Underground Facilities and Infrastructure for P5

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Underground Facilities and Infrastructure Frontier

Topical Group		Topical Group co-Conveners and Liaisons			
		Co-conveners			Liaisons
UF01	Underground Facilities for Neutrinos	Accelerator Neutrinos Tim Bolton	0νββ Patrick Decowski Danielle Speller		Neutrinos Albert de Roeck Astronomical ν Gabriel Orebi Gann
UF02	Underground Facilities for Cosmic Frontier	LXe DM Kaixuan Ni Low Mass Scott Hertel	LAr DM Emilija Pantic		Particle DM Hugh Lippincott Jodi Cooley Instrumentation Eric Dahl
UF03	Underground Detectors	Gravity Waves Laura Cadonati			Instrumentation Frontier Maurice Garcia-Sciveres
UF04	Supporting Capabilities	Radon Richard Schnee	Cleanliness Alvine Kamaha	Low Background Assay Brianna Mount	
UF05	Synergistic Research	Nuclear Astrophysics Daniel Robertson	Geo-microbiology TBD	Geo-engineering TBD	QIS, QC Maurice Garcia-Sciveres
UF06	An Integrated Strategy for Underground Facilities and Infrastructure	Laura Baudis Kevin Lesko	Jeter Hall John Orrell		Early Career Pietro Giampa William Thompson

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Focus of Underground Facilities Group

- Understand current and planned underground facilities, underground space for experiments, and supporting capabilities
- Develop requirements and wishes for the future experiments and in new frontiers (e.g. QIS)
- Develop synergistic relationships among experiments (shared space, parallel use, partnerships, shared technology)
- R&D space and growth of new technologies
- Understand underground space requirements in closely related fields (nuclear astrophysics, $0\nu\beta\beta$, …)
- Create a vision for underground facilities in the coming decades
- Did not focus on underwater/ice neutrino or gravitational wave observatories

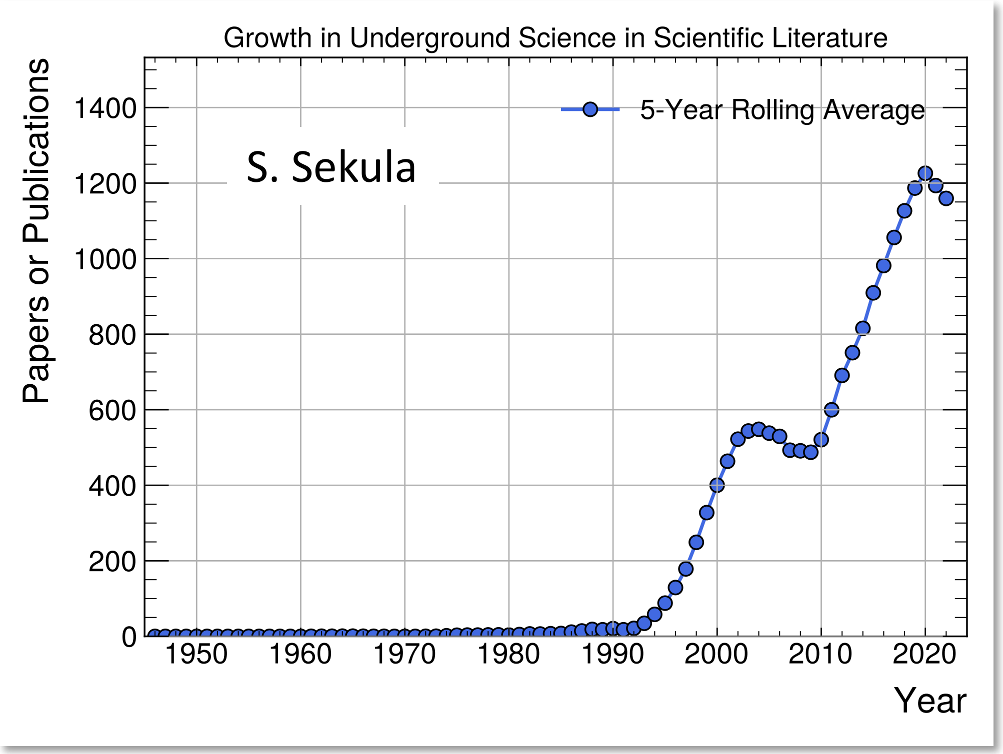
2013 Underground Facility Recommendations (1401.6115)

