriate credits, oral acknowledgements, legal disclaimers and patent or copyright notices.

5. The publication complies with all applicable patent, copyright, intellectual property, and other applicable laws, as well as the requirements of the User's Memorandum of Understanding with the South Dakota Science and Technology Authority.

D. Acknowledgements

Publications should contain the appropriate credit line, including the funding source(s); the DOE or other agency contract number; any applicable facility (non-NSF or non-DOE contract number); and an acknowledgement of the assistance provided by the Sanford Lab. The acknowledgement of the Sanford Underground Research Facility must be included for publications that are based on work performed in whole, or in part, at the Sanford Lab. The following are examples of credit lines:

SURF Physics Overview – Current

Strong science program with exciting future possibilities

- **LZ:** Direct search for **dark matter** using 10 tonnes xenon within ultra-pure water shield + Gd-loaded liquid scintillator veto

  Status: All purified Xe UG at SURF, condensing underway, outer detector filled w/ liquid scintillator. Operations in 2021, run for 5 years

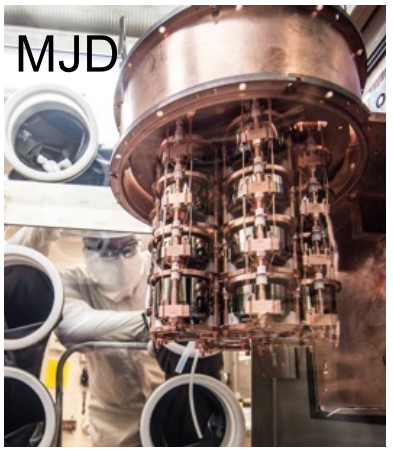
- **MAJORANA DEMONSTRATOR:** Investigate **neutrinoless double beta decay** using 44 kg Ge in two cryostats, 30 kg enriched ^{76}Ge inside multi-layer compact shield

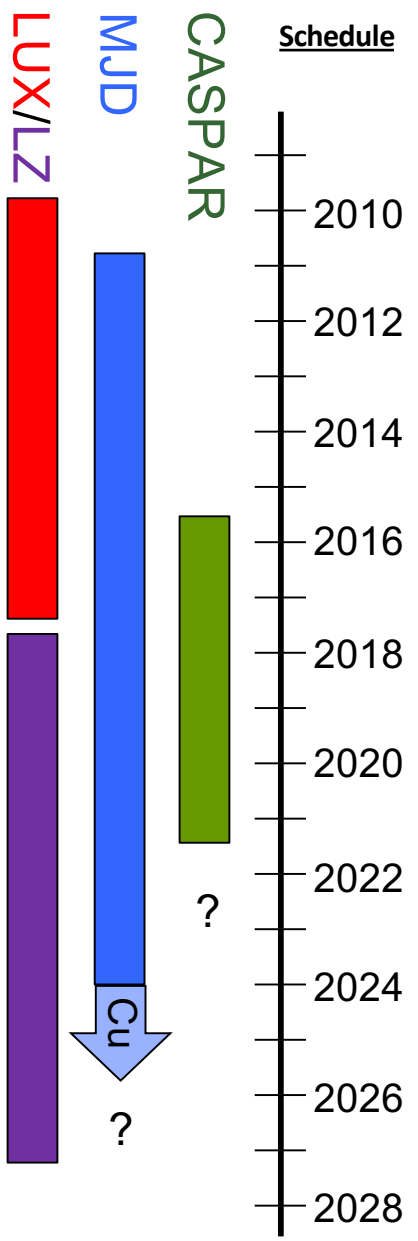
  Status: Data 2015-2021 (achieved 65 kg-yr exposure), bkgd studies continue. Ultra-pure electroformed Cu production continues (avg U, Th decay chain $\leq$ 0.1 μBq/kg). LEGEND detector characterization and R&D. Planning for ^{180m}Ta

- **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 ^{14}N, ^{11}B, ^{27}Al, ^{22}Ne (gas), ^{18}O, ^{7}Li, ^{20}Ne, ^{22}Ne (solid). Planning for next phase of operation

- **BHUC:** 4x **low-bkgd assay** counters operating with ~10s ppt sensitivity (6 counters total in 2021)





SURF Material Assay at BHUC

Establishing national & international-level low-bkgd capabilities

Detector	Crystal		[U] mBq/kg	[Th] mBq/kg	BHUC 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 upgrade 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 upgrade 2020.
Dual HPGe ("Twins") (BLBF, BHSU, UCSB)	p-type (120%)	2x 2.1 kg	**~0.01** (~1 ppt)	**~0.01** (~3 ppt)	Davis Campus: Sep 2020 (Ross Campus: Jul 2017 (initial), Mar 2018)	Commissioning	Low-bkgd upgrades 2016-2017; flexible shield. Cooling system upgrades 2020.
Ge-IV *(Alabama, Kentucky)*	*p-type (111%)*	*2 kg*	***~0.04*** *(~3 ppt)*	***~0.03*** *(~8 ppt)*	*Davis Campus: Nov 2020 (initial), Fall 2021 (Ross Campus: Oct 2017 (initial), Jul 2018)*	*Installation underway*	*Vertical design, requires gantry + hoist. Cooling system upgrades 2020.*
RHYM+RESN *(LLNL)*	*p-type (>100%)*	*2x ~1.1 kg*	***<0.1*** *(<10 ppt)*	***<0.04*** *(<10 ppt)*	*Davis Campus: Sep 2020 (initial), Fall 2021*	*Installation underway*	*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: **ICP-MS** (Black Hills State University) and **Rn emanation** characterization (SD Mines). Other: BetaCage (SDSMT prototype), XIA UltraLo-1800 (LZ)

Our 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.