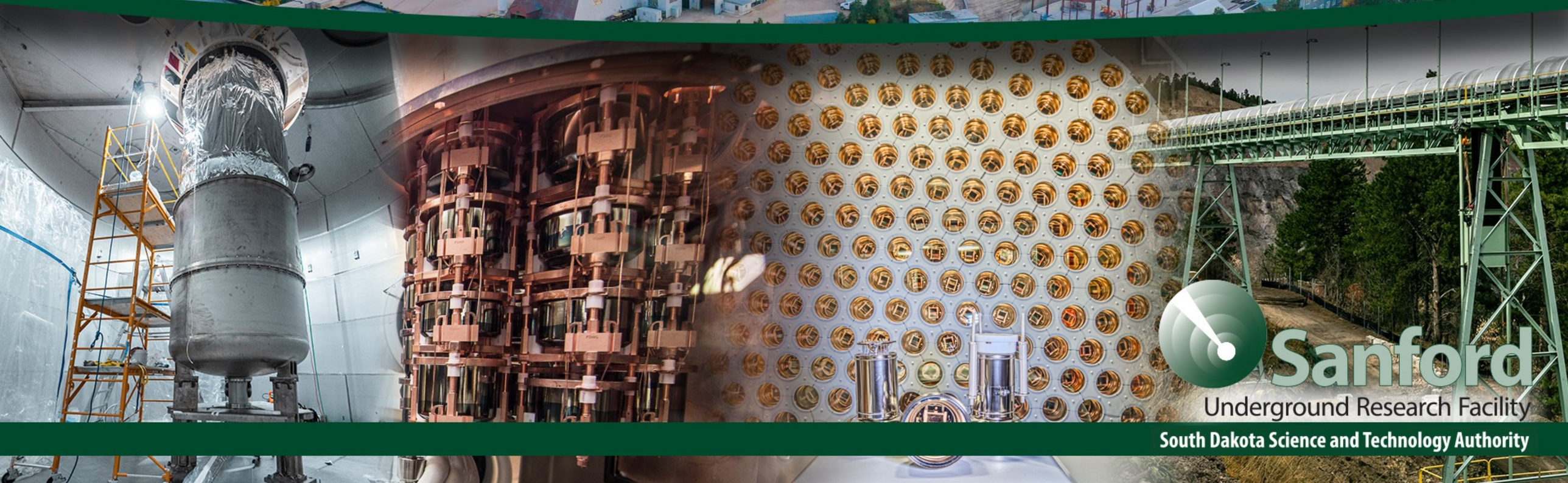
Sanford Underground Research Facility

Biology Research at SURF

Markus Horn

Research Scientist, SDSTA



Sanford
Underground Research Facility
South Dakota Science and Technology Authority

Dr Markus Horn

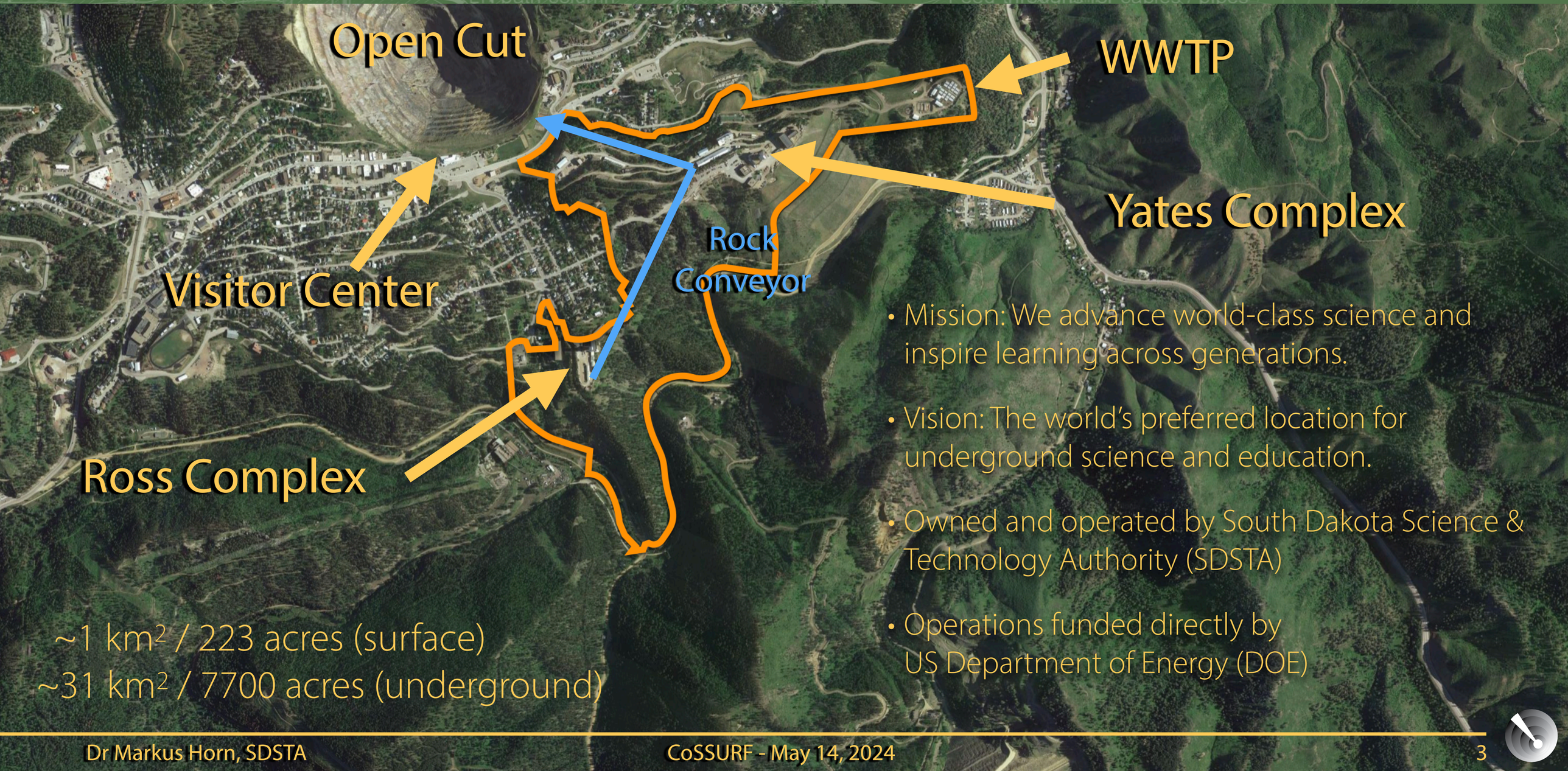
More than 15 years in Underground physics / laboratories