1. Locate LBNE underground to realize its full science potential. This step would also provide a natural base for additional domestic underground capabilities at SURF in the future.
2. The U.S. has leading roles in many of the future dark matter, neutrinoless double beta decay and neutrino experiments.
3. More coordination and planning of underground facilities (overseas and domestic) is required to maintain this leading role, including use of existing U.S. infrastructure and closer coordination with SNOLAB as the deepest North American Lab.
4. Maintaining an underground facility that can be expanded to house the largest dark matter and neutrinoless double beta decay experiments would guarantee the ability of the U.S. to continue its strong role in the worldwide program of underground physics.

In 2022, underground science and infrastructure are thriving

Underground science has progressed markedly since 2013. Many of the exciting physics opportunities in the coming decades will be underground. Many research topics have made progress or appeared since 2013:

- **Long Baseline Neutrinos** – *DUNE & Hyper-K*
- **Short Baseline Neutrinos** – IsoDAR, SBNP
- **G2 Dark Matter** – *LZ, SuperCDMS, XENONnT, PandaX-4T, DarkSide50, DEAP, NEWS-G, PICO, DAMIC, SENSEI, CRESST, Edelweiss*
- **Nuclear Astrophysics** – *CASPER, LUNA*
- **Low Background Assay** – *BHUC, LNGS, SNOLAB, PNNL, LBNL*
- **Ton-scale Double-beta Decay & G-3 Dark Matter** – *nEXO, LEGEND-1000, CUPID, ARGO, XLZD, DARWIN, PANDA*
- **Extensive R&D into new Dark Matter technologies** – *OSCURA, TESSERACT, SPSNDs, qubits, low-gap materials, DarkSPHERE*
- **Emerging Uses** – QIS, Atom interferometry
- **Synergistic Uses** – geomicrobiology, geology, engineering, environmental monitoring



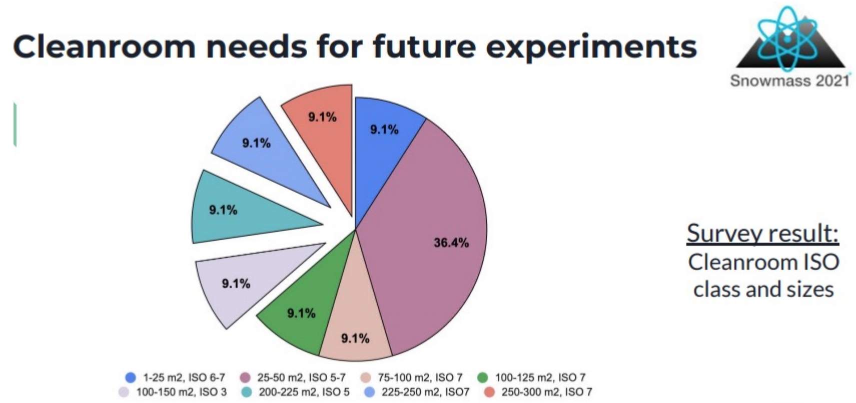
Scientific output has more than doubled since 2012

See the Snowmass science frontier reports for details and other ideas.

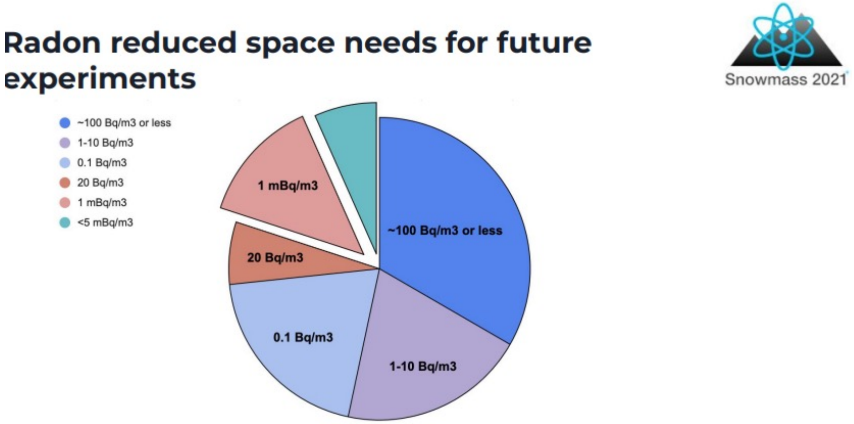
Forgive me for any omissions!

