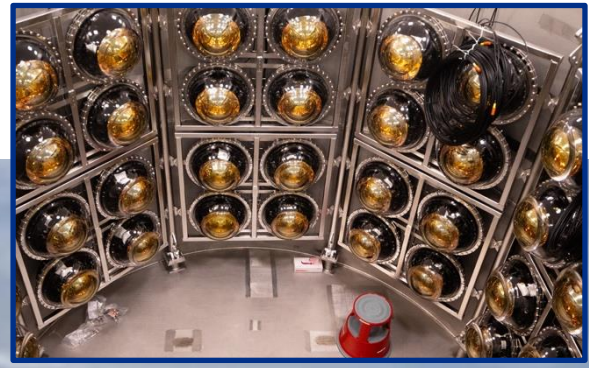
# Deep Science at Boulby Underground Laboratory:


Status and future plans for the UK's deep underground science facility, LRT 2026

Beth Green, Boulby Underground Laboratory

Earth and environmental science, astrobiology and planetary exploration

Astroparticle physics and ultra low background studies



Underground lab at Boulby

# ICL Boulby Mine:

A working **polyhalite** and **rock-salt** mine on the Northeast coast of England.
Owned by Israel Chemicals Ltd. (ICL-UK). Locally operated as Cleveland Potash Ltd.
Major local employer: ~500 direct staff and 2000 indirect employment.

The **deepest mine in the UK** at 1300m, and world's first polyhalite mine, $K_2Ca_2Mg(SO_4)$ shipping worldwide for agricultural fertiliser.

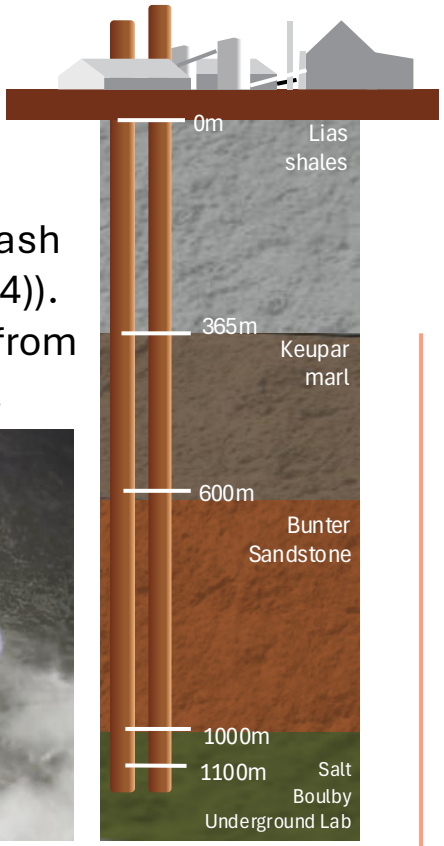
Potash

Polyhalite

Salt


Over 40 kms of tunnel mined each year (now >1,000kms in total), the long-lived roadways being cut in the lower NaCl layer.

Excavations are in Salt (NaCl), Potash (KCl) and Polyhalite ($K_2Ca_2Mg(SO_4)$). Permian evaporite layers left over from the Zechstein Sea (250m.yrs past).

# Deep Science at Boulby Underground Laboratory:

Science and Technology Facilities Council
Boulby Underground Laboratory

The UK's deep underground science facility operating in a working potash and salt mine.
1.1km depth (2805 mwe). With low background surrounding rock-salt
Operated by the UK's Science & Technology Facilities Council (STFC) in partnership with the mine operators ICL-UK

>4000m$^3$ class 1k & 10k (ISO 6 & 7) clean room lab space. 10Gb Internet. AC, air filtration, constant environmental monitoring, 5T & 10T lifting, LN generation, fume hood & clean prep space.

3000m$^3$ Outside Experimentation Area (OEA) with power & internet. Supported access to wider mining environments. Supported access to surrounding geology & UG environs. Power, wifi/internet

- Currently supporting >10 active projects, >250 scientists and students supported across active research programs, >60 institutions.
- Funded and operated by STFC (Science & Technology Facilities Counsel)
- Facilities, Operations, H&S, science programs and outreach are managed by our 25 onsite staff, supported by Rutherford Appleton Laboratory PPD.