- PhD Astroparticle Physics University of Karlsruhe (KIT), GER
- Scientist at Imperial College London, Oxford University, Yale and UC Berkeley / LBNL
- Underground laboratory experience in France, United Kingdom and USA

2016 - present: Research Scientist, SDSTA

- Experiment point-of-contact (MJD, Bio-Geo-Eng & others)
- Member of LUX-ZEPLIN collaboration

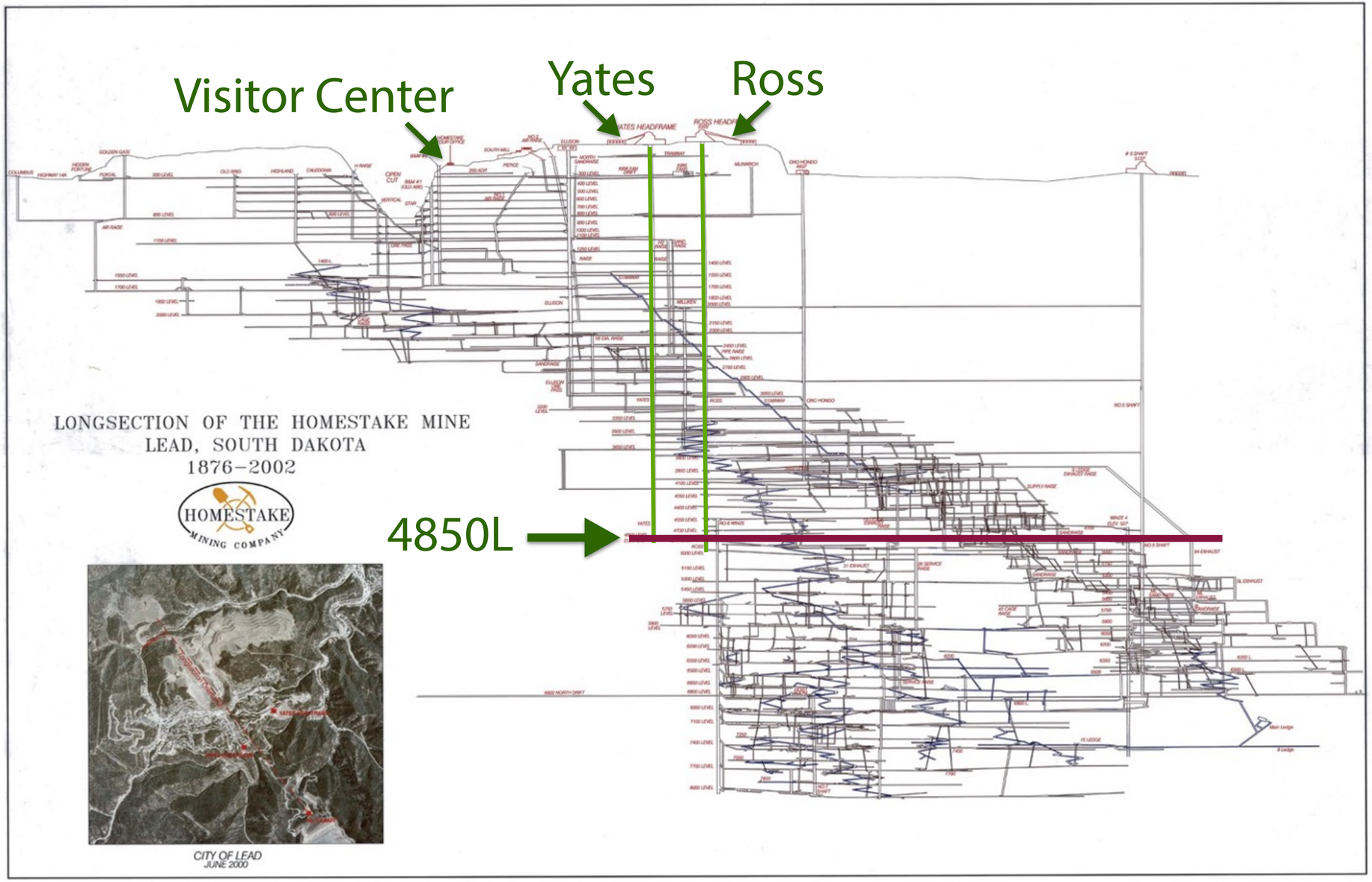
Sanford Underground Research Facility



- Mission: We advance world-class science and inspire learning across generations.
- Vision: The world's preferred location for underground science and education.
- Owned and operated by South Dakota Science & Technology Authority (SDSTA)
- Operations funded directly by US Department of Energy (DOE)