Underground experiments require clean spaces and assay capability

- Clean rooms
  - Quantified dust rates
  - Radon reduction
- Assay equipment
  - Non-destructive bulk (HPGe)
  - Surface counting
  - Destructive mass spectroscopy
  - Radon
- Materials production/purification
  - Crystals
  - Copper
  - and storage



Survey result:
Cleanroom ISO class and sizes



Figures from UF04: A. Kamaha, B. Mount, R. Schnee

Supporting capabilities report: https://arxiv.org/abs/2209.07588

More clean space is needed, and more sensitive assay is needed

- More clean room space is required
  - Particularly low radon space
- Assay throughput is acceptable
  - e.g. 61 HPGe available in the community
  - R&D to increase sensitivity needed
  - More radon capability may be needed
- Specialized materials production/purification is increasing and will be driven by specific project needs

Table from UF04: A. Kamaha, B. Mount, R. Schnee

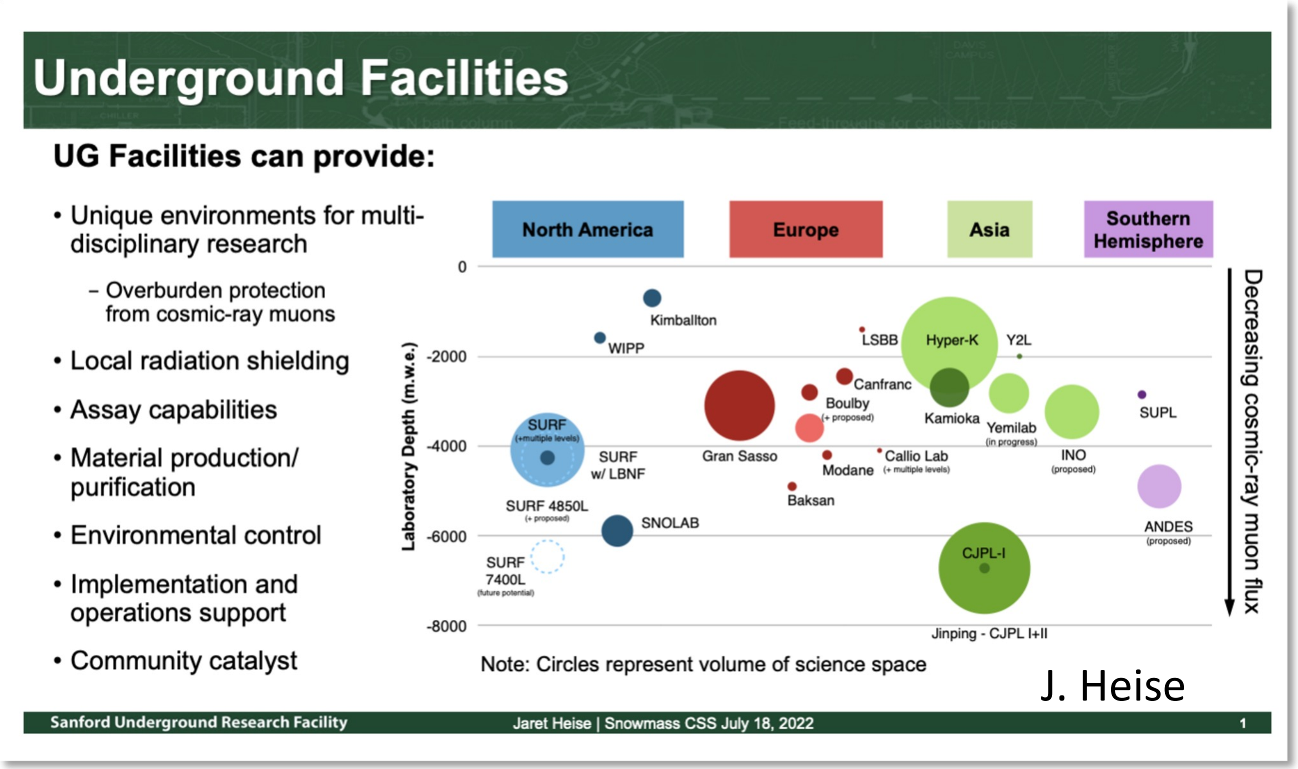
Facility	Apx. Facility overburden (mwe)	# Low Background HPGe	Apx. Sensitivity [U], [Th] (mBq/kg)
China Jinping Underground Laboratory	6720	3	1
SNOLAB	6000	5	.04-.035
Sanford Underground Research Facility (SURF)	4850	6	.05-.7
LPSC/LSM Laboratoire Souterrain de Modane	4800	2	.4-4
Gran Sasso National Laboratory (LNGS)	3100	8	.016-15
Boulby Underground Laboratory UK	2850	6	<.1-1
Kamioka Observatory, ICRR, Univ. of Tokyo	2700	3	Not relayed
Y2L/Yemilab	1750/2500	3	Not relayed
LAFARA underground laboratory, French Pyrénées	220	5	Not relayed
Pacific Northwest National Laboratory	38	14	Not relayed
Berkeley Low Background Counting Facility	15	1	6-24
LLNL Nuclear Counting Facility	10	3	Not relayed
South Dakota School of Mines and Technology	0	2	200-2000

