Sanford Underground Research Facility

Jaret Heise, Science Director

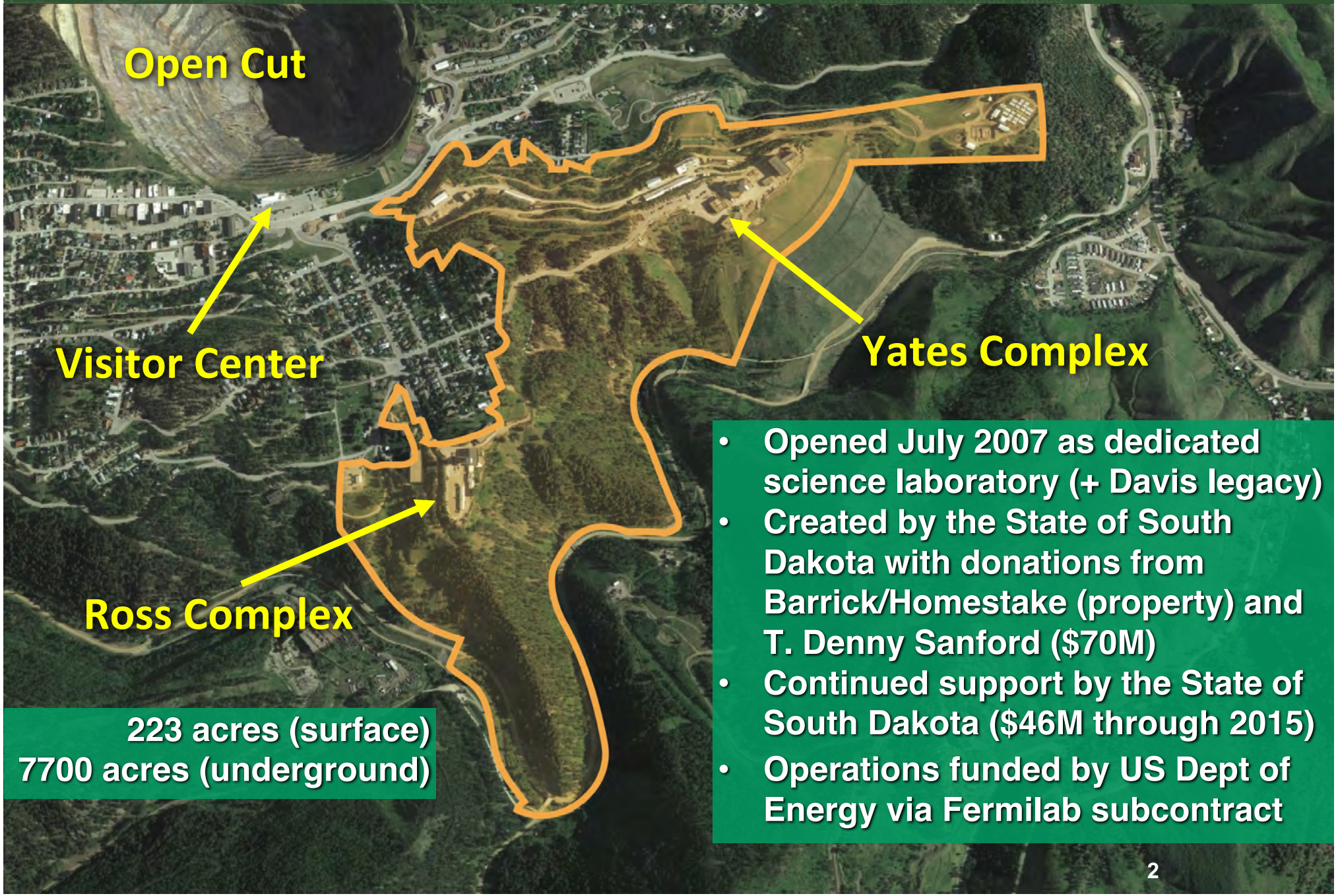
July 2017

Sanford Underground Research Facility

South Dakota Science and Technology Authority

Sanford Underground Research Facility

Dedicated facility for underground scientific research

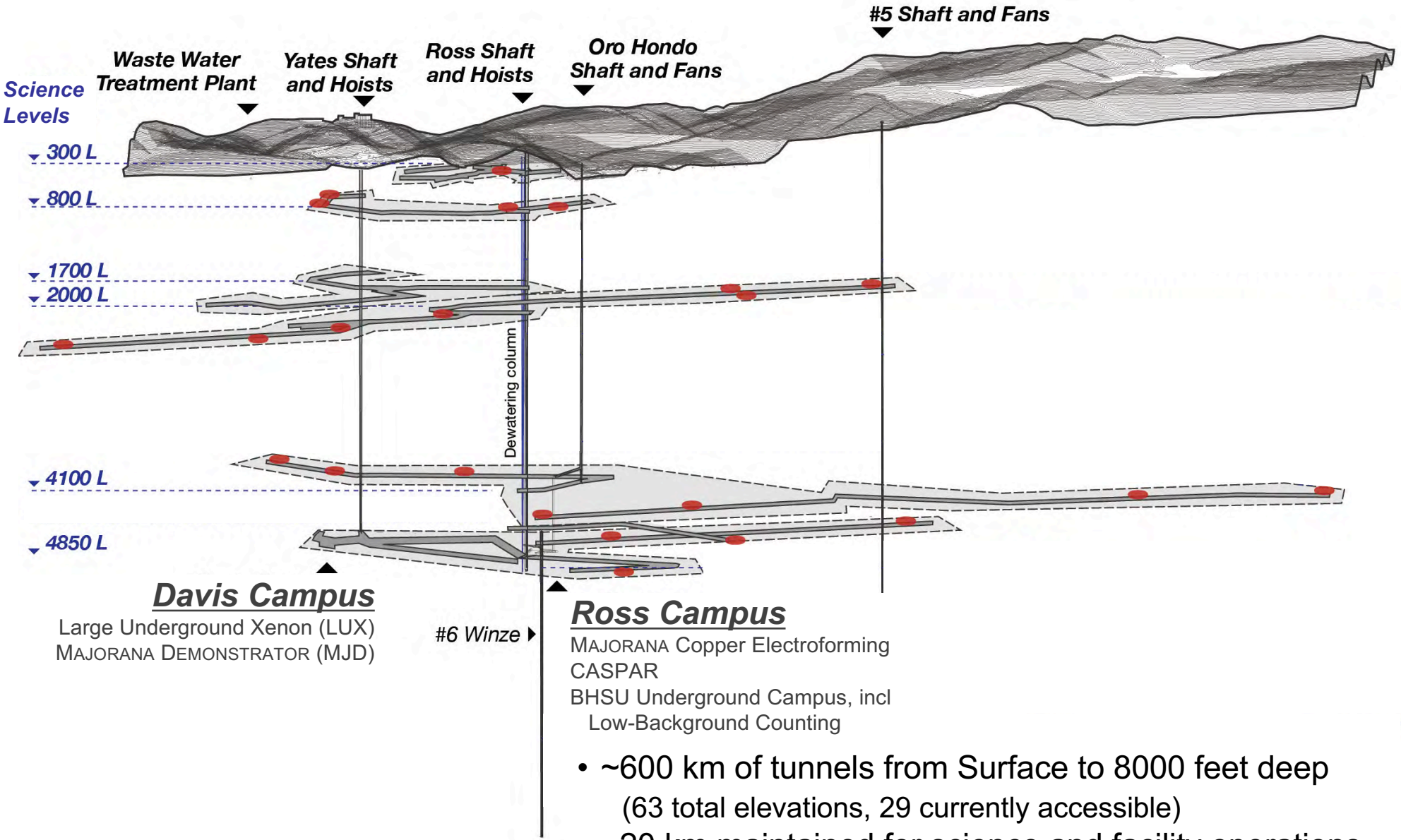


223 acres (surface)
7700 acres (underground)

- 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 support by the State of South Dakota ($46M through 2015)
- Operations funded by US Dept of Energy via Fermilab subcontract

SURF Underground Lab Geography

Yates & Ross + ventilation shafts, multiple levels for science



Davis Campus

Large Underground Xenon (LUX)
MAJORANA DEMONSTRATOR (MJD)

Ross Campus

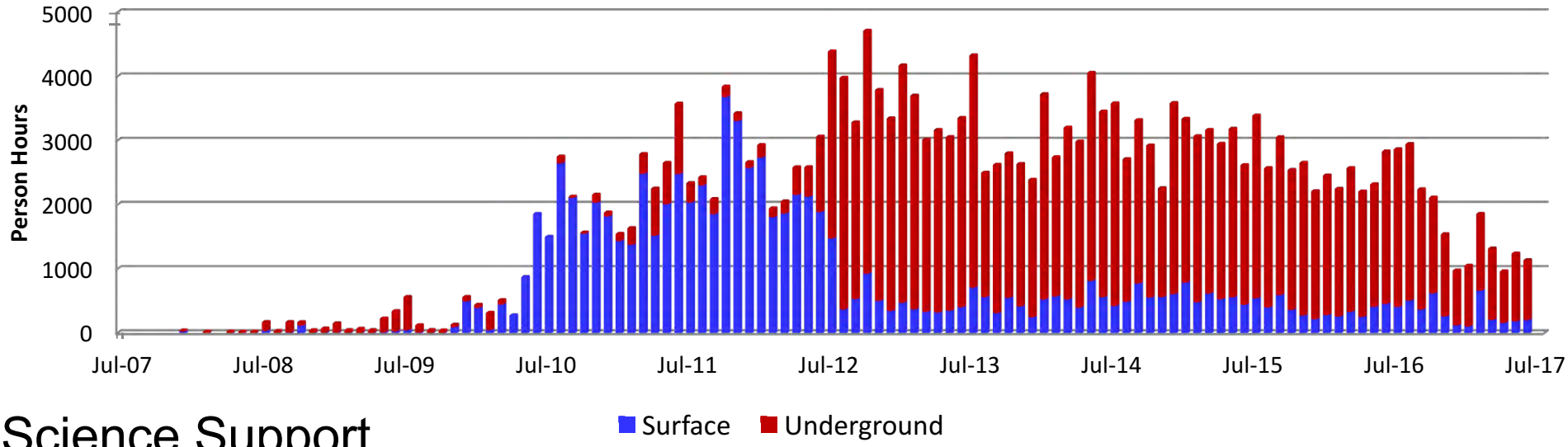
MAJORANA Copper Electroforming
CASPAR
BHSU Underground Campus, incl
Low-Background Counting

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

SURF Science Overview

Expanding community of researchers from multiple disciplines

- Science Mission
  - "To advance compelling underground, multidisciplinary research in a safe work environment and to inspire and educate through science, technology, and engineering"
  - Currently **24 active groups** on multiple levels representing physics, biology, geology and engineering