## Science Programme Status and Plans:

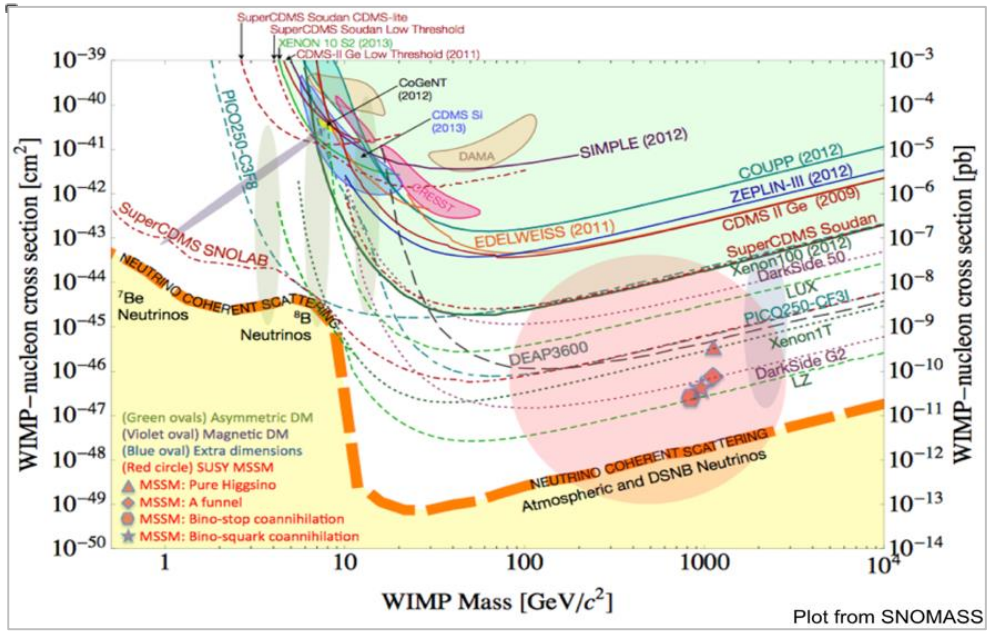
- Low background particle and nuclear physics
- Earth and Environmental Sciences
- Astrobiology & Planetary Exploration Studies
- Quantum Sensors and Computing
- Outreach and Education

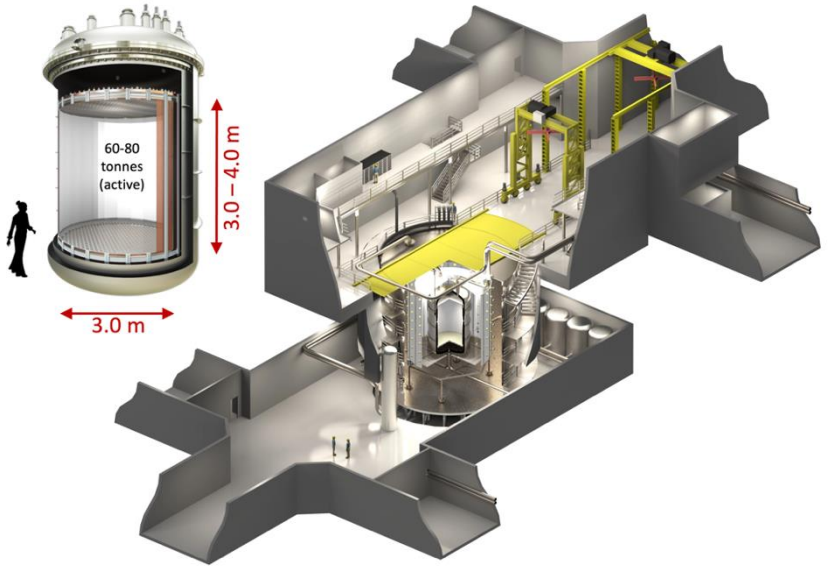
MANCHESTER 1824 The University of Manchester · BGS British Geological Survey · Farm Urban · esa · NASA · FAIR-SPACE · NPL National Physical Laboratory · THE CROWN ESTATE · The University Of Sheffield. · AWE NUCLEAR SECURITY TECHNOLOGIES · Durham University

# The Search for Dark Matter:

Science and Technology Facilities Council
Boulby Underground Laboratory

- BUL has a strong and longstanding history of studies in direct dark matter searches - including the development of two-phase liquid Xe TPC with the ZEPLIN programme
- BUL continues to lay the groundwork for future world-leading DM search experiments, with deep underground copper electroforming for Dark-SPHERE and XLZD component electroplating
- Preliminarily working with XLZD on material screening and manufacturing tests - soon within new bespoke cleanroom in BUL Main Hall
- Contender to host the world's next great dark matter experiment XLZD, bringing investment, growth, skills, and industry partnership to the North East of England