In 2022, the international underground infrastructure is running out of space

There are a number of large projects under consideration and/or design

- neutrinoless double beta decay
- accelerator based neutrinos
- nuclear nonproliferation
- engineering

There is an opportunity for the US to host a G3 dark matter experiment because currently available space is heavily subscribed.

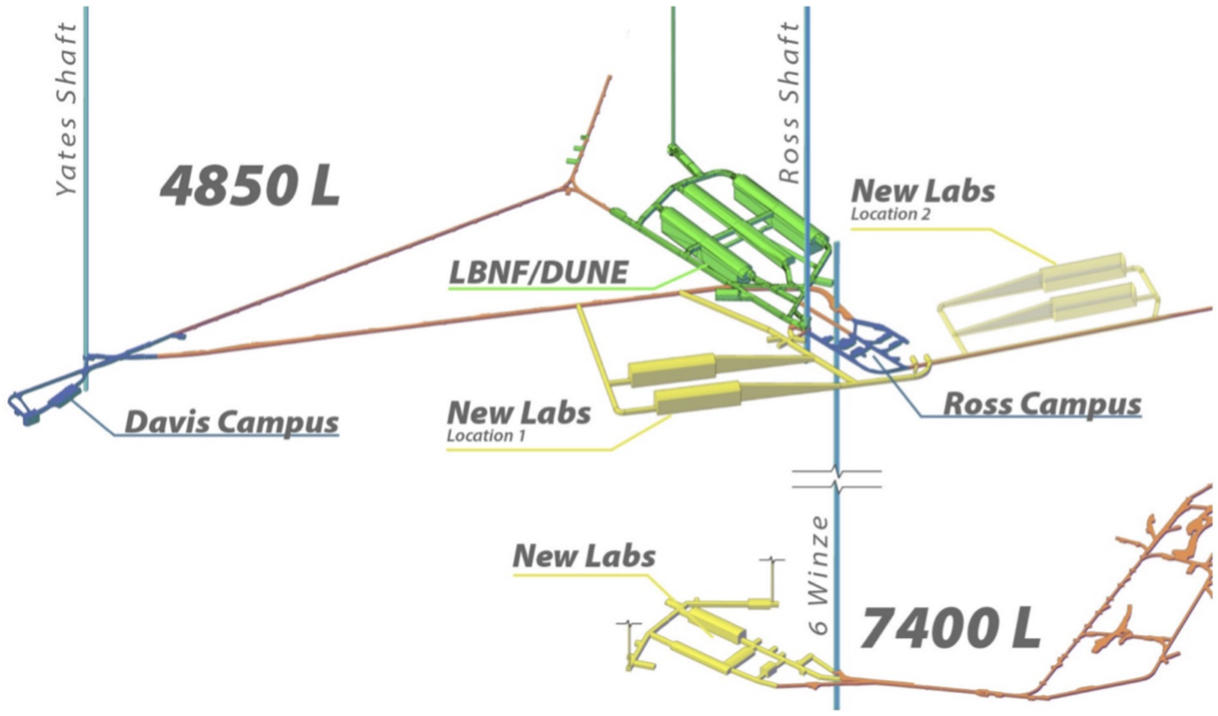


Expanding SURF is a scientific opportunity

Expanding SURF to host large projects will allow the US to host a large next generation project like G3 dark matter. Will also enable small and mid size projects as well as associated R&D.

