Fiber-Optic Strain Monitoring of Rock Masses in Large Underground Facilities

DUSEL Fiber-Optic

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Research Questions

Geosciences

- How do rock masses deform as a function of spatial scale over long times?
- How does the static deformation field measured by strain sensors relate to microseismicity?
- How are the deformation field and fracture flow coupled?

Geoengineering

- Large cavity engineering
- General mine monitoring, and safety – How is the mine “breathing?

Technology Objectives

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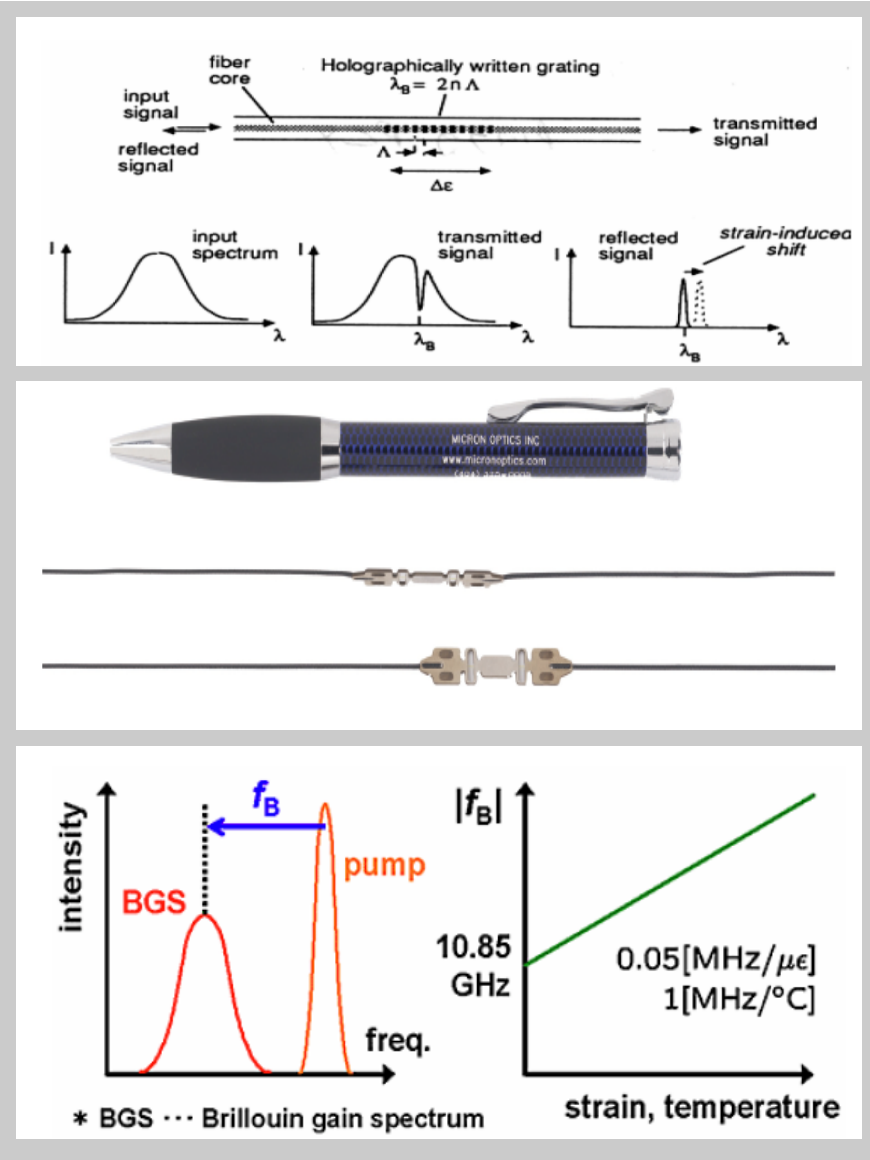
- Determine rock properties that control rock deformation over multiple scales of length and time
- Advance the technology of characterizing rock deformation
- Perform long-term (decadal) structural health monitoring (SHM) of DUSEL.
- Integrate deformation sensors with other physical and chemical fiber-optic sensors into a laboratory-wide environmental and safety monitoring system

Fiber-Optic Sensor Principles

Fiber-Bragg Grating (FBG) sensors are discrete. Scale of measurement is 1 cm to 2 meters with 1-με sensitivity.

Distributed Strain and Temperature (DST) is continuous. The optical fiber itself is the sensor. Scale: Measurement can extend to kilometers with 30-με sensitivity and 1-meter spatial resolution.