**ZEPLIN-II & III:**
The world's first 2-phase Xenon dark matter detectors (Finished 2011)

*ZEPLIN-III @ Boulby*

**DRIFT-II:**
Pioneered directional dark matter detection

*DRIFT-II @ Boulby*

# News-G & Darksphere

UNIVERSITY OF BIRMINGHAM

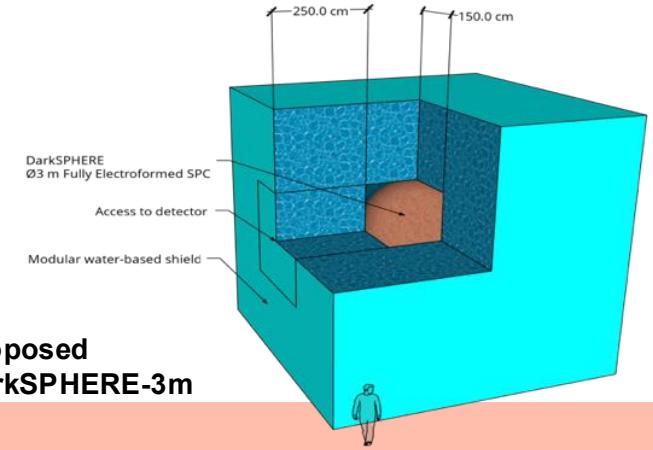
Science and Technology Facilities Council
Boulby Underground Laboratory

## Spherical proportional counters (SPC) at Boulby

### NEWS-G Activities at Boulby

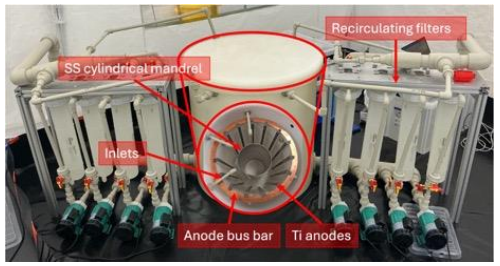
- Instrumentation developments
  - Multi-anode sensor
  - Gas filtration
  - Rate effect studies
- Neutron spectroscopy (with $N_2$ gas)
  - Neutron background surveys
  - Industrial applications
- High-purity copper electroformation
- **Towards scaled-up, electroformed, detector at Boulby, 3m diam. 5 bar $He:CH_4H_{10}$ *DarkSPHERE***

*K. Nikolopoulos, P. Knights, L. Millins, G. Rogers, D. Spathara, P. Walters*
*University of Birmingham*
*and international NEWS-G Collaboration (France, Canada, Greece, USA)*