The space will be timely and cost-effective by leveraging the excavation enterprise currently deployed for LBNF.

See Jaret's talk next!

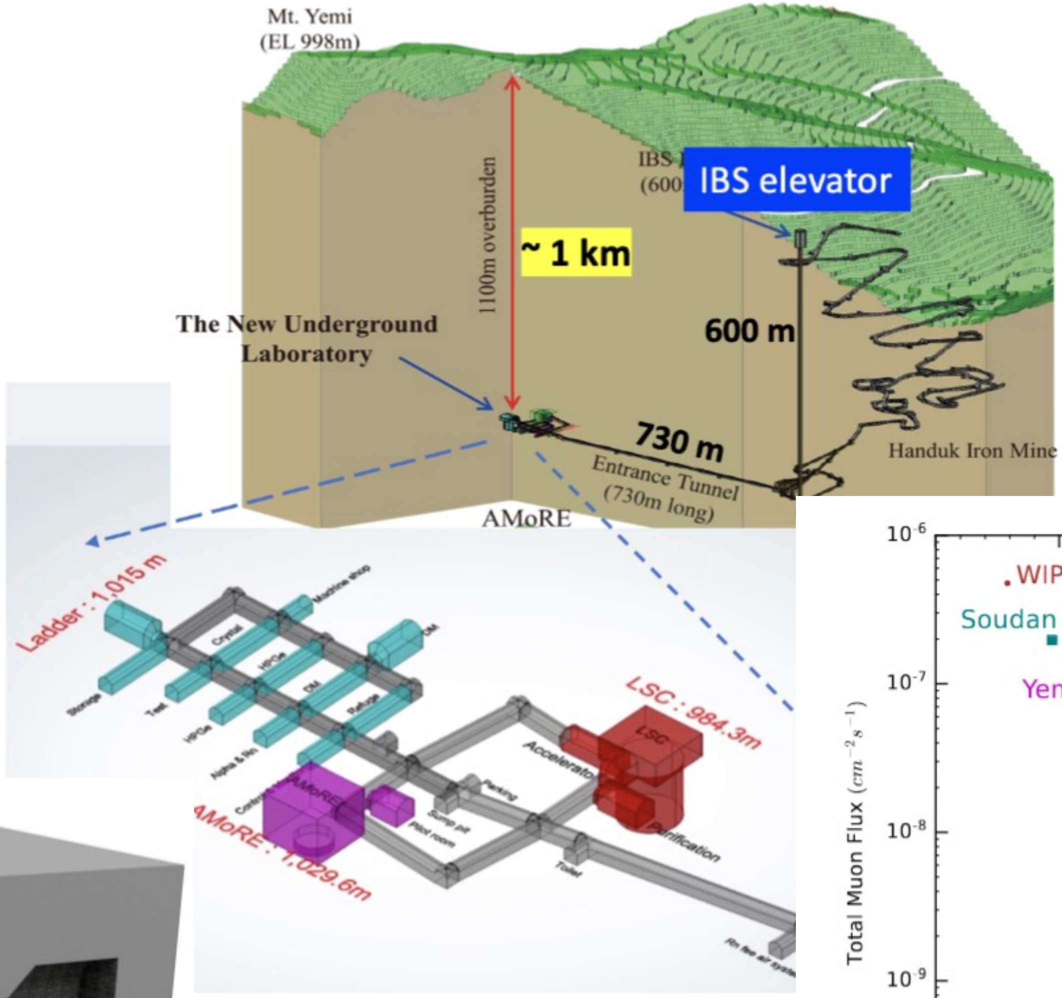


Recommendations for Underground Facilities and Infrastructure

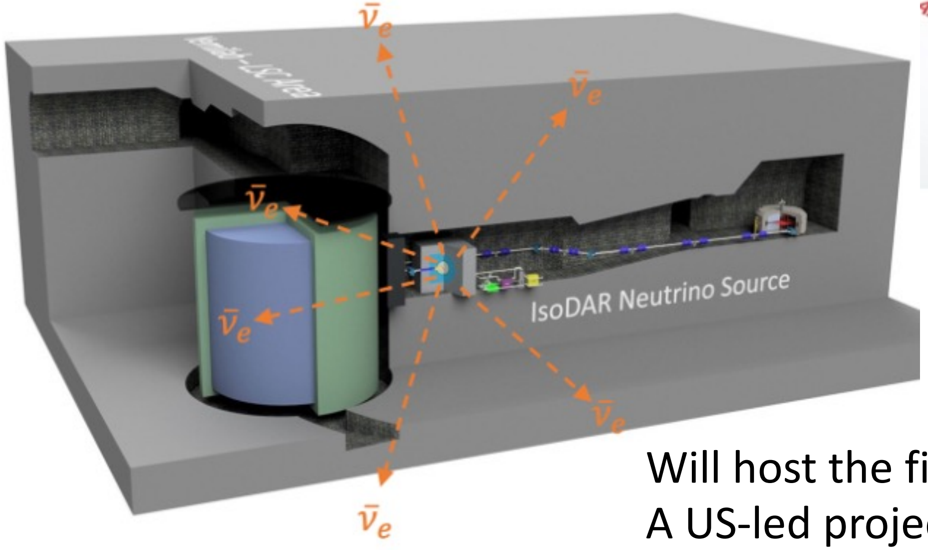
- Leverage the LBNF excavation to expand SURF for large projects, particularly G3 dark matter
  - This will also allow hosting mid-size and small projects
- Designate SURF a Department of Energy User Facility