- Science Support
  - Total SURF staff = 125 people (majority support facility maintenance, 24-hr shaft operations):
    - Robust organization with resources to ensure safe and successful science
    - Science Dept = 6 people, incl 3 staff scientists, cleanroom custodian, technician for laboratory systems
    - Engineering Dept = 10 people, many supported by other expts
    - Environment, Safety & Health Dept = 9 people, incl training, industrial hygiene, radiation/experiment safety
  - Mature experiment implementation program: http://www.sanfordlab.org/researchers/proposal-guidelines
  - Facility air handling, cleaning support + modest protocols achieve Class ~3000; Class 100-1000 supported in specific facilities with additional effort and protocols; new low-Rn systems and cleanroom

SURF Science Program

Research activities ranging from the surface to the 5000L

Physics

LUX/LZ – *Dark matter, 2-phase Xe TPC*

MAJORANA DEMONSTRATOR – *Neutrino-less double-beta decay using Ge, also copper electroforming*

CASPAR – *Nuclear astrophysics with 1 MV accelerator*

BHUC – *BHSU Underground Campus, incl biology & physics labs*

Berkeley LBF – *Low-bkgd counter (x2)*

CUBED – *Low-bkgd counter (x1); also past bkgd characterization (possibly future Crystal Growth)*

LZ SOLO – *Low-bkgd counter (x1)*

Alabama/USD/ – *Low-bkgd counter (x1)*

Plus interest from others (e.g., R&D)

Engineering

Xilinx, Inc – *Chip error testing*

Video Gauge – *UG monitoring*

Shotcrete – *Mining safety*

Plus interest from others

Geology

GEOX™ – *Optical fiber applications, tiltmeters, env monitoring*

Hydro Gravity – *Local gravity for water tables, densities*

PODS – *Petrology, ore deposits, structure (mainly drill core)*

Transparent Earth – *Seismic arrays*

kISMET/SIGMA-V – *Geothermal*

Rock Melt – *Storage in crystalline rock*

Radiogenic Analysis – *Heat flow, nu's*

Plus interest from others

Biology

Biodiversity – *BHSU*

Biofuels – *SDSMT*

Lignocellulose – *SDSU*

Syngas/Biofuels – *SDSMT*

NASA Astrobiology Institute – *USC/DRI*

GoLife – *Bigelow Lab/DRI*

Plus interest from others

Total Active = 24 groups
(36 Total Groups Since 2007)

SURF Science Institutions

Current researchers from all around the world (78 institutions)

United States

- **Augustana University, Sioux Falls, SD**
- Bigelow Laboratory, East Boothbay, MA
- **Black Hills State University, Spearfish, SD**
- Brandeis University, Waltham, MA
- Brookhaven National Laboratory, Upton, NY
- Brown University, Providence, RI
- Caltech, Pasadena, CA
- Case Western Reserve University, Cleveland, OH
- Colorado School of Mines, Golden, CO
- **Dakota State University, Madison, SD**
- 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
- Jet Propulsion Laboratory, Pasadena, CA
- Lawrence Berkeley National Lab, Berkeley, CA
- Lawrence Livermore National Lab, Livermore, CA
- Los Alamos National Lab, Los Alamos, NM
- National Energy Technology Lab, Albany, OR / Morgantown, WV
- 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
- Princeton University, Princeton, NJ
- Rensselaer Polytechnic Institute, Troy, NY
- RE/SPEC, Inc, Rapid City, SD
- Sandia National Laboratory, Albuquerque, NM
- **South Dakota School of Mines & Tech, Rapid City, SD**
- **South Dakota State University, Brookings, 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 (AZ/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
- UC Santa Barbara, Santa Barbara, CA
- 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 North Dakota, Grand Forks, ND
- 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, Madison, WI
- University of Washington, Seattle, WA
- Washington University in St Louis, St. Louis, MO
- Yale University, New Haven, CT
- Xilinx, Inc., San Jose, CA

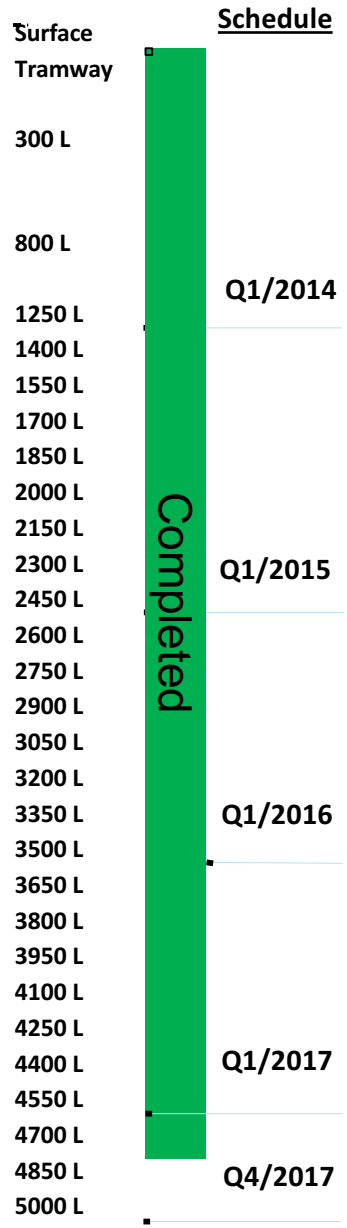
World

- Center for Underground Physics (IBS), Daejeon, Korea
- Joint Institute for Nuclear Research, Dubna, Russia
- Imperial College London, London, UK
- 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
- Rutherford Appleton Laboratory, Didcot, UK
- Technische Universitat Munchen / Max Planck Institute, Munich, Germany
- University College London, London, UK
- University of Bristol, Bristol, UK
- University of Edinburgh, Edinburgh, Scotland
- University of Liverpool, Liverpool, UK
- University of Oxford, Oxford, UK
- University of Sheffield, Sheffield, UK

SURF Facility Overview

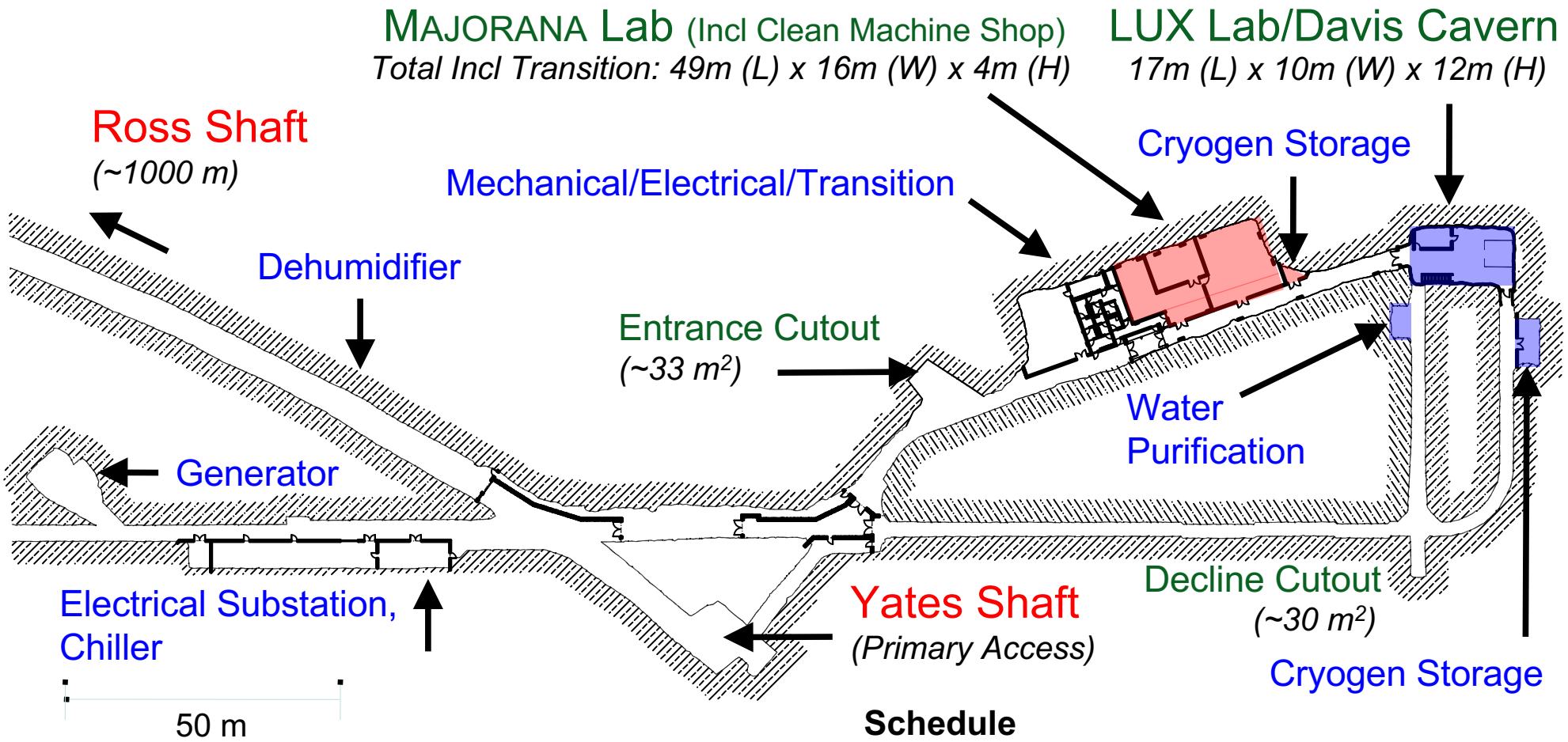
Supporting current science while upgrading for future projects

- Facility Highlights
  - Deep (4300 mwe) underground facility dedicated for science, with significant capacity & expansion possibilities
  - Redundant safe access with 2 principal shafts (incl redundant power and network utilities)
- Ross Shaft Rehabilitation
  - Full replacement of steel & ground support ~95% complete
  - Total project $32M, on track for 2017 completion
- Yates Shaft
  - Provides main access for personnel and materials
  - Schedule accommodates 24-hour underground coverage
- Ventilation
  - Total underground air flow = 510,000 m^3/hr (300,000 cfm); 4850L = 135-170k m^3/hr (Yates), 35-43k m^3/hr (Ross)
  - Dedicated air handling units + chillers for main laboratories
- Laboratories
  - Underground: Ross and Davis Campuses + non-lab areas
  - Surface: Surface Lab renovation complete, incl low-Rn cleanroom and Rn-reduction system (~300 m^3/hr)
  - Other support incl surface storage/staging + warehouse
  - LBNF (surface + UG), exploring additional cavern options