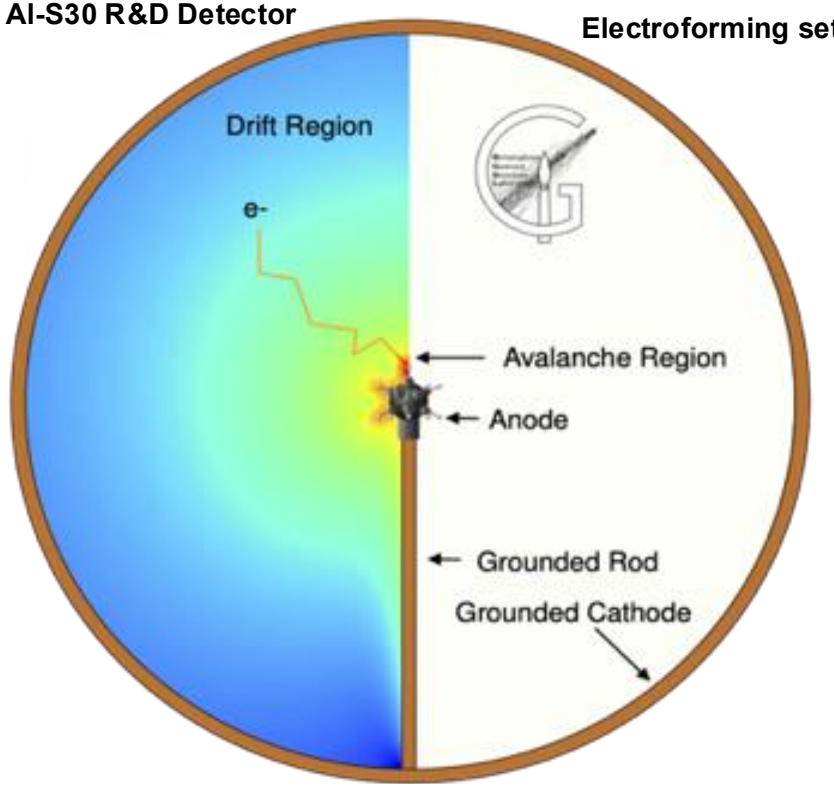



**Proposed DarkSPHERE-3m**

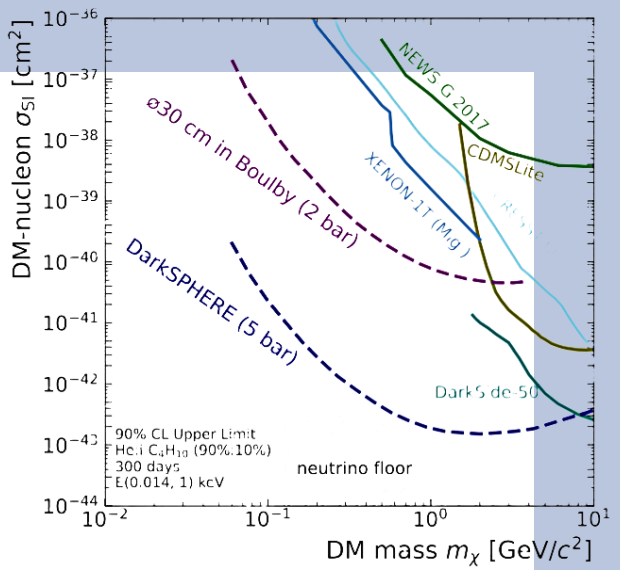
**Al-S30 R&D Detector**




**Electroforming setup**




**SPC concept: Variable target**
**Low $E_{th}$, Low mass sensitivity**




See:
Giovanni Rogers talk
Lachlan Millighan poster

# Boulby Underground Screening Facility (BUGS)

See Posters:
Alice Hamer – Radon Emanation
Kayleigh Johnson – ICP-MS
Beth Green – Ge and XIA

- World Class Deep Underground Material Screening Facility
- BUGS hosts 8 germanium detectors, 2 XIA UltraLo-800s, 2 radon emanation systems, and our ICP-MS on the surface
- All housed in a Class 1000 clean room
- Screened samples for projects such as LZ, Darkside, Super-K, Quest-DMC, SABRE, AWE
- Recent upgrades such as new nitrogen gas line, new radon reduction system.


# Emerging Quantum Technologies Programme at Boulby:

Science and Technology Facilities Council
Boulby Underground Laboratory


## QuASAR

*Quantum Atom-experiment for Sensing And fundamental Research*

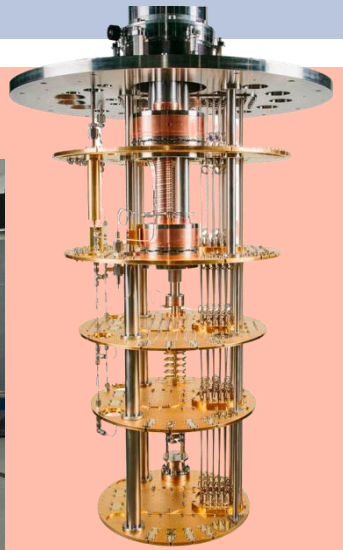
Durham University

- "The world's first deep underground quantum mechanics experiment"
- In collaboration with Durham University
- Aiming to super-cool rubidium atoms to be a fraction of a degree above absolute zero
- Demonstrator project to prove feasibility of deep underground quantum experiments at Boulby
- Springboard for future quantum science – e.g. quantum sensor development, atom interferometry

National Quantum Computing Centre

## Dilution Refrigerator:

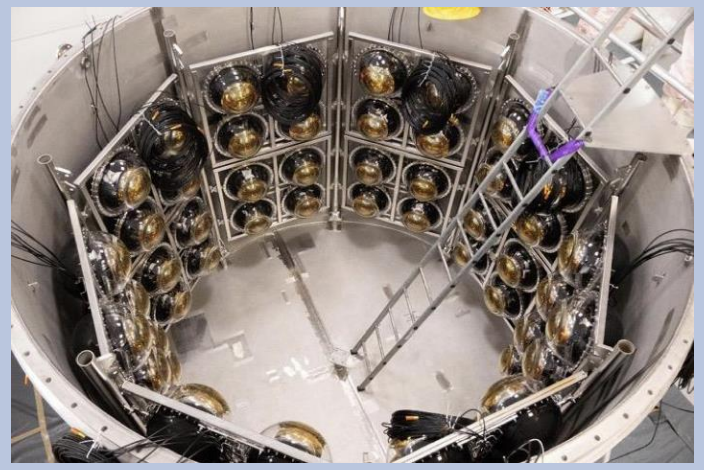
- BUL recently took delivery of a dilution refrigerator from the National Quantum Computing Centre (NQCC)
- Sent underground across 10 crates, installation late '26
- Will open new doors for quantum sensor, quantum computing and tabletop DM research
- Includes training of a Quantum Engineering Apprentice and L6 apprentice with Durham University
- Natural and exciting expansion of BUL science programme

# BUTTON:

*A technology testbed for future (anti)neutrino detection*

- An antineutrino detector utilising Cherenkov light and water based liquid scintillator
- Part of a worldwide effort to develop WbLS detector technology. Other experiments include EOS at LBNL and the Brookhaven 30-ton at BNL
- BUTTON-30 is a proof of concept for a future 1-kT detector providing 100-tonne fiducial volume.
- 20 tonnes when empty and 50 tonnes when full
- During installation, the detector had to be sent down in pieces and welded together underground
- Proof that Boulby Lab can host larger experiments.