- Provide full support for LBNF/DUNE underground activities and user hosting
- Support R&D and decision making for G3 dark matter so facilities can be ready by late 2020s
- Support the research and development on future projects and enabling capabilities

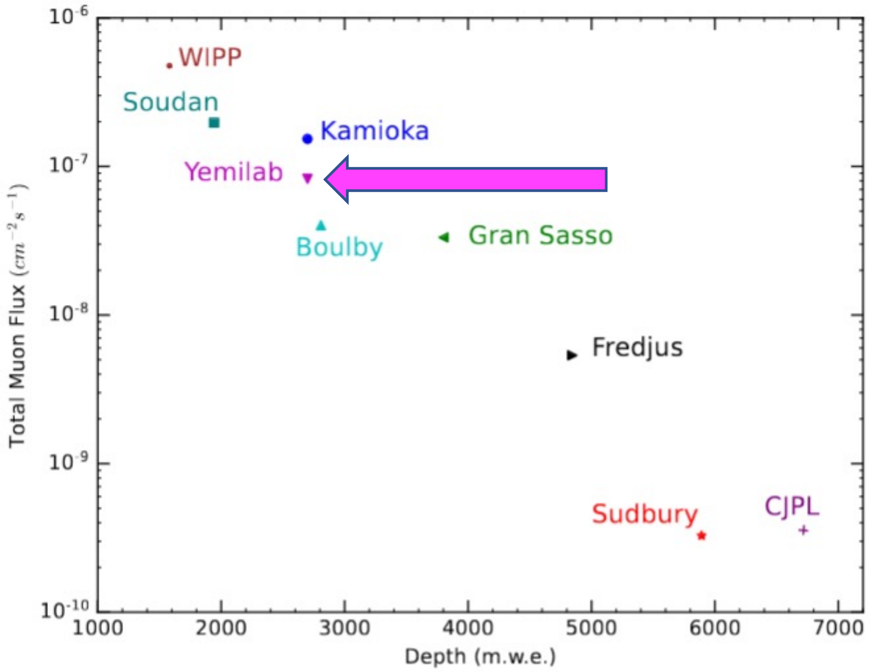
- UF&I Snowmass report: https://arxiv.org/abs/2211.13450

BACKUP



New!
Yemilab in South Korea





Will host the first underground high-intensity accelerator-based neutrino source:
A US-led project funded by NSF