4850L Davis Campus

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



$16M South Dakota commitment

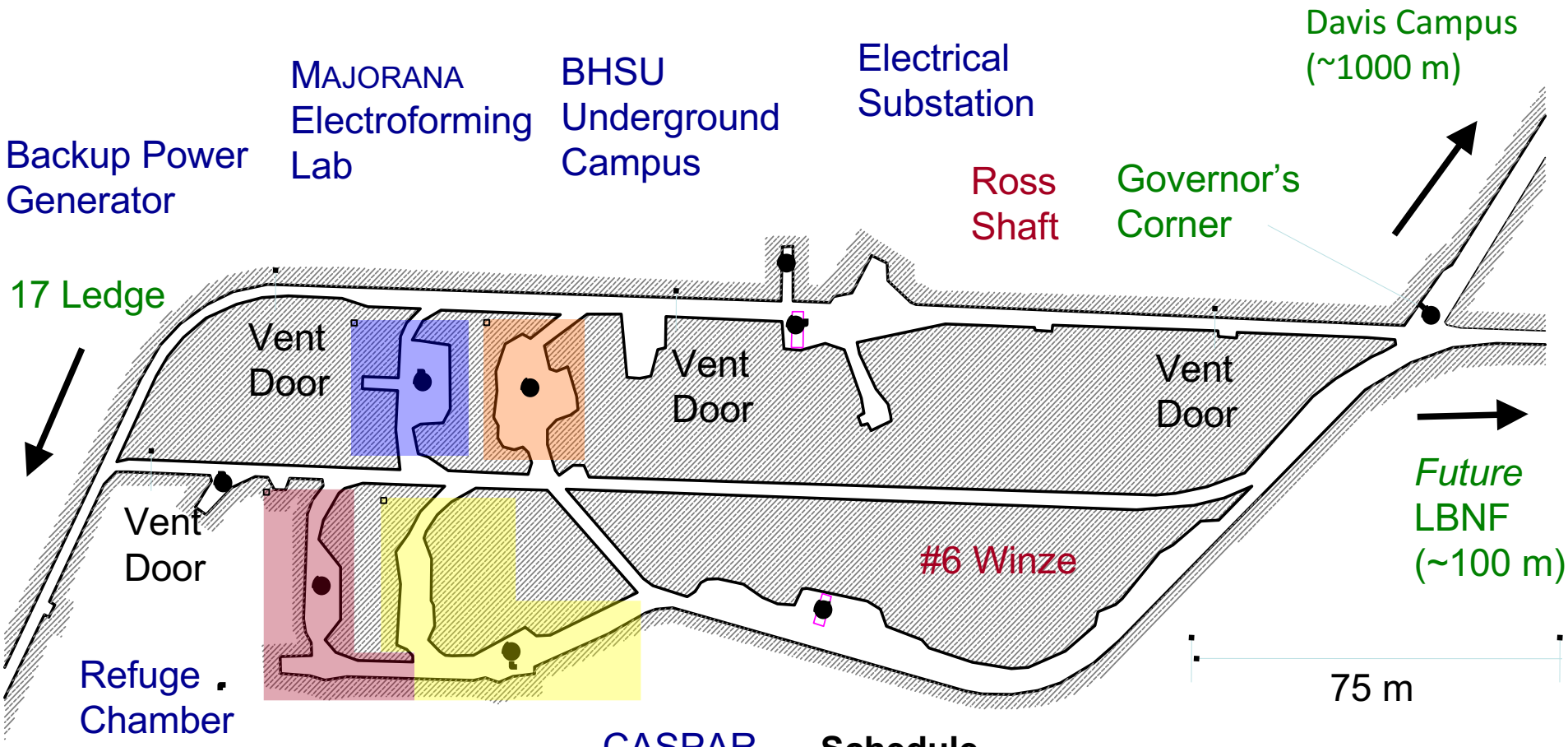
- Mar 2012: MJD occupancy
- May 2012: LUX occupancy
- Apr 2013: Low-Bkgd Counter (CUBED) occupancy
- May 2014: Low-Bkgd Counter (BLBF) occupancy
- May 2015: Low-Bkgd Counter (BLBF) installed

Schedule

- **LUX:** Data taking ended May 2016, decommissioned in mid-2017
- **LBCs:** Relocated in 2015
- **LZ:** Underground occupancy 2018, data taking 2020, decommission in ~2026
- **MJD:** Data, decommission through 2020

4850L Ross Campus

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



~$4M South Dakota commitment

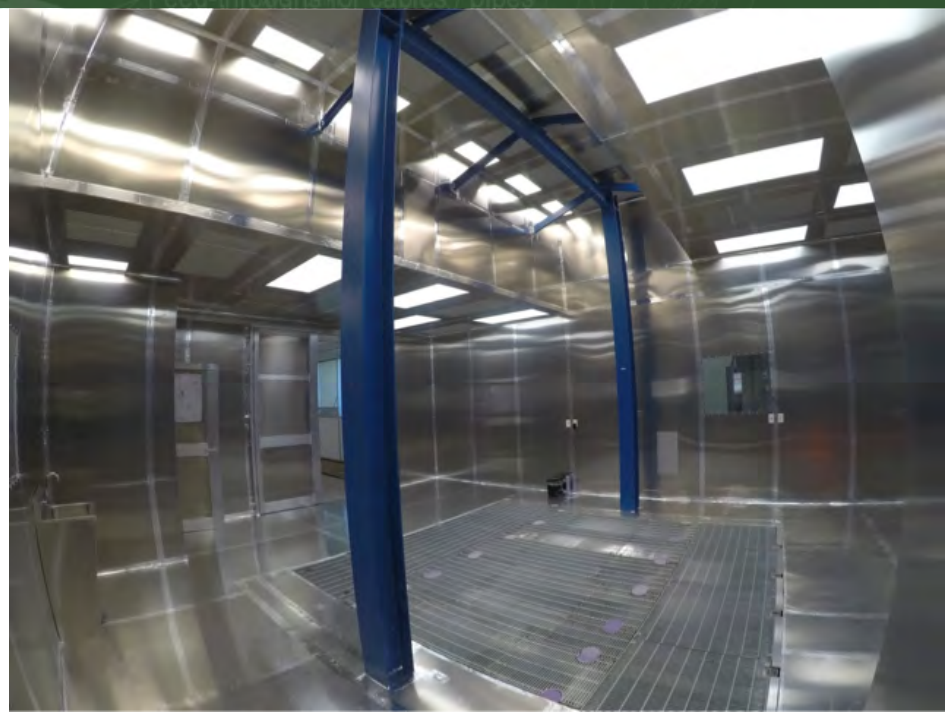
- Mar 2011: MJD Electroforming Lab occupancy
- Sep 2012: Refuge Chamber installed
- Aug 2015: CASPAR occupancy
- Sep 2015: BHUC occupancy
  (low-bkgd assay instruments)

Schedule

- **E-Forming Lab:** MJD needs met Apr 2015; decommissioning underway (continue at Davis)
- **BHUC:** Indefinite use
- **CASPAR:** ~10+ yr operation, then DIANA?
- **Refuge:** Laboratory after Ross, Yates Shaft rehab finished? (e.g., DIANA expansion?)

Surface Campus

SURF reduced-Rn system supplies air to new LZ low-Rn cleanroom

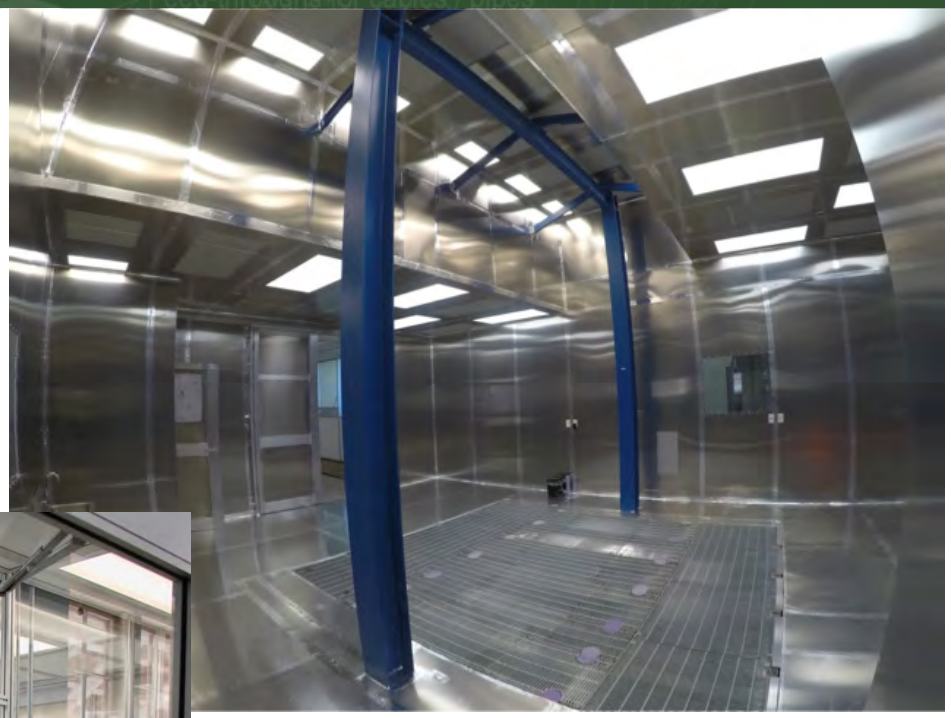


- **Specs:** 1000x Rn reduction, 300 m^3/hr
- **Supplier:** Ateko, Czech Republic (same as Y2L, Gran Sasso, etc)
- **Design:** Compress air to 9 bar, cool to -60C dew point, flow air through carbon adsorption columns, then reduce pressure and reheat as desired
- **Status:** Commissioned and operating

- **Specs:** Design/protocols support Class 100
- **Supplier:** SBB Inc., Syracuse, NY
- **Design:** Metal panels (Al) with careful consideration for sealing joints, balancing relative pressures in various areas, special entry ports (personnel entry via air shower, soft-wall for materials, etc)
- **Status:** Commissioned, clean, garb in use

Surface Campus

SURF reduced-Rn system supplies air to new LZ low-Rn cleanroom



- **Specs:** 1000x Rn reduction, 300
- **Supplier:** Ateko, Czech Republic (same as Y2L, Gran Sasso, etc)
- **Design:** Compress air to 9 bar, c dew point, flow air through carbor columns, then reduce pressure a desired
- **Status:** Commissioned and opera