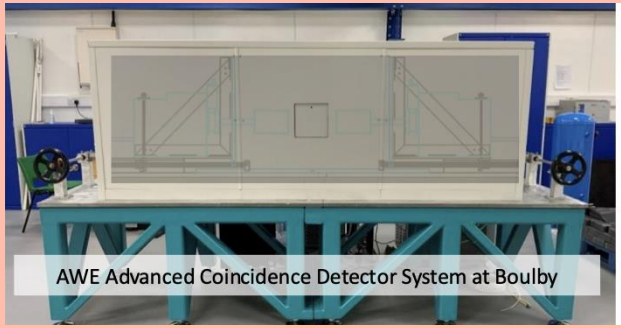



# RECON:

*Rare Element Coincidence Observatory of Nuclei*

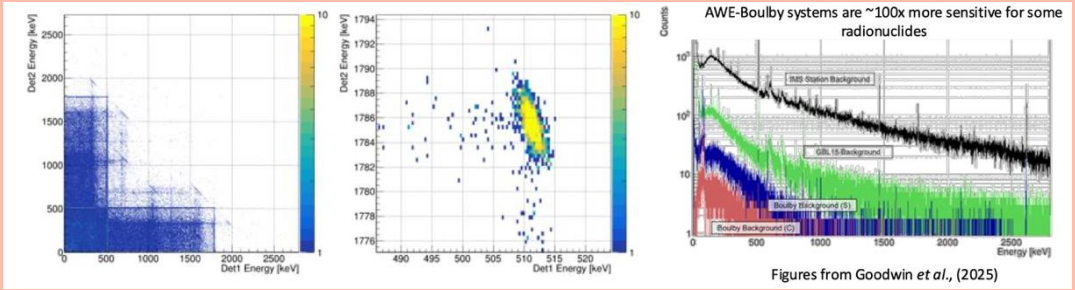
NUCLEAR SECURITY TECHNOLOGIES

Science and Technology Facilities Council
Boulby Underground Laboratory





- Advanced Coincidence detector system at Boulby lab
- Enhancing the capability to monitor for signs of nuclear threats
- Used for verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT)
- ~ 8 year collaborating relationship between Boulby and AWE.
- **New twin system coming soon!**



# Space exploration & Planetary Science:

Science and Technology Facilities Council
Boulby Underground Laboratory


**Biosphere:**
Using the mine environment as an analogue for Mars to research how we would do medical procedures in space

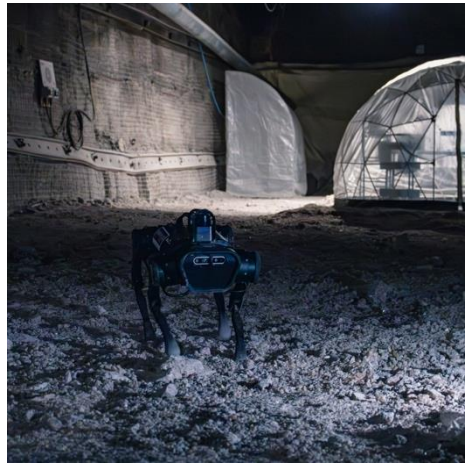
**MINAR:**
*Mine Analogue Research*
- NASA / JPL signatures of life studies

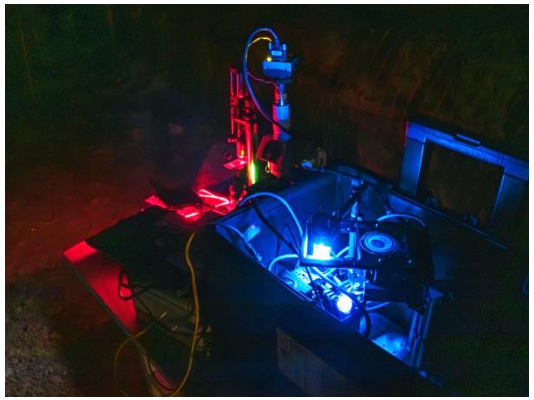
**Teesside University:**
- Investigating desiccation cracks for preserved organic matter
- Researching hydrocarbons in brine pools