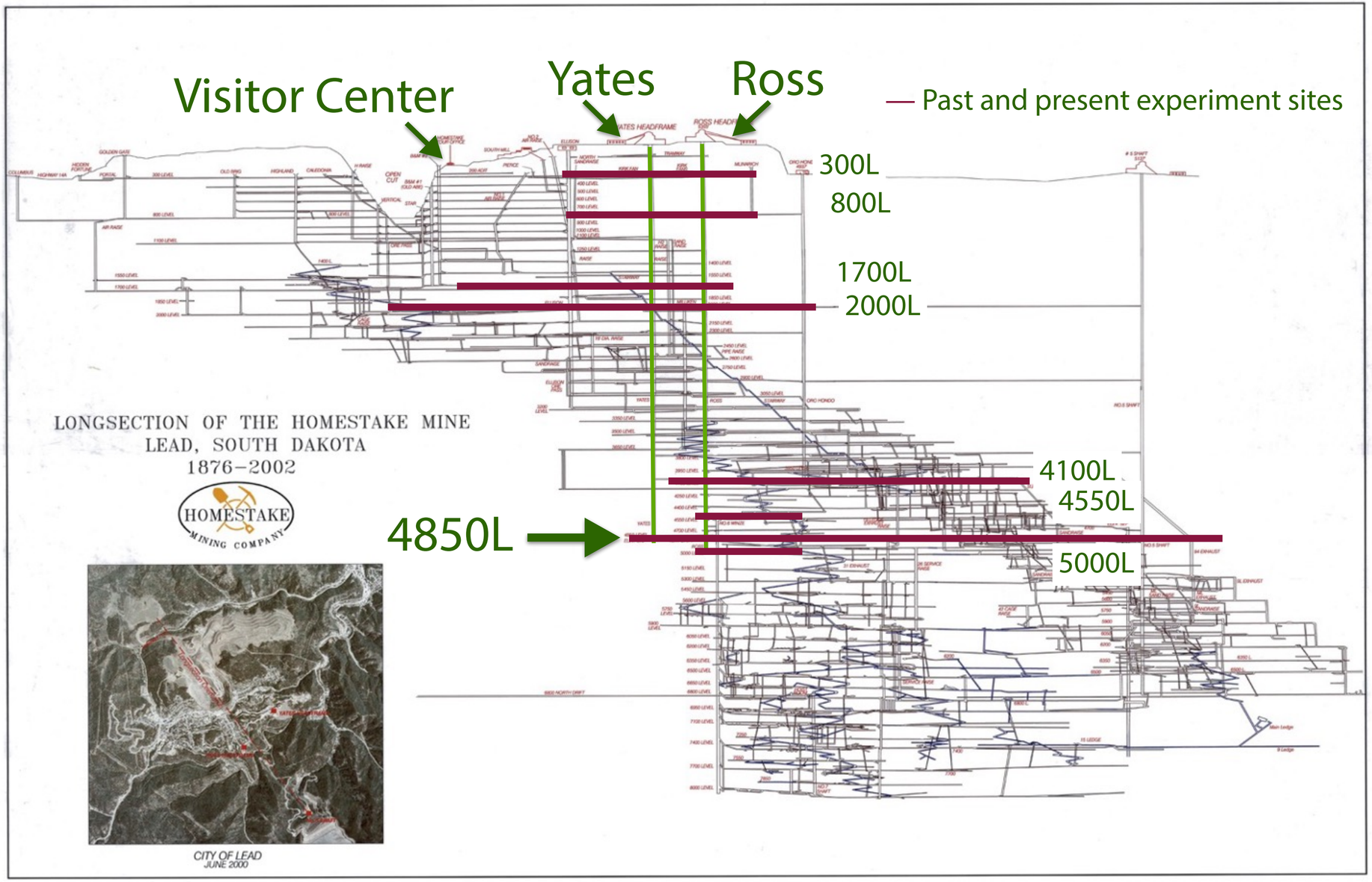
~1 km² / 223 acres (surface)
~31 km² / 7700 acres (underground)

Homestake Mine Legacy



- ~ 600 km / 380 miles of tunnels from surface to 2.4 km / 8000 ft deep, 63 total elevations, 29 currently accessible
- ~ 20 km / 12 miles maintained for science and facility operations

Homestake Mine Legacy



- ~ 600 km / 380 miles of tunnels from surface to 2.4 km / 8000 ft deep, 63 total elevations, 29 currently accessible
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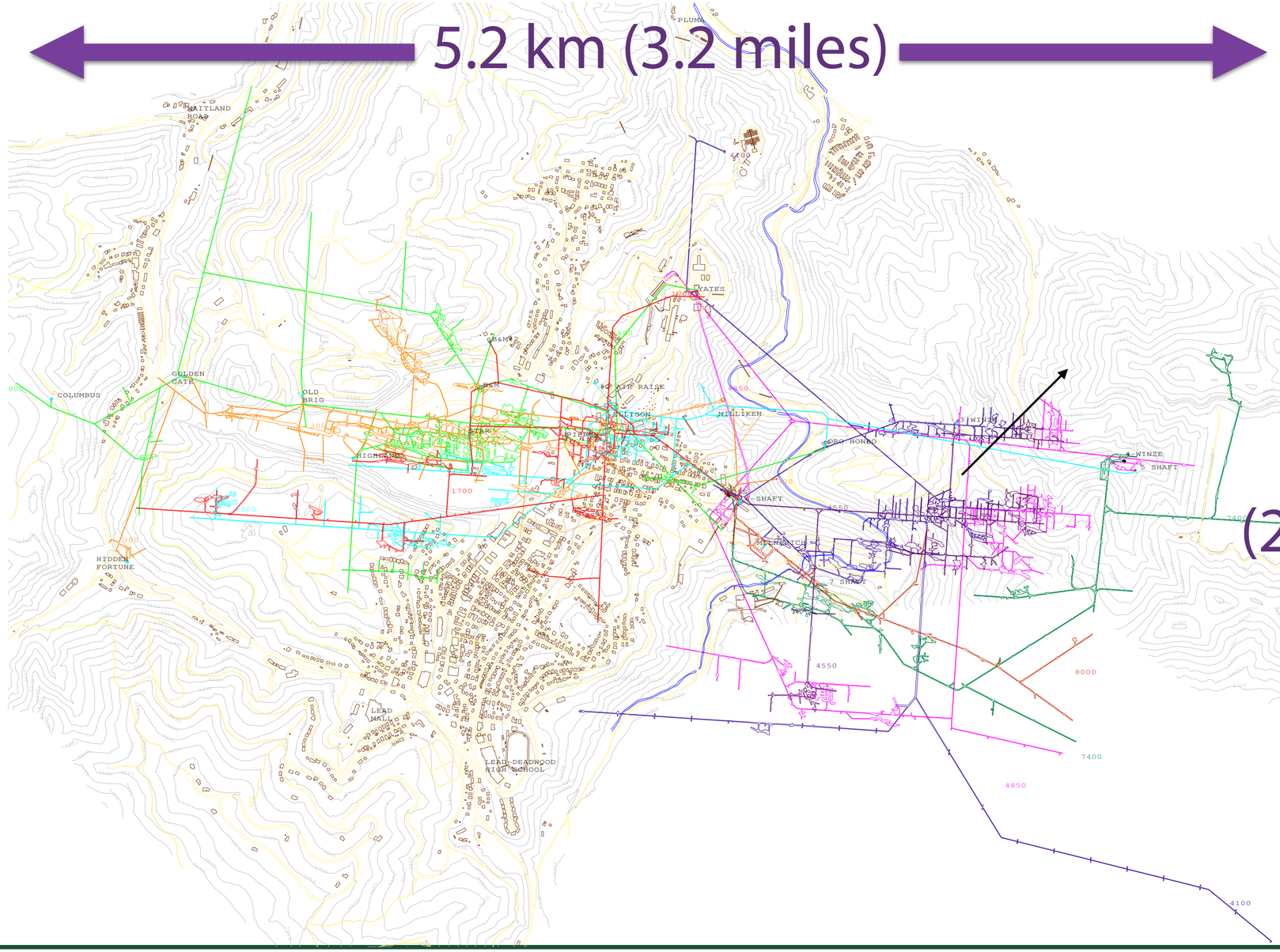
Homestake Mine Legacy