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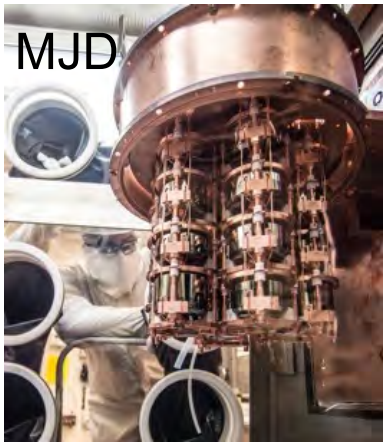
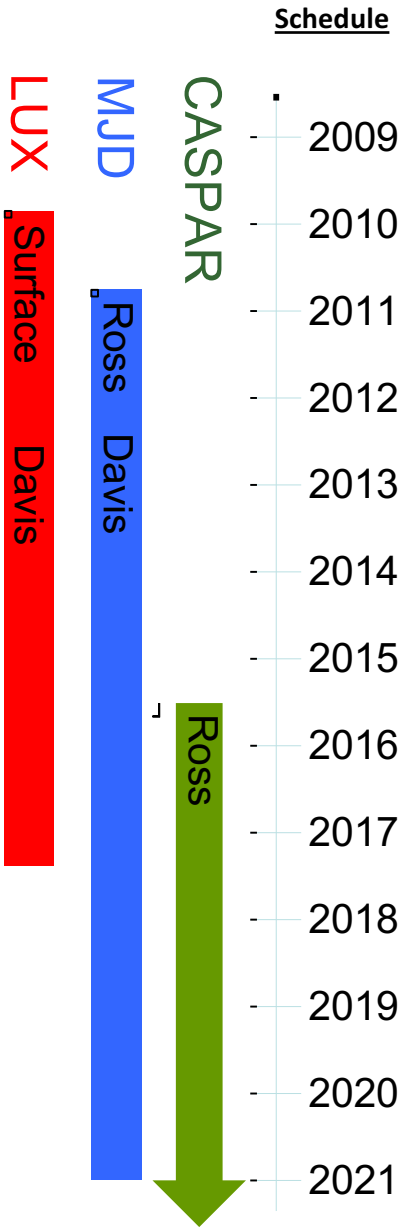
: Commissioned, clean, garb in use

SURF Science Program

Current physics projects

- Large Underground Xenon (LUX)
  - Direct search for **dark matter** using 370 kg xenon within ultra-pure titanium cryostat, ultra-pure water shield
  - **Results:** World-leading sensitivity for 3.5 yrs over most of WIMP mass, 3.35 x 10^4 kg-days exposure (427 live days)
  - **Status:** WIMP search and final calibrations complete, decommissioning complete by mid-2017
- MAJORANA DEMONSTRATOR (MJD)
  - Investigate **neutrinoless double beta decay** using 44 kg Ge in two cryostats (+ proto), 30 kg enriched ^{76}Ge inside Cu/Pb/HDPE shield (~72 tons) with active muon veto
  - **Results:** Initial Module 1 bkgds presented July 2016
  - **Status:** Commissioning (Mod 1 since 2015, Mod 2 2016)
  - Production physics data in 2017
- CASPAR
  - Study of stellar nuclear fusion reactions, esp. neutron production for **slow neutron-capture nucleosynthesis**
  - **Status:** Accelerator underground, beamline components assembled, beam operation started May 2017
  - Beam commissioning underway, physics data in 2017
- BHUC
  - **Low background assay** (4x LBCs operating in cleanroom)



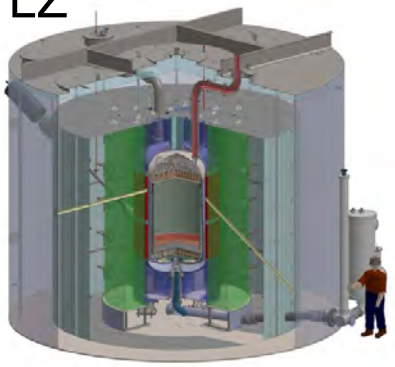


SURF Science Program

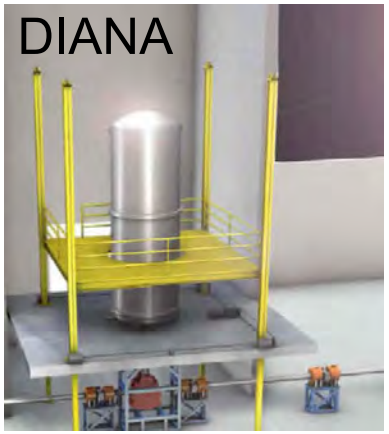
Future physics projects

- BHUC
  - **Low background assay** with 10-12 instruments, various capabilities (gamma, beta, alpha) and various sensitivities
- LUX-ZEPLIN (LZ)
  - Direct search for **dark matter** using 10 tonnes xenon within ultra-pure titanium cryostat, Gd-LS + ultra-pure water shield
  - **Goal:** 100x final LUX WIMP sensitivity
  - **Status:** Assays underway (Ti, PMTs), all xenon on contract with delivery by early 2018, Xe purification started at SLAC
- CASPAR / DIANA?
  - Study of stellar nuclear fusion reactions, esp. neutron production for **slow neutron-capture nucleosynthesis** using proton or He beams and specialized target system
  - **Goal:** Measure stellar H_2, He, C, O_2 burning
  - **Status:** Design completed (but may need modifications)
- DUNE at LBNF
  - **Neutrino physics** using 1.2 (up to 2.4) MW FNAL beam and 70 kT total (40 kT fiducial) LAr TPC, 1300-km baseline
  - **Goal:** Precisely measure oscillations, CPV, mass hierarchy
  - **Status:** Geotech studies completed 2014, test blast program completed spring 2016, U.S. appropriation supports 2017 construction start, excavation to begin 2019 (~3-yr duration)

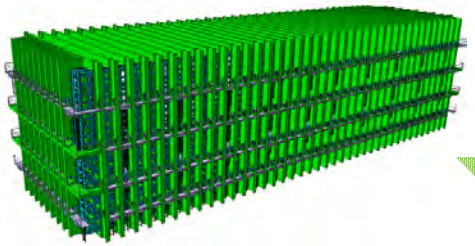
LZ

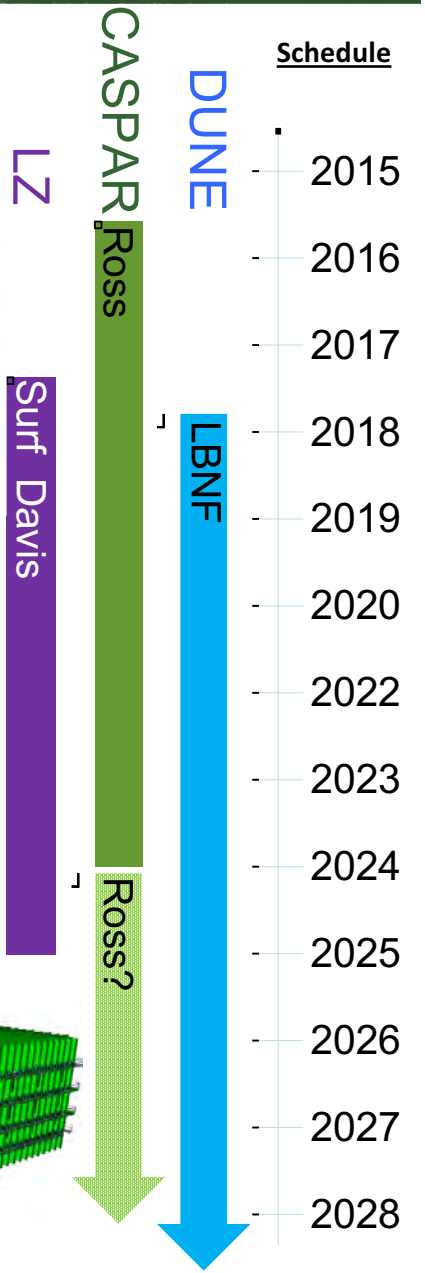


DIANA



DUNE





BHSU Underground Campus

Multi-disciplinary lab supporting SD research

SURF Science Support – Material Assay

Establishing national-level assay capability

Detector	Crystal		[U] mBq/kg	[Th] mBq/kg	BHUC Install Date	Status	Comments
	Type	Size					
Maeve (BLBF)	p-type	2.2 kg	**0.1** (~10 ppt)	**0.1** (~25 ppt)	Nov 2015 (from Oroville, Davis Campus May 2014)	Production assays	Old Pb (200-yr old) inner shielding
Morgan (BLBF)	p-type	2.1 kg	**0.2** (~20 ppt)	**0.2** (~50 ppt)	Nov 2015 (Davis Campus May 2015)	Production assays	Low-bkgd upgrade 2015
Mordred (USD/CUBED, BLBF)	n-type	1.3 kg	**0.7** (~60 ppt)	**0.7** (~175 ppt)	Jul 2016 (Davis Campus Apr 2013)	Production assays	Low-bkgd upgrade 2015-2016, shield access mod plans
SOLO (LZ/Brown)	p-type	0.6 kg	**0.6** (~50 ppt)	**0.3** (~75 ppt)	Feb 2016 (from Soudan)	Production assays	Shield reconfigured and optimized
Dual HPGe *(BLBF, BHSU, UCSB)*	*p-type*	*2x 2.1 kg*	***~0.01*** *(~1 ppt)*	***~0.01*** *(~3 ppt)*	*Jul 2017*	*Both detectors and Pb shielding UG at SURF*	*Low-bkgd upgrades 2016-2017, shield design complete*
Ge-IV *(Alabama, USD)*	*p-type*	*1.2 kg*	***<7.4*** *(<600 ppt)*	***<2.4*** *(<600 ppt)*	*Aug 2017*	*Detector and Cu shielding UG at SURF*	*Locate outside cleanroom, shield design converging*

Planned BHUC instruments:

- BetaCage (SDSMT proposal)
- XIA UltraLo 1800 (LZ, purchased)

Nearby (offsite) instruments:

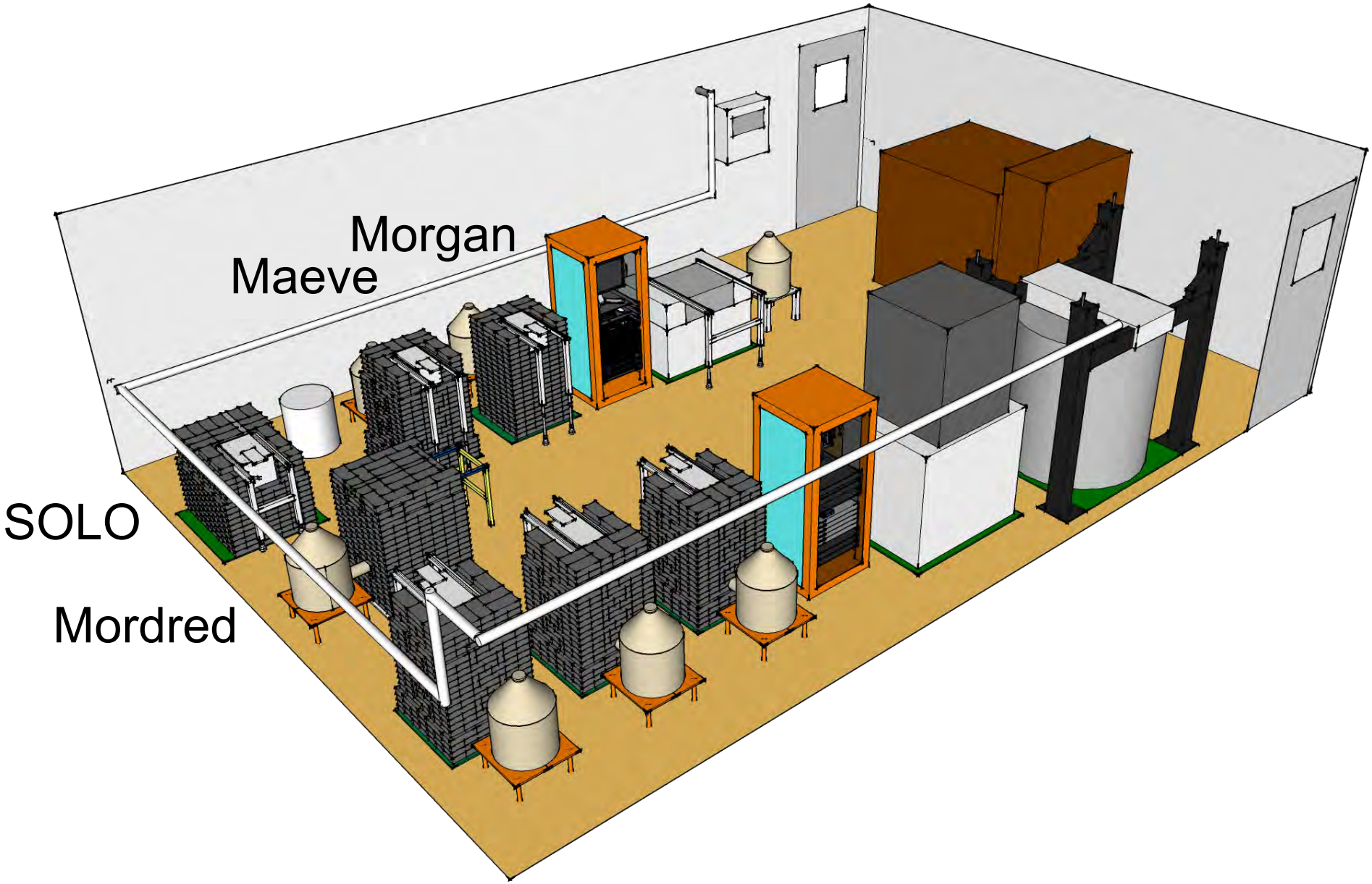
- Aglient 7900 ICP-MS (BHSU)

BHSU Underground Campus

Establishing national-level capability for low-background assays

BHSU Underground Campus

Establishing national-level capability for low-background assays



Experiment Implementation Program
Identify interfaces and hazards within approval framework

- **Project Documentation (update annually or as needed)**
  - Expression of Interest (optional for some), incl funding proposal narrative or EPS
  - Experiment Planning Statement, incl Expt/Facility Requirements, Decommissioning, Cost Estimates
  - Memorandum of Understanding, incl initial decommissioning plan
  - Insurance (general liability, workers' compensation)
  - Services Agreement(s), incl General Services Agreement and/or sub-contract(s) if applicable
  - Decommissioning Plan
- **Environment, Safety & Health**
  - Hazard Analysis: Experiment Hazard Assessment Summary (if applicable), procedures, quantitative analysis (if applicable), certifications (if applicable)
  - Inventories: Chemical, electrical, radioactive materials, pressure vessel, hoisting & rigging
  - Training: Sanford Lab modules, Experiment training & equivalences, recordkeeping; also waivers
- **Review Process**
  - Commensurate with hazards, Science/ESH + Subject Matter Experts
  - SURF review recommendations managed by SURF, closed by concurrence of Science/ESH Directors
- **Laboratory Integration**
  - Facility Access: Badging, shift scheduling (4-day work week: M-Th & T-F), Guides, emergency access
  - Planning & Communication: Shipping and transport, work planning, shift reports, incident reports, emergency communication (incl evacuation drills)
  - Integration: Mailing list, Science Integration meeting, Lab Coordinator (shared laboratory space), Experiment Point of Contact, management meetings
  - External Review and Evaluation: Standing up Scientific Program Advisory Committee; also input from other advisory committees (ESH Oversight Committee)
- **Authorization To Proceed**
  - Lab Director based on Science recommendation and ESH concurrence

SURF Recent Happenings

Events

July 2017

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
25	26	27	28	29	30	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
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SURF Recent Happenings

Events

- **Jul 4: Independence Day**

July 2017

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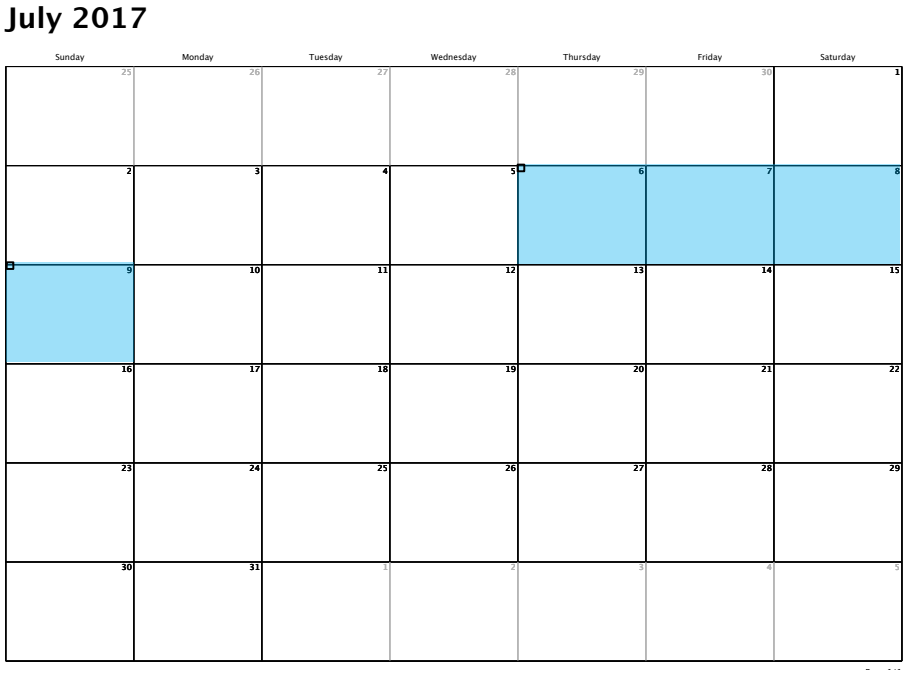
SURF Recent Happenings

Events

- Jul 4: Independence Day
- **Jul 6-9: FNAL Physics Advisory Committee**



SURF Recent Happenings

Events

- Jul 4: Independence Day
- Jul 6-9: FNAL Physics Advisory Committee
- Jul 8: **Neutrino Day**

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SURF Recent Happenings

Events

- Jul 4: Independence Day
- Jul 6-9: FNAL Physics Advisory Committee
- Jul 8: Neutrino Day
- Jul 11: **DOE Visit**

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SURF Recent Happenings

Events

- Jul 4: Independence Day
- Jul 6-9: FNAL Physics Advisory Committee
- Jul 8: Neutrino Day
- Jul 11: DOE visit
- Jul 12: **CASPAR Initial Operations**

July 2017

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SURF Recent Happenings

Events

- Jul 4: Independence Day
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- Jul 8: Neutrino Day
- Jul 11: DOE visit
- Jul 12: CASPAR Initial Operations

VIP Visitor

July 2017

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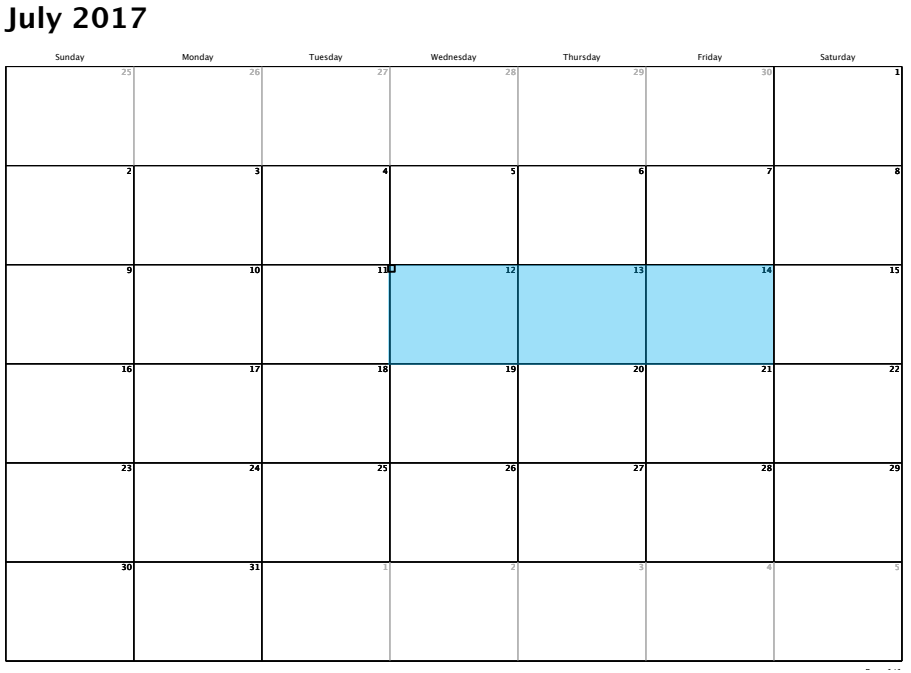
SURF Recent Happenings

Events

- Jul 4: Independence Day
- Jul 6-9: FNAL Physics Advisory Committee
- Jul 8: Neutrino Day
- Jul 11: DOE visit
- Jul 12: CASPAR Initial Operations
  VIP Visitor
- **Jul 12-14: Safety Oversight Committee**



SURF Recent Happenings

Events

- Jul 4: Independence Day
- Jul 6-9: FNAL Physics Advisory Committee
- Jul 8: Neutrino Day
- Jul 11: DOE visit
- Jul 12: CASPAR Initial Operations
  VIP Visitor
- Jul 12-14: Safety Oversight Committee
- **Jul 17-22: LZ Collab Meeting**