**PanCam and CLUPI**
Cameras for ESA's Rosalind Franklin Rover

**Lulea University:** KORE Rover 3D Area Mapping

**USSL:**
Using Boulby's low BG environment and radiation sources to test sensors for satellites





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esa

# Earth and Environmental Science:

*Developing program of Earth science research at Boulby by a consortium of UK universities and industry*

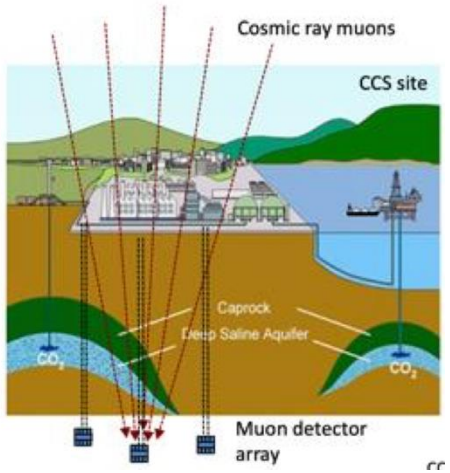
University of Bristol · University of Oxford · British Geological Survey · Science and Technology Facilities Council · Boulby Underground Laboratory

## Seismology:

*Boulby Underground Lab, ICL, University of Oxford, University of Bristol*

Network of seismometers and seismic nodes located throughout the largest mine in Britain

## Muon Tomography / Geo Survey:




Using muon tomography for CCS monitoring

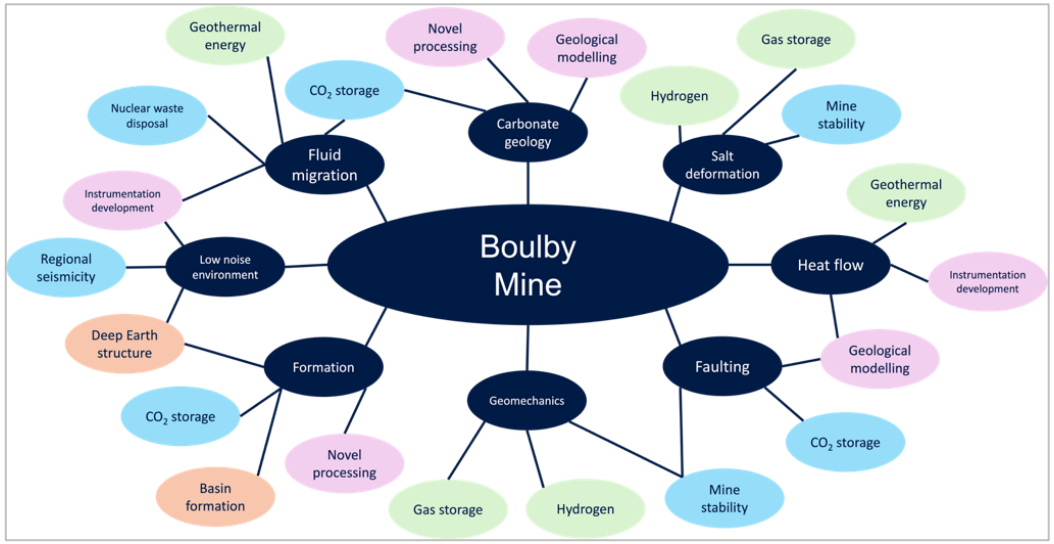
Muon tomog, for early warning tsunami detection

Tested both in the lab and in the depths of Boulby Mine (collaboration with ICL)

Spin-out company **Geoptic**, muon tomographic surveying for railway infrastructure, among other things

## RESOURCE:

*Renewable Energy Storage in Underground Caverns*

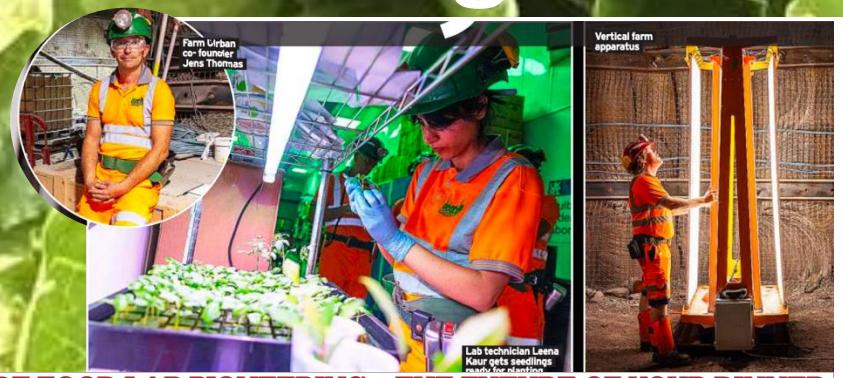



Boulby is a testbed for storing compressed gas in deep underground caverns.