5.2 km (3.2 miles)



3.5 km (2.2 miles)

- ~ 600 km / 380 miles of tunnels from surface to 2.4 km / 8000 ft deep, 63 total elevations, 29 currently accessible
- ~ 20 km / 12 miles maintained for science and facility operations

Science Program

PHYSICS

- MAJORANA DEMONSTRATOR
- BHUC
- CASPAR
- LUX-ZEPLIN
- LBNF/DUNE

ENGINEERING

- DoD - Pedestrian Dead Reckoning
- NIOSH - Heat Stress Study
- Caterpillar*
- Thermal Breakout
- Xilinx (AMD)*
- Blast Monitoring
- Shotcrete

BIOLOGY

- BHSU Biodiversity
- DeMMO / Astrobiology
- Carbon Sequestration
- BuG ReMeDEE
- m-sense
- 2D BEST
- Phytoremediation (MAP)
- Liberty BioSecurity*
- Chemistry

GEOLOGY

- 3D DAS
- BH Seismic
- CUSSP
- DEMO-FTES
- Geochemistry
- Core Archive*
- EGS Collab†

CURRENTLY

30 GROUPS

22 active

68 total

since 2007

Biology Research @ SURF

- Underground "extreme" environment
  - Unique physical-chemical conditions
    - incl. total darkness or low light level
    - high humidity
    - low/high stable temperature
    - high pressure
    - differing pH
    - salinity
    - scarcity of nutrients

- No competitive exclusion driven by low-nutrient environment, instead cooperative and mutualistic consortia, where well-adapted species support growth of others to overcome limitations of environment
- Research typically performed via sampling, off-site cultivation and genome sequencing

Biology Research @ SURF

- Extremophiles - microorganism in extreme conditions
  (e.g. temperature, pressure, pH, salinity, etc.)
  - Methane regulation/oxidation
    via biogeochemical mechanisms
    - Acid-loving microbes consuming methane

  - Carbon sequestration in rock accelerated via microbial enzymes
    - Geologic carbon sequestration is the process of storing CO2 (pressurized, liquid) injected into porous rock formations underground. Microbial enzymes increase the speed of the reaction and ensures that the captured CO2 does not leave the solution
  - Bioplastics and biofuels - produced in short time span rather than fossil fuels