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SURF Recent Happenings

Events

- Jul 4: Independence Day
- Jul 6-9: FNAL Physics Advisory Committee
- Jul 8: Neutrino Day
- Jul 11: DOE visit
- Jul 12: CASPAR Initial Operations
  VIP Visitor
- Jul 12-14: Safety Oversight Committee
- Jul 17-22: LZ Collab Meeting
- **Jul 18: LUX Exhibit at Visitor Center**

July 2017

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
25	26	27	28	29	30	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	1	2	3	4	5

SURF Recent Happenings

Events

- Jul 4: Independence Day
- Jul 6-9: FNAL Physics Advisory Committee
- Jul 8: Neutrino Day
- Jul 11: DOE visit
- Jul 12: CASPAR Initial Operations
  VIP Visitor
- Jul 12-14: Safety Oversight Committee
- Jul 17-22: LZ Collab Meeting
- Jul 18: LUX Exhibit at Visitor Center
- **Jul 21: LBNF/DUNE Groundbreaking**

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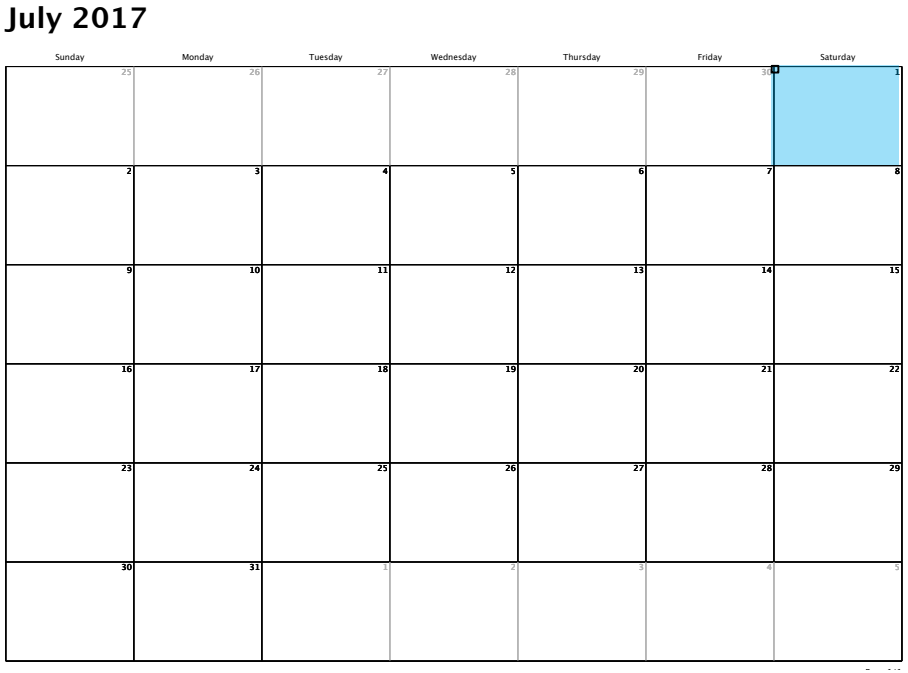
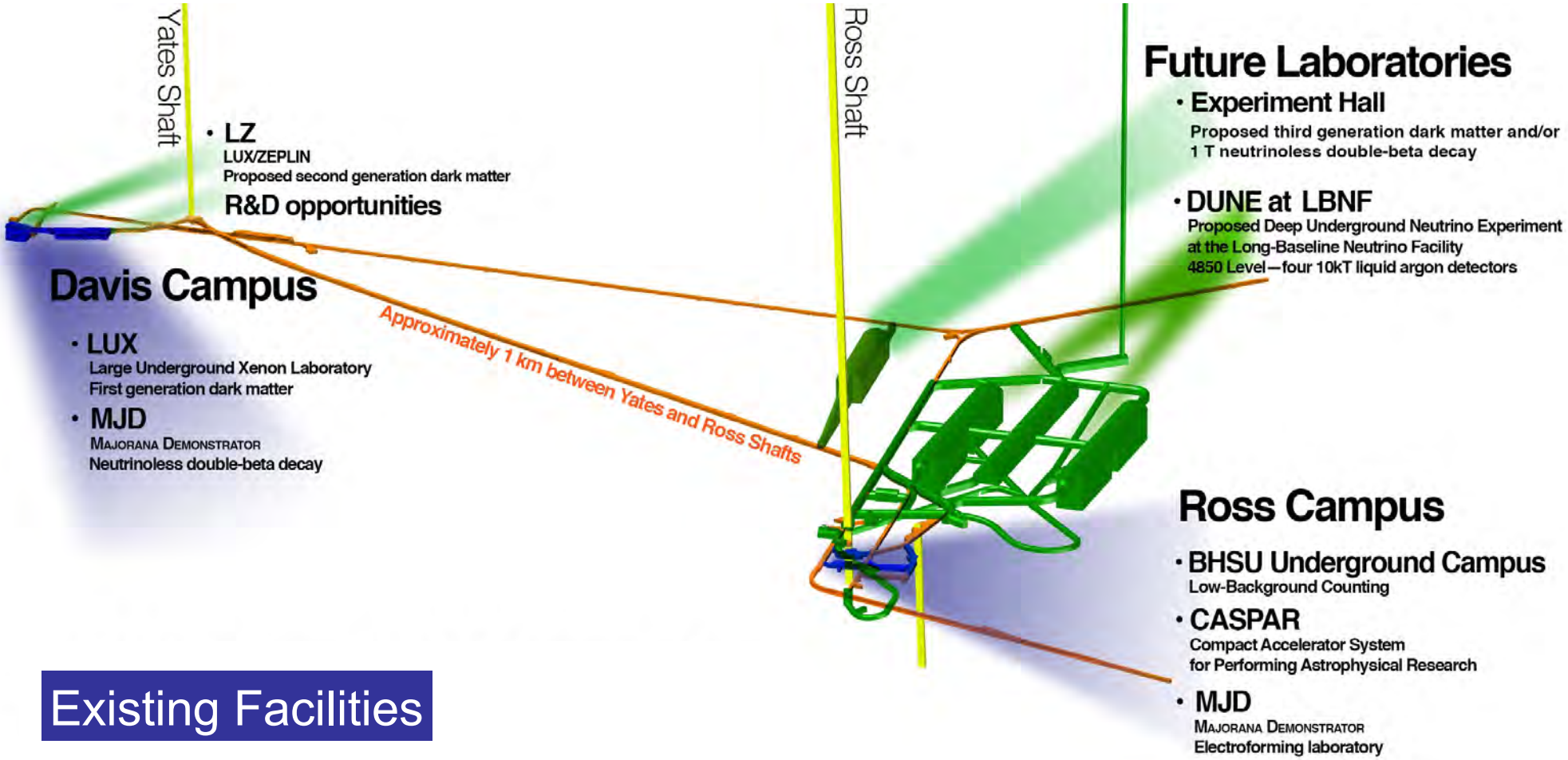


Canada 150
1867 - 2017

4850L Science Facilities

SURF research through 2050 and beyond



Existing Facilities

Future Facilities

See also Ianni plenary talk Jul 27

Heise, J. Phys, Conf **606** 012015 (2015),
also arXiv:1503.01112 (2015)
Lesko, Phys Procedia **61** 542 (2015)

Sanford Underground Research Facility

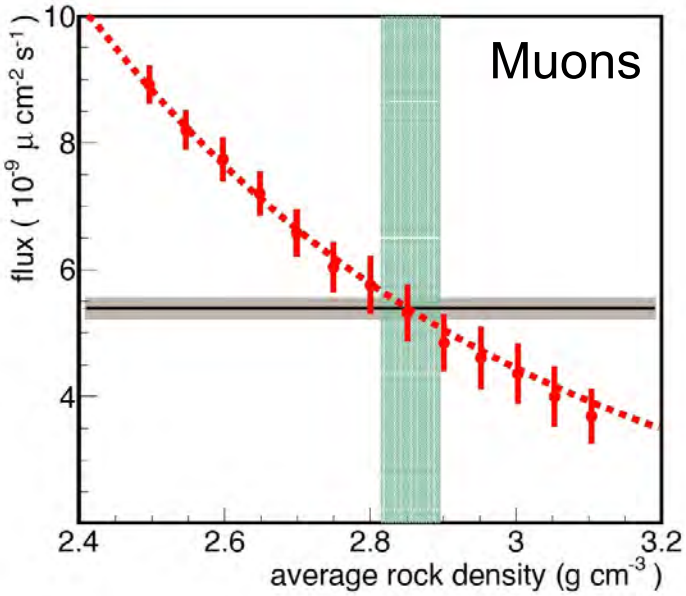
Thank You!

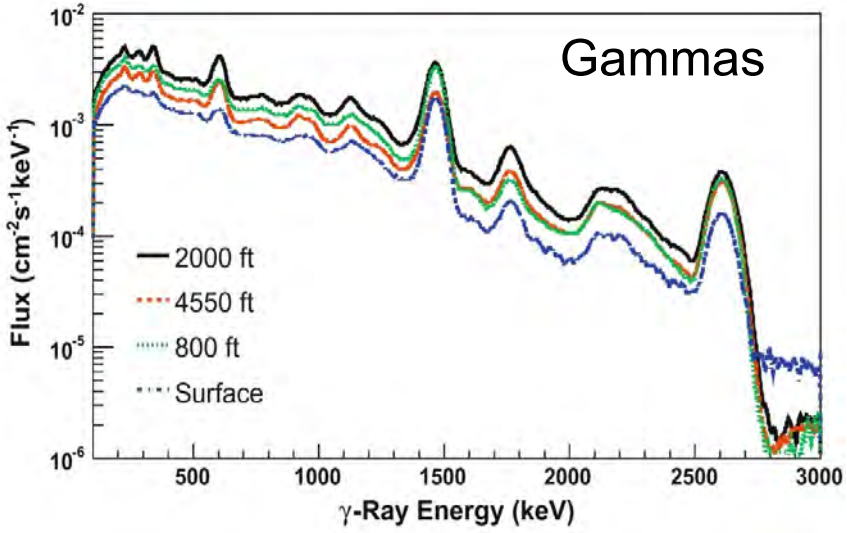
Sanford Underground Research Facility

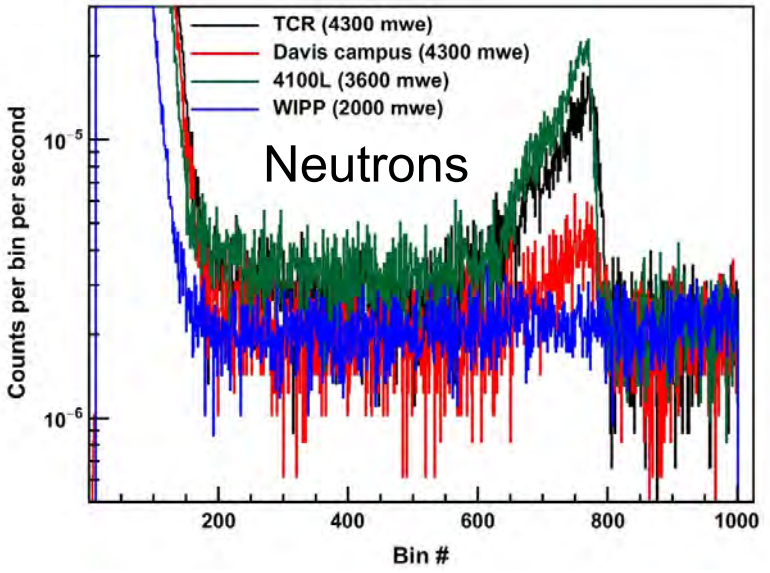
Thank You!