Storing excess energy in these caverns to be released when production is low. This helps to regulate the production of renewable energy

In collaboration with the British Geological Survey (BGS) and the University of Cardiff

# Mining for Food Security:




INSIDE FOOD LAB PIONEERING THE FUTURE OF YOUR DINNER

DAILY MIRROR

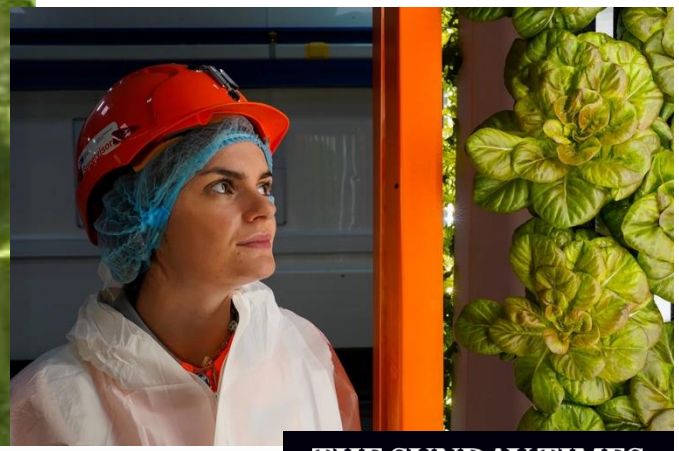
- The first deep underground vertical farms
- In collaboration with the University of Sheffield and Farm Urban
- Funded by STFC and BBSRC
- Aiming to turn disused / abandoned places into thriving farms
- No ‘seasonality’ in crops deep underground
- No need for pesticides
- Not effected by the environmental issues arriving sue to climate change
- Estimated 30-50% energy savings so far
- This is also being researched as a socioeconomic study; to see how feasible it would be long term
- Boulby is an active mine, although this project is aiming to expand this across multiple abandoned mines.
- This will create jobs for lots of ex-miners!

itv NEWS

First lettuce harvested in project to grow vegetables 1km underground

Fri 24 Jul 5.20pm • Crops have been grown a kilometre beneath the North Yorkshire coast in a new project by the University of Sheffield.

**Future media coverage:**
Reuters, BBC Inside Science, The one show



THE SUNDAY TIMES

Delving into dark matter inside Britain’s deepest science laboratory

Farm Urban

UKRI Science and Technology Facilities Council
Boulby Underground Laboratory

UKRI Biotechnology and Biological Sciences Research Council

The University Of Sheffield.

Subterranean salad: underground farmers seek solution to food crisis in disused UK mines

The Guardian

# Public Engagement at Boulby Underground Laboratory

**Unique challenges afford exciting opportunities:**

- Must be **18+** to enter site and go underground
- Boulby science is (importantly and necessarily) **complex** and **broad**

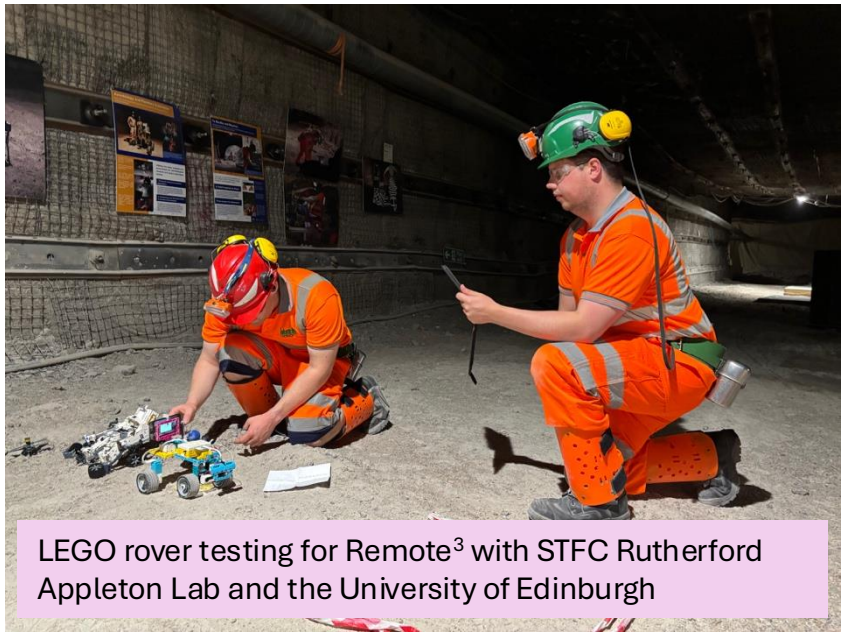
**Public engagement must therefore be:**