Biology Research @ SURF

Water sampling for lab cultivation / genome analysis

acidophile or methanophile bacteria

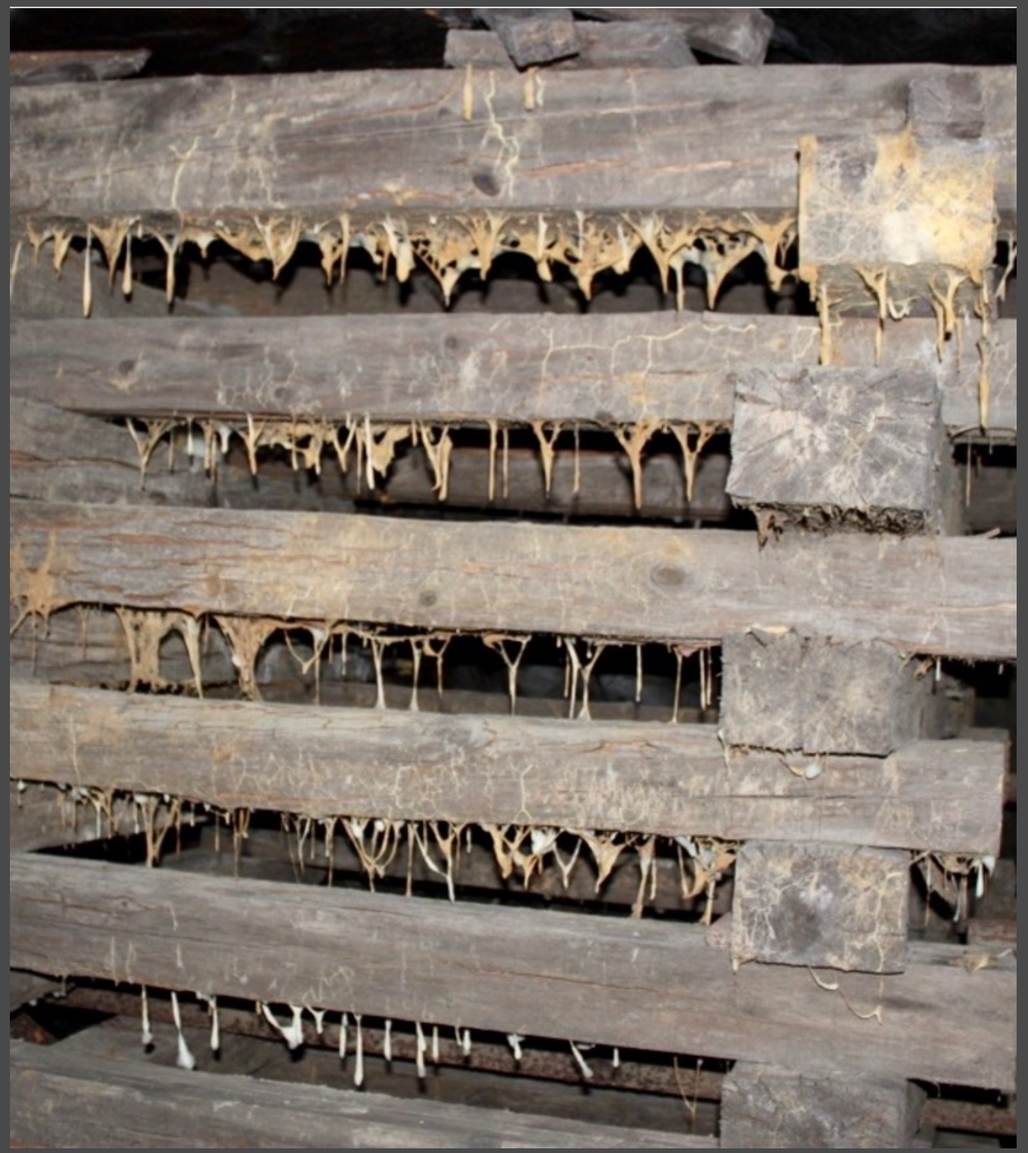
Biology Research @ SURF

Ceiling stalactite

White fungus

Biology Research @ SURF

Biology Research @ SURF

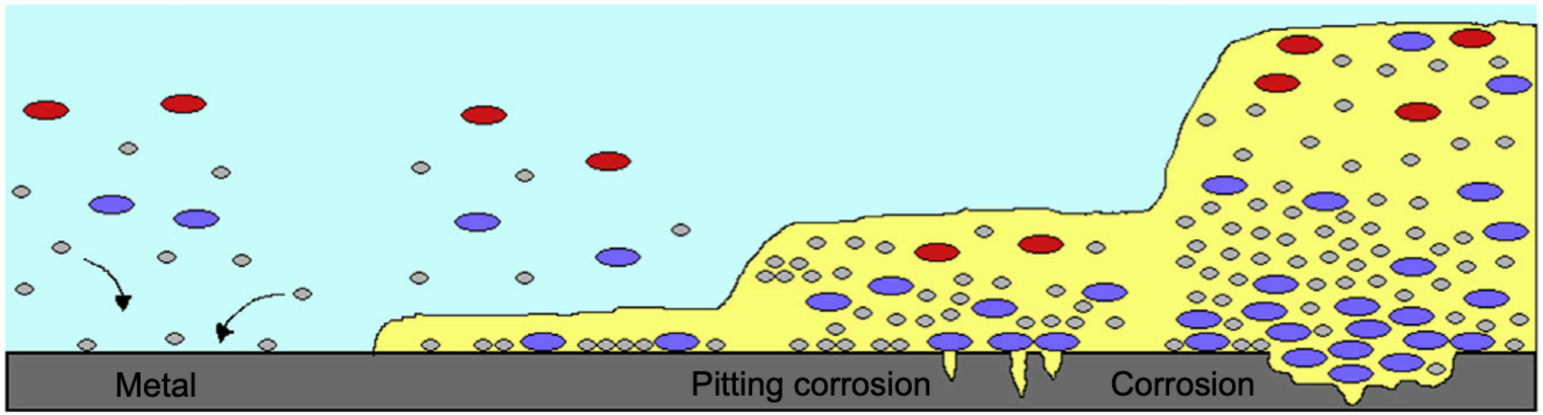


Biology Research @ SURF

- Biofilms - layers of bacteria adhering to surfaces
  - Potential to develop superior corrosion-resistant metals (e.g. oil & gas industry)

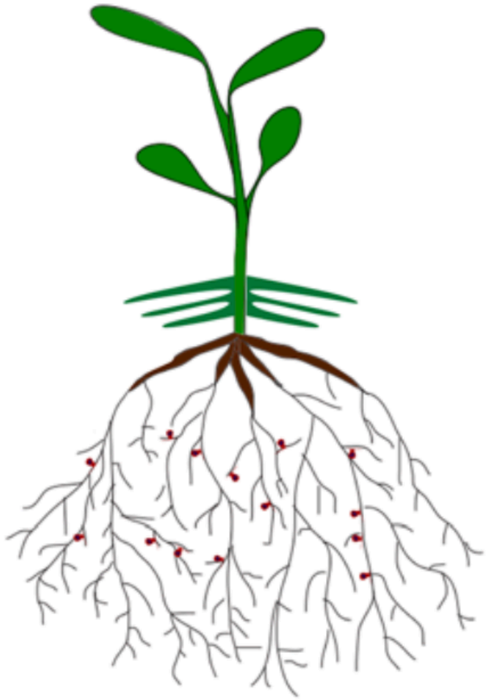
→ chemolithotrophic bacteria attain energy from oxidation of inorganic compounds

→ develop materials/coatings to control biofilm



Biology Research @ SURF

- Biofilms - layers of bacteria adhering to surfaces
  - Potential to develop superior corrosion-resistant metals (e.g. oil & gas industry)
  - Agriculture - nitrogen-fixing bacteria can supplement crops to use less fertilizer