SURF Backgrounds – Summary

- **Muons:** [MJD (Abgrall *et al.*), Astro. Phys. **93** 70-75 (2017)]
  - 4850L (Davis Campus): (5.31 ± 0.17) x 10^{-9} muons/cm^2/s
- **Neutrons:** [Best *et al.*, NIM A **812** 1-6 (2016)]
  - 4850L (Davis Campus/Yates Amphibolite Fm): (1.7 ± 0.1 ± 0.2) x 10^{-6} neutrons/cm^2/s
  - 4850L (Ross Campus/Poorman Fm): (8.1 ± 0.1 ± 0.9) x 10^{-6} neutrons/cm^2/s
- **Gammas:** [Mei *et al.*, Astro. Phys. **34** 33-39 (2010)]
- **Radon:** Average 2012-2017, occasional excursions due to changing ventilation route, fan maintenance, etc
  - 4850L (Davis Campus): ~300 Bq/m^3
  - 4850L (Ross Campus): ~500 Bq/m^3

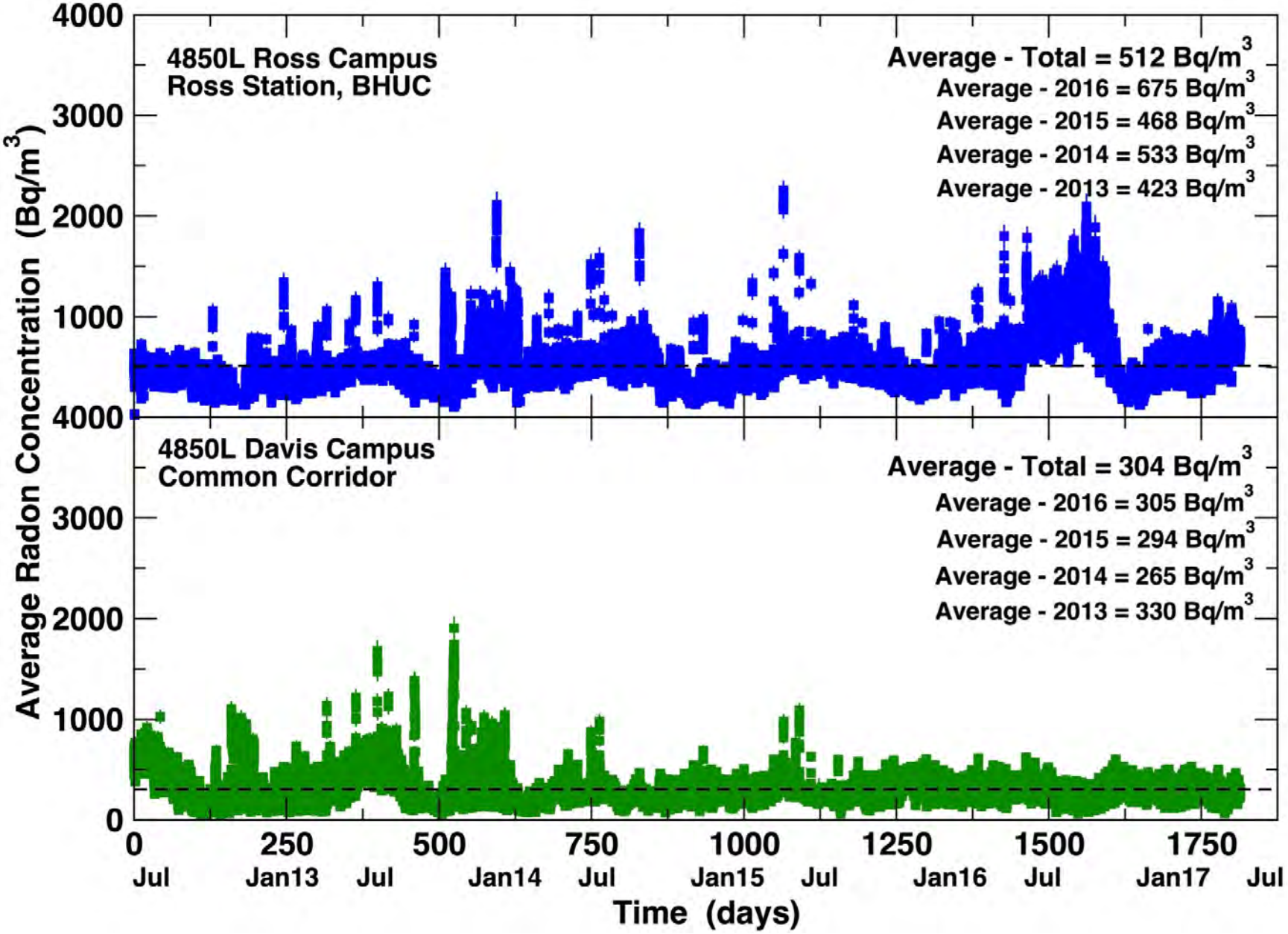






SURF Background – Radon

Excursions due to ventilation: changing route, fan maintenance



SURF Science Support – Personnel

Resources to assist with safe implementation of experiments

Markus Horn (PhD)
Research Scientist
- Davis+Ross Campuses

David Taylor (BSME, PE)
Expt Review Engineer (15%)
- Reviews, cryogen safety

Jaret Heise (PhD) – *Director*
- Manage science implementation and programs

Mark Hanhardt (MS)
Expt Support Scientist
- Davis+Ross Campuses

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

Others
UG Maintenance Crew
- Transport (no pic)

Tom Regan
Consultant - Safety
- Bio/geo (no pic)

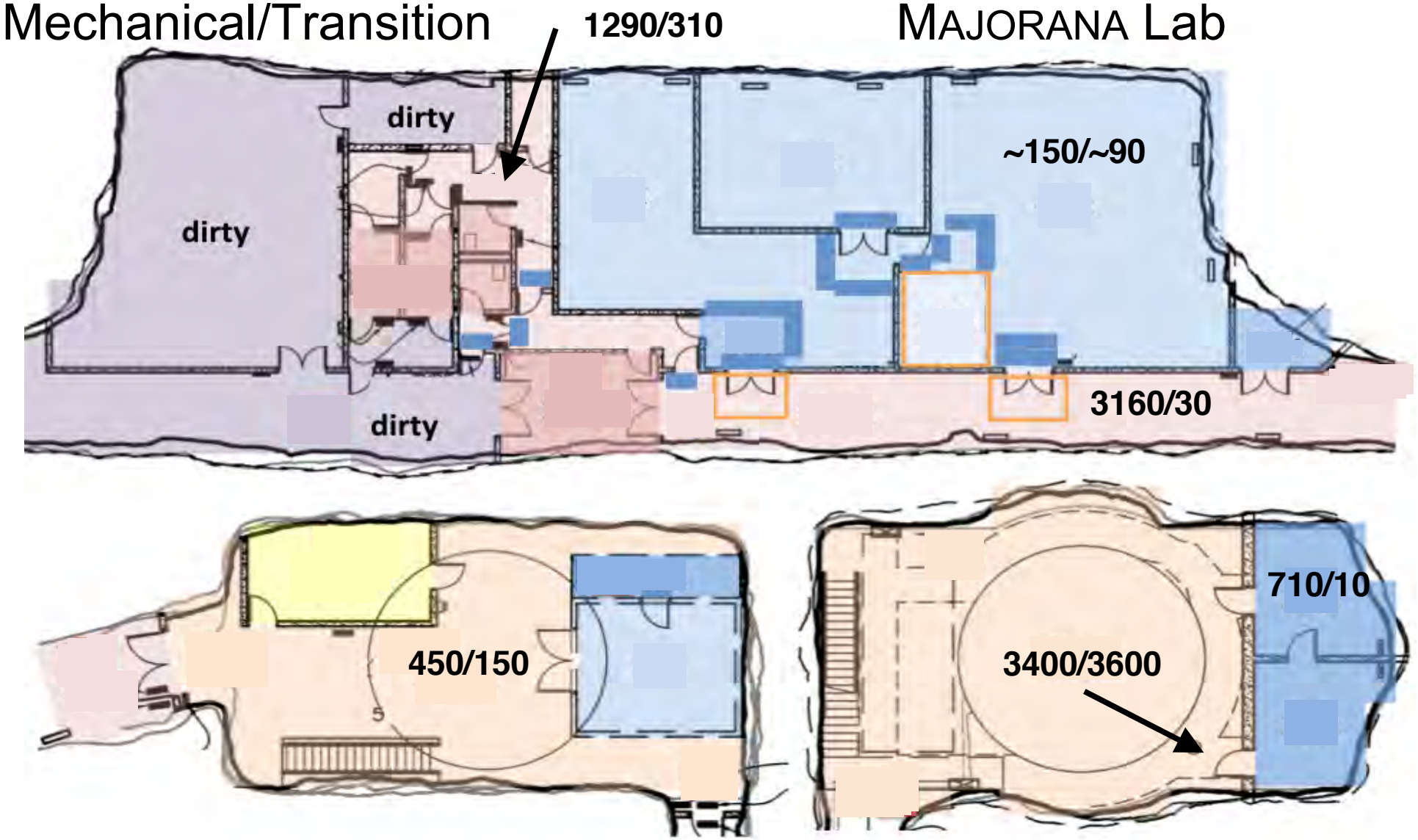
Robyn Varland – *Lab Custodian*
- Davis Campus, Surface (+ other)