- **Portable** for use in classroom workshops and demonstrations, or…
- **Virtual** for remote audiences
- **Adaptable** for differing demographics
- Cover a **broad range** of scientific disciplines, or be adapted to focus on just one at a time

**While also:**

- Aligning with **STFC**, **UKRI** and **ICL-Boulby** missions and strategy

BUL @ Durham Miners' Gala with Durham University


LEGO rover testing for Remote[3] with STFC Rutherford Appleton Lab and the University of Edinburgh

See also J. Gutteridge poster

6,200 people engaged throughout 2025…

… across 68 different events…

… 23 live links, reaching ~1600 people

11,531 total reach from the Remote[3] programme across its lifetime, with students from 355 schools

# Public Engagement at Boulby Underground Laboratory

## Remote[3]

- Collaboration with **STFC's Rutherford Appleton Laboratory** and the **University of Edinburgh**
- Coaching and mentoring student teams to design, build and program **LEGO MINDSTORM Mars rovers**
- Engagement with **remote and disadvantaged schools** with little STEM interaction
- Rovers **tested deep underground** at Boulby
- Strong **curriculum links** for early block-based programming


Student-made poster for project evaluation – posing with BUL apprentice Joel

**Now being expanded into 3 children's hospitals and more schools in Teesside**

Rover proving ground, 1.1 km underground

See also J. Gutteridge poster

# Public Engagement at Boulby Underground Laboratory

## Storytelling

- Classroom-based workshop built on BUL underground rover testing programme
- *The Little Robot and the Mars Mystery*
- Introduces concepts about **space travel**, the **solar system**, and deep underground science
- Can be delivered **virtually** and **in-person**
- Great opportunity to involve **apprentices** and **new starters** in BUL schools' programme to built confidence, mentoring and public speaking skills


Kayleigh Johnson, laboratory technician apprentice, delivering a storytelling workshop in Nottinghamshire

**Now being expanded with a new storytelling package around microbiology**


Expanded again to World Poetry Day webinar and in-class workshops

**And there's more PE!**

See also J. Gutteridge poster

# Expansion of deep underground capabilities in the North East

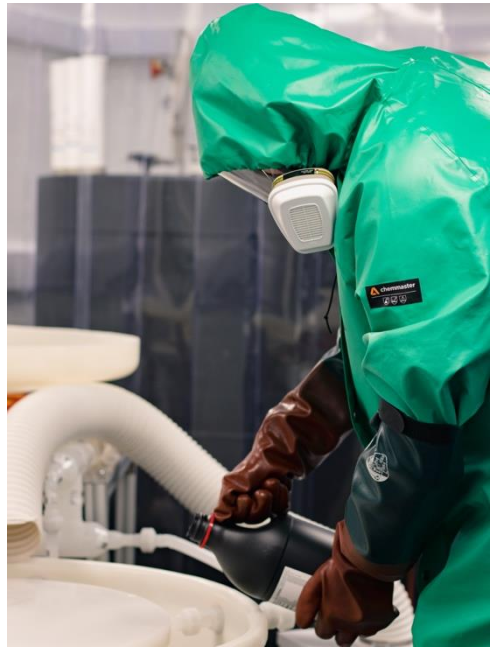
- Plans underway for **major expansion** of the facilities at Boulby, to enable an expanded science programme onsite from the early 2030s
- The expansion will bring substantial scientific, cultural, economic and skills / education benefit to the Tees Valley region and the UK as a whole
- Expansion plans include the excavation and outfitting of a new cavern at 1.1 km depth, providing greater than a **factor five increase** in space to support world-class, multidisciplinary, pure and applied deep underground research
- **This stage of expansion is underway now!**

The creation of the new facility will deliver even greater impact to the Tees Valley region through:

- **Internationally impactful** science projects,
- Increased **national** and **international** recognition
- **Inward investment** for new infrastructures, engineering and projects
- The creation of **skilled jobs** in STEM and technical support
- Fostering partnerships with **local industry**
- Meaningful **education** and **outreach** with local schools and colleges

# In Summary:

Science and Technology Facilities Council
Boulby Underground Laboratory



- Boulby hosts a wide array of multidisciplinary science projects, both pure and applied
- Boulby's science programme is more multidisciplinary than ever before
- Strong engagement programme with local, regional and national impact
- Expanding science-enabling capabilities with new laboratory space excavated
- Contender to host the world's next great dark matter experiment, XLZD