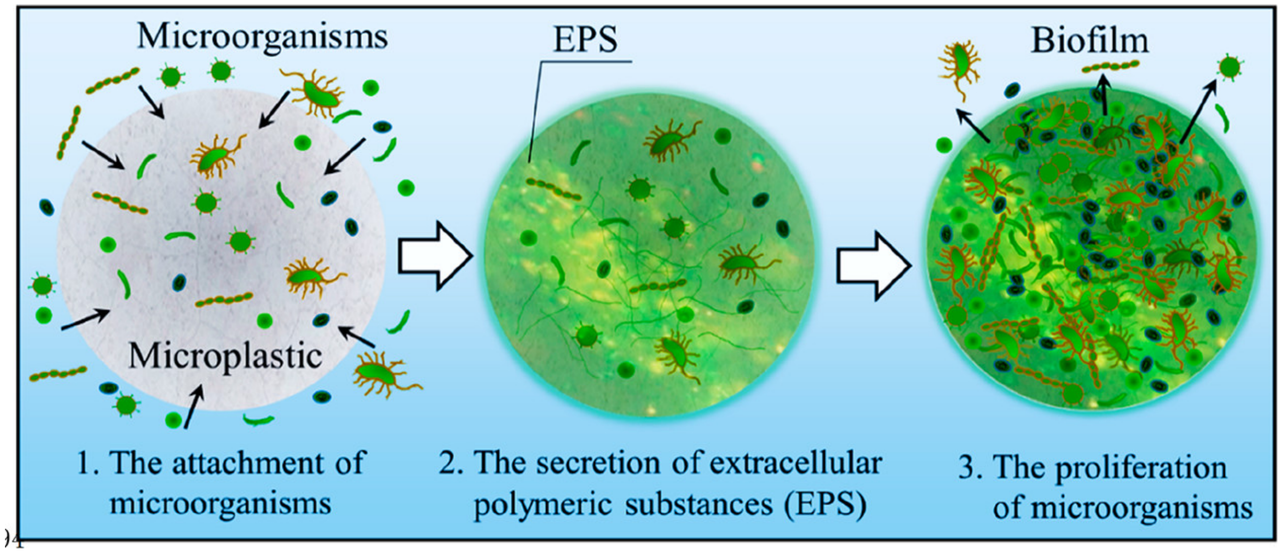
Problem:
Nitrogen fertilizers produced from atmospheric nitrogen or natural gas not sustainable.

Alternative:
biological nitrogen fixation, e.g. symbiosis legumes and rhizobia (but not associated with rice, wheat, maize)

→ understanding of free-living nitrogen-fixing bacteria

Biology Research @ SURF

- Biofilms - layers of bacteria adhering to surfaces
  - Potential to develop superior corrosion-resistant metals (e.g. oil & gas industry)
  - Agriculture - nitrogen-fixing bacteria can supplement crops to use less fertilizer
  - Microplastics - influence of biofilms on microplastics and possible ecological consequence



→ property changes: density, roughness, size, etc.