Oren Loken
Facilities Technician
- Davis+Ross system maint

Kathy Hart (BS)
Consultant - Geology
- Vulcan DB, logs, model

SURF Science Support – Cleanliness

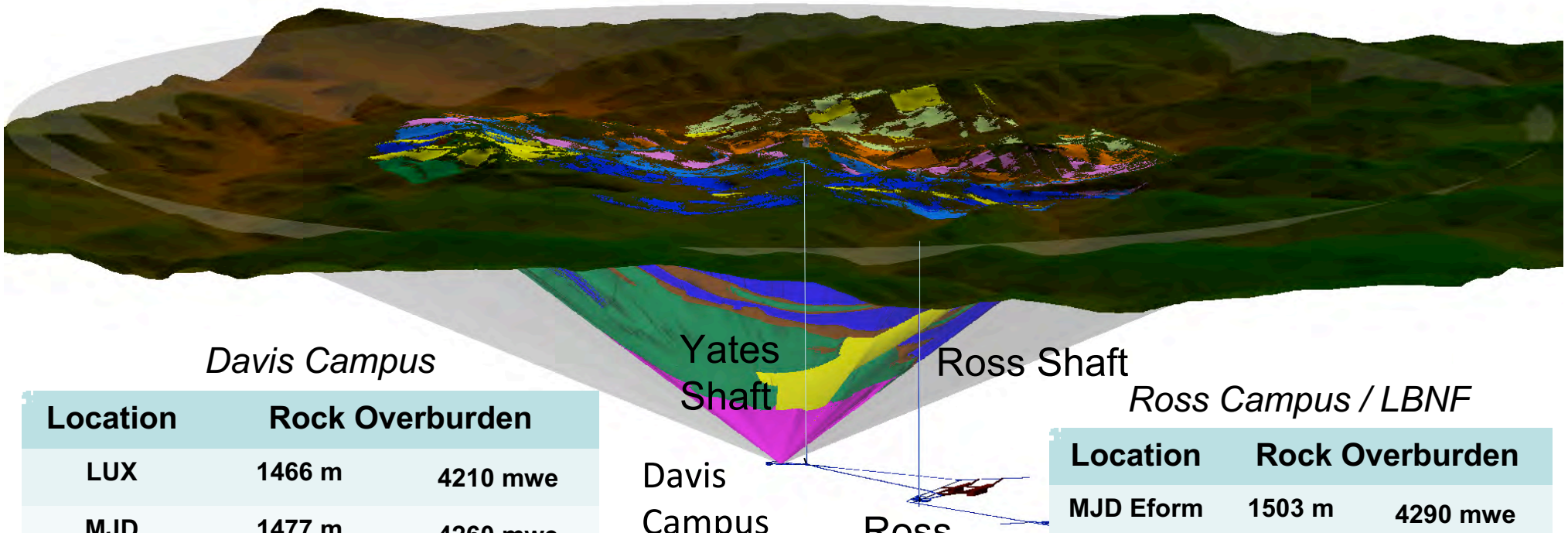
Particle Count Data (Occupied/Unoccupied)



SURF Science Support – Geology Model

Site Well Understood, Including Drill Core & Logs

- 3D model of seven main rock formations + Rhyolite intrusives
- Detailed surface topology: Aerial survey for site performed 2011 (1' contours)
- Global coordinates: Survey performed summer 2016 (incl world's longest plumb bob)
- Rock density data: Hart, Trancynger, Roggenthen, Heise, SD Acad Sci **93**, 33 (2014)



Davis Campus

Location	Rock Overburden	
LUX	1466 m	4210 mwe
MJD	1477 m	4260 mwe
R&D Space	1494 m	4300 mwe

Ross Campus / LBNF

Location	Rock Overburden	
MJD Eform	1503 m	4290 mwe
BHUC	1503 m	4380 mwe
CASPAR	1499 m	4170 mwe
LBNF (avg)	~1400 m	~3870 mwe

Representation of 3D cone of rock above 4850L Davis Campus

SURF Laboratory Space

Summary for various science campuses, incl timelines

Location	Laboratory	Existing/*Planned* Space		Availability (CY)	Comments
		Area (m^2)	Vol (m^3)		
Surface	Surface Laboratory	190	600	~2026	LZ detector assembly starting 2017; also Rn-reduction system in satellite facility
Davis Campus (4850L)	LUX Lab – Davis Cavern (upper/ lower) + 2 rooms	375	1976	~2026	Renovations to start Fall 2017, LZ finished by ~2026
	Counting Rms (2)	33	140	~2026	LZ timeframe
	MJD Labs (3 rooms)	300	1279	~2021	DEMONSTRATOR expected occupancy through ~2020, could be used for initial stages on path to tonne-scale DBD
	Cutout Rms (2)	63	253	~2026	LZ timeframe
Ross Campus (4850L)	MJD E-forming Lab	228	742	~2018	MJD removed by end 2017 (possibly sooner)
	BHUC (low-bkgd assay)	266	773	–	Occupancy mid-2015, indefinite use
	CASPAR	395	1130	~2027?	Operation in 2017 with ~10+ year program, continue use with DIANA?
	Refuge Chamber	258	866	2022? (earliest)	Re-purpose after Yates Shaft rehab; future CASPAR/DIANA expansion?
LBNF Campus (4850L)	*LBNF*	*9,869*	*194,365*	*~2021-22*	*Excavation begins 2019, lasts ~3 yrs*
	New Excavation (proposed)	*2000 (nominal)*	*45,084 (nominal)*	*~2022*	*Most economical following LBNF (start exc 2022), nominal 20x24x100-m cavity*

Experiment Implementation Program

- Experiment Implementation Program (EIP)
  - Available via public website: http://www.sanfordlab.org/researchers/proposal-guidelines
- Experiment Phases and Implementation Requirements
  - Phases: Conception, Proposal, Installation, Commissioning, Operation, Decommissioning
  - Different elements of the implementation documentation serve as the basis for authorization at different phases of an experiment's activities
  - For each phase and for authorization step(s) associated with significant hazard(s) within phases, the main project documentation as well as ongoing operational documentation is reviewed to verify that information is complete and up-to-date
  - Recognize equivalence for some agency requirements (e.g., DOE Hazard Analysis Report)
- Integrated Safety Management
  - EIP reflects that all activities performed at Sanford Laboratory must be conducted in a manner that ensures protection of the workers, the public and the environment
  - References SURF Environment, Safety & Health Manual: http://www.sanfordlab.org/esh
- Implementation Process
  - SURF responsibilities specified for reviewing and receiving/approving documents
  - SURF experiment point of contact

SURF Science Opportunities

Physics, biology, geology, engineering

- **General:** Significant footprint, incl surface areas + 300L, 800L,1700L,2000L,4100L,4850L; services (power, network) to some locations on most levels
- **Physics:** Average rock overburden of ~4300 mwe at existing 4850L laboratories, demonstrated track-record of safe operation and meeting experiment needs
  - Engineered facility + support for lab operations (LN, some monitoring) and cleanrooms
- **Biology:** Isolation from surface microorganisms, variety of locations that result in different environmental conditions (temperature, humidity), variety of niches (different rock formations, access to water courses/seeps from various sources)
  - Most current active research based on 4850L, with some access to 800L, 2000L, 4100L
  - Current research focused on biofuels and biodiversity
  - Recent NASA funding included partnership with physics development and sharing core
- **Geology:** Seven main rock formations + rhyolite intrusives, drill core archive (2688 holes, ~90 km) + recent 4850L drill holes (17 holes, ~2.6 km), DB support (Vulcan, drill core), logs
  - Most current active research based on 4100L, 4850L + access to drill core archive
  - Current research incl enhanced geothermal, also seismic detectors and access to drill core
  - Recent DOE funding for new drill holes incl SURF subawards for site prep
- **Engineering:** Variety of environments for testing real-world applications (especially related to mining), depth for some testing
  - Most current active research based on 4850L, surface

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 ~20 ppl/day for science
- **Environment, Safety & Health (and Security)**
  - Manage Safety Manual, incl policies, forms (e.g., oxygen deficiency, Job Hazard Analysis, etc)
  - Safety resource (e.g., reviews, training, monitoring, waste, radiation, record keeping, ERT, etc)
- **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
- **Business Services / Finance & Human Resources**
  - Shipping/receiving, procurement, user support (incl event planning), IT, contracts/rebilling, badging
- **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 Laboratory Design
4850L Davis Campus Development

- **Key Design Requirements**
  - Environmental Conditioning: 21C, 50% RH
    - Working in clean room garb resulted lowering the temperature, leading to higher relative humidity and HV breakdown, corrosion concerns – this illustrates the importance of challenging requirements.
  - Chilling System: Air cooled chilled water system (closed loop)
  - Cleanliness:
    - AHU-1/Davis Cavern Cleanroom: Nominal Class 1000 (5,250 cfm, ~150 air changes per hour)
    - AHU-2/LUX+Common: Nominal Class 10,000 (8,590 cfm, ~6 air changes per hour)
    - AHU-3/MJD: Nominal Class 2000 (7,250 cfm, ~18 air changes per hour)
  - Power: 1500 kVA, backup for life safety, incl comm, AHUs, exhaust fans, egress lighting
- **Ground Support**
  - 1” dia. x 10’ long resin-grouted threaded rebar
  - Standard- and low-activity aggregate shotcrete (7.5 cm thick)
- **Monitoring**
  - Single- and multi-point extensometers for ground movement
  - Life safety: smoke/heat/low O2, also CO
  - Radon, particle counts
- **Special Considerations**
  - Shielding: 6-m high x 8-m diameter water shielding tank (72,000 gallons), iron plates below
  - Water purification system (commercial RO/ultra-filtration)
  - Internal detector stand
  - Material transport from shaft station to lab (air bearings), via decline/stairs (electric dolly)

SURF Laboratory Design
4850L Ross Campus Development

- **Key Design Requirements**
  - Environmental Conditioning: 20–25C, 20–50% RH
  - Chilling System: water heat rejection (~40 gpm, not closed loop)
  - Cleanliness:
    - BHUC Counting Cleanroom: Nominal Class 1000 (2,400 cfm, ~30 air changes per hour)
    - BHUC Multi-Use Cleanroom: Nominal Class 10,000 (600 cfm, ~23 air changes per hour)
    - CASPAR: No cleanliness class (1000 cfm, ~1.3 air changes per hour)
  - Power: 300 kVA (CASPAR+BHUC), E-Forming = 75 kVA (not incl filter fan), emergency = egress lighting (no generator for AHUs, etc)
- **Ground Support**
  - 6’ - 8’ long resin-grouted threaded rebar, 12’ long cement-grouted cable bolts
  - Standard-activity aggregate shotcrete
- **Monitoring**
  - Life safety: smoke/heat/low O2, also CO
  - Radon, particle counts
  - Radiation (gamma, neutron)
- **Special Considerations**
  - Reduce radon emanation from rock walls using special coatings, macropoxy/TSL’s
  - Radiation shielding from CASPAR accelerator (doors, utility mazes)

Sanford Underground Research Facility

http://www.sanfordlab.org