→ vector of pollutants to environment

→ vector of pollutants to organism

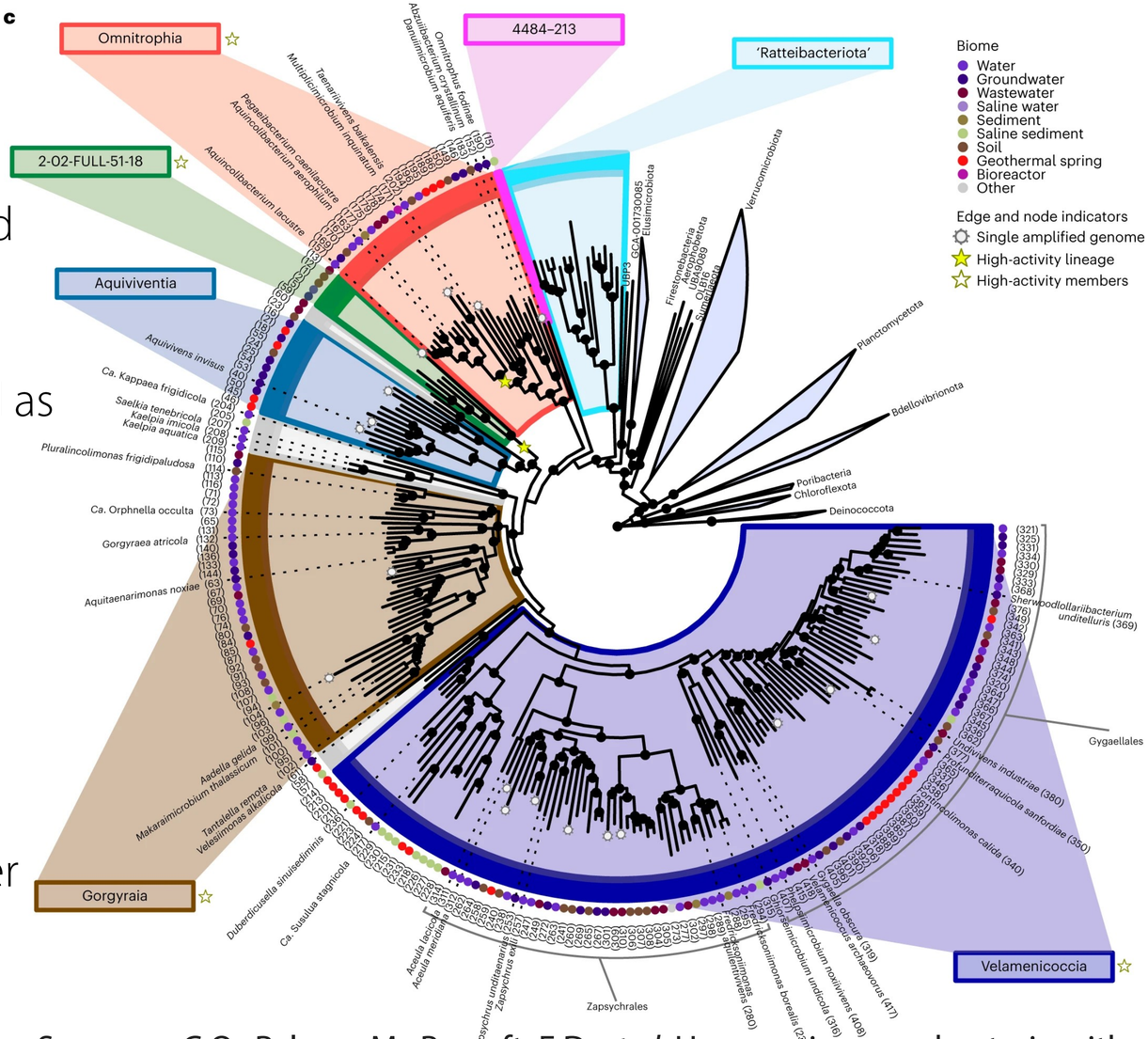
Biology Research @ SURF

Biofilms,
biofilms,
biofilms…

Biology Research @ SURF

- Microbial "Dark Matter"
  - Nano-sized bacteria ("Omnitrophota") common in many environments (oceans, soils, hot springs, even alongside and inside other organisms)
  - Very poorly understood, because can not (yet) be cultivated as single species in laboratory studies (e.g. only 2 species recently microscopically observed)
  - Study objectives: systematics (genomic datasets), ecology, parasitism/predation (cell size, genomic features, 'hyperactivity'), metabolism
  - Understanding lifestyles may enable cultivation and uncover better description of biology of these organism

—> …"bringing "Dark Matter" into the light!



Seymour, C.O., Palmer, M., Becraft, E.D. *et al.* Hyperactive nanobacteria with host-dependent traits pervade Omnitrophota. *Nat. Microbioly* (2023).

Biology Research @ SURF

Repeated and/or long-term sampling & in-situ cultivation

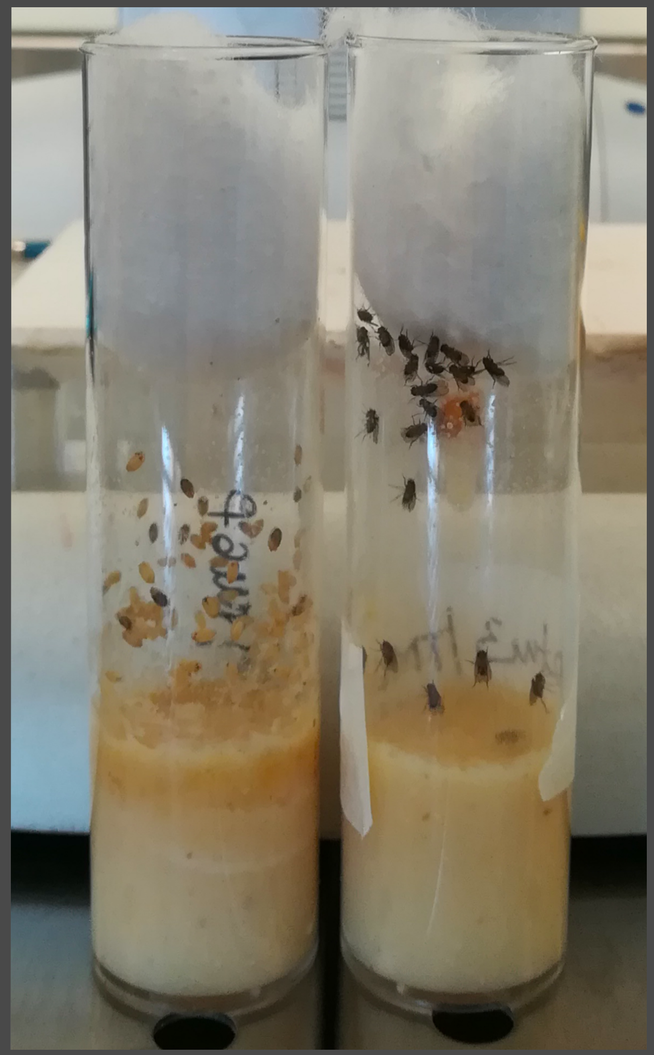
Biology Research @ SURF and other U/G labs

- Astrobiology
  - In-situ, electrode-assisted cultivation of subsurface microbes using novel and traditional techniques
  - If life exists, or ever existed on Mars (or other planetary body), evidence thereof most likely be found in the subsurface <—> Mars Rover @ Boulby
- Study of radiation effects (or lack of) on life (LNGS)
  - Experiments with Drosophila (fruit fly) have shown cells grown in low-radiation environment being less resistant against genotoxic damages than in regular environment
  - Example: Success of radiation therapy relies on inducing cell apoptosis, but also cell proliferation and tumor regenesis. Understanding longer-term regenerative responses may improve radiation therapy

Biology Research @ SURF and other U/G labs

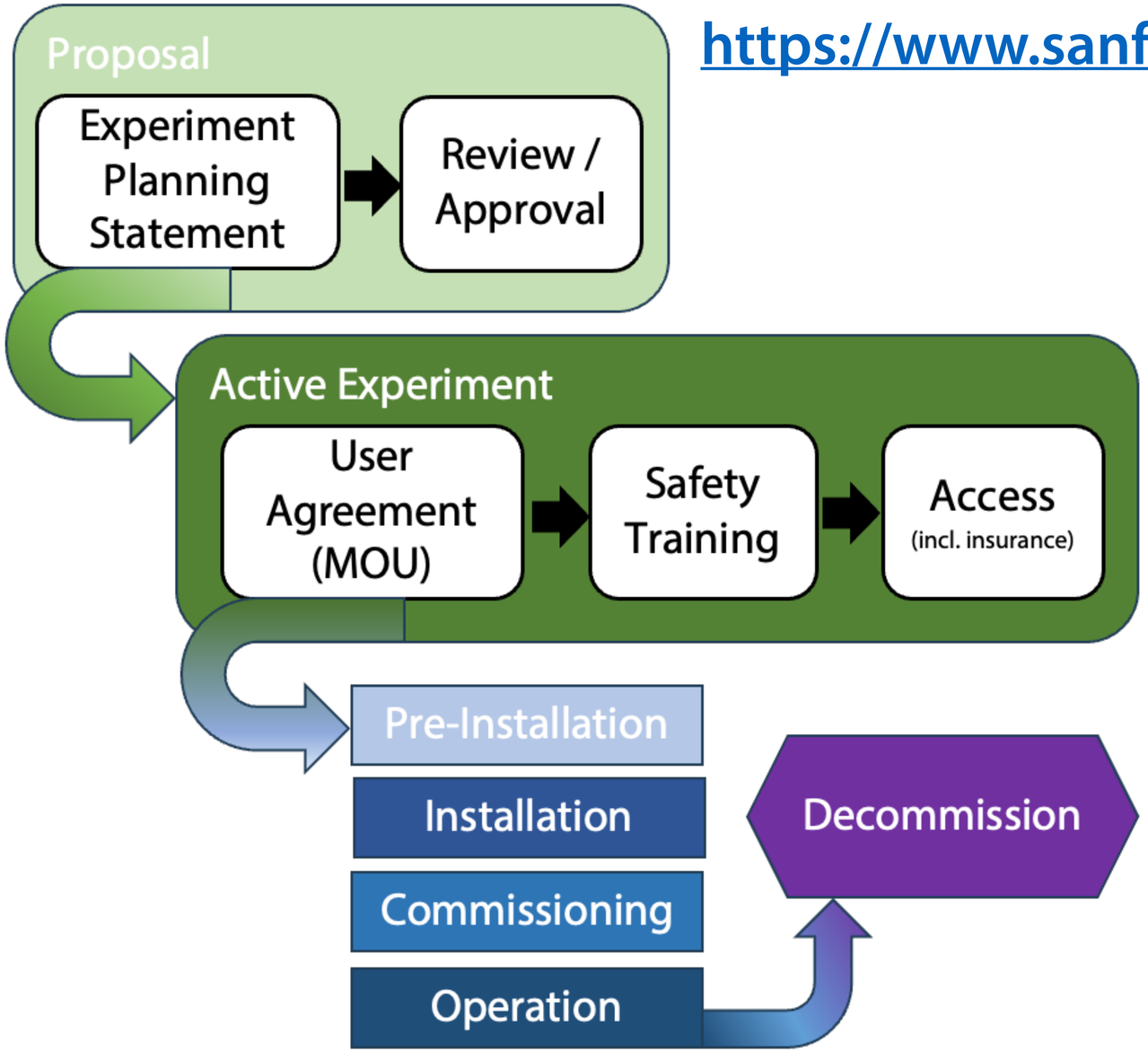
ICL & NASA @ Boulby

Biology Research @ SURF and other U/G labs



Fruit fly experiments

Science Implementation Program



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

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SANFORD UNDERGROUND RESEARCH FACILITY

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Home | Research Proposal Guidelines

RESEARCH PROPOSAL GUIDELINES

All proposals must follow these guidelines

RESEARCHER RESOURCES

Proposal Guidelines
Science Liaison Office
SURF User Association
Visitor information

We are excited at Sanford Lab to contribute to cutting-edge science by providing the best environment for experiments that require unique underground facilities. We are glad to work with you to get your experiment running. To begin the process of approval and installation, follow the steps in the order listed below:

1. Read the **Experiment Implementation Program**.
2. Read the **Experiment Integration and Support** document.
3. Complete a draft of the **Experiment Planning Statement** describing your project.
4. Contact the **SURF Science Director**.
5. Complete the **User Agreement**. The User Agreement references the SURF **waiver** required for underground access, the SURF **ESH Standards** and the SURF **Publication Policy**.

PROPOSAL DOCUMENTS

SCI-(1000-S)-135416 Experiment Integration & Support.pdf
362.8 KB | PDF
SCI-(1000-F)-69417 User Agreement
44.7 KB | DOCX
SCI-(1000-F)-34460 Experiment Planning Statement
74.2 KB | DOCX
SCI-(1000-F)-212612 User Agreement Acknowledgement.docx
31.8 KB | DOCX
SCI-(1000-S)-186874 Publication Guidelines.pdf
255.3 KB | PDF
Acknowledgement of Risk and Waiver
101.2 KB | PDF
SCI-(1000-S)-34478 Experiment Implementation Program.pdf
1 MB | PDF

Experiment Planning Statement

Project Name

Date Submitted: **mm/dd/yyyy**

Status: ☐ Preliminary (Expression of interest, Support letter request) ☐ Formal implementation request ☐ Update

1. Project Summary

Discipline: ☐ Physics ☐ Biology ☐ Geology ☐ Engineering ☐ Other:

Project Description
Provide a brief project description, including purpose, scientific merit and scope. Add relevant citations or references as appropriate. If necessary, add additional space to this form.

IDEA – Inclusion, Diversity, Equity and Access
SDSTA is committed to creating a culture that centers on inclusion, diversity, equity and access (IDEA); see https://sanfordlab.org/sdsta/inclusion-diversity-equity-and-access. It is critical that all partners and stakeholders embody SDSTA's commitment to IDEA as both a moral imperative and a necessary ingredient for a successful collaborative scientific environment. Describe project efforts and considerations in these areas.

- Project Description, incl. funding
- Experiment Equipment, incl. chemicals
- Infrastructure needs, e.g. area, site environment, power, internet, etc.
- Hazards and ESH
- Access requirements & schedule
- Operations, and Decommissioning plans

Summary

- Sanford Underground Research Facility's mission is to be a "true" multidisciplinary research facility, incl. Biology, Geology, Engineering and Physics.
- Active Biology research program at SURF for more than 10+ years, resulting in many high-impact publications
- Robust Science Implementation Program in place to support all projects (small or large, incl. proprietary research)
- Contact: mhorn@sanfordlab.org
  or jheise@sanfordlab.org

SANFORD UNDERGROUND RESEARCH FACILITY

END