Micron Optics OS3600 FBG

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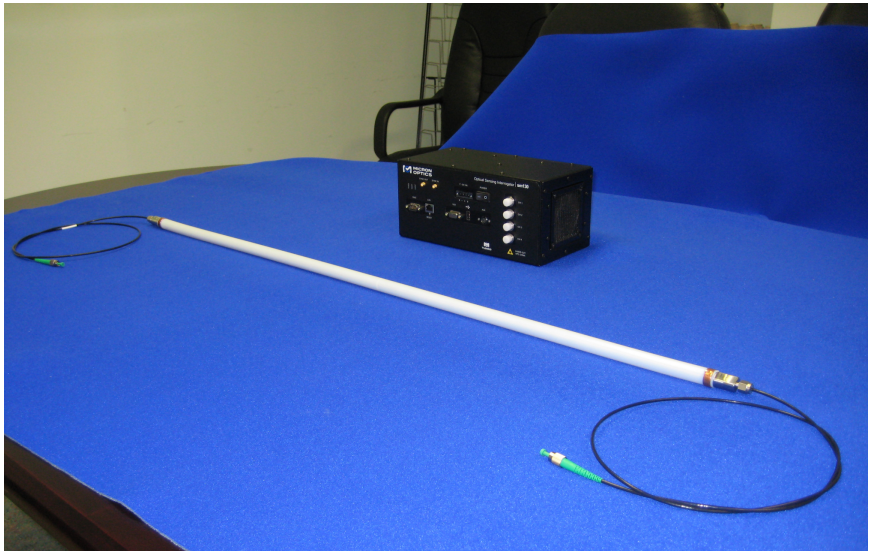

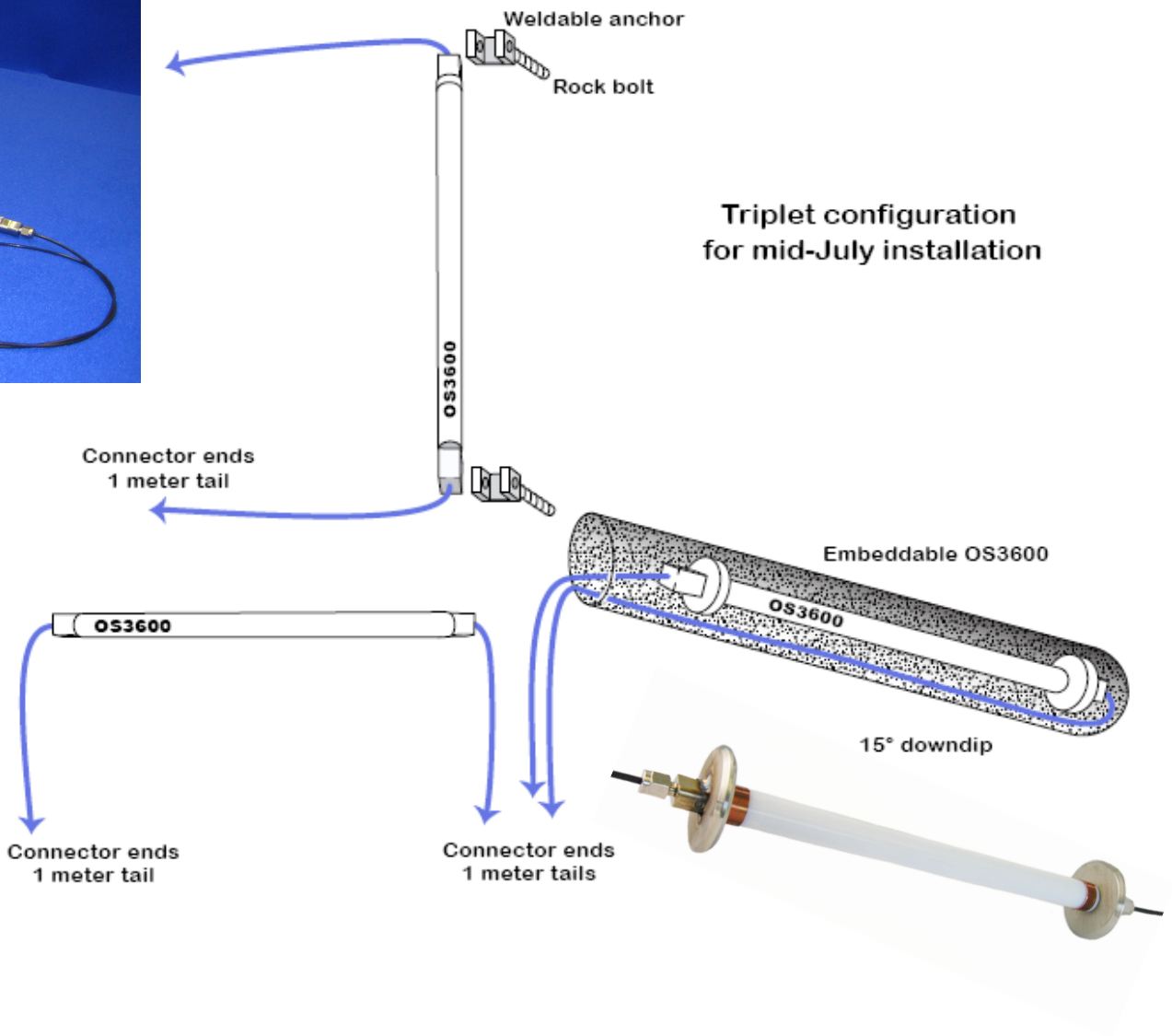

Observations

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Data collection is just beginning. A triplet of 1-meter FBG tube strain gages in Cartesian directions on an east-west wall of powder room next to DUGL station on 4100L was installed July 29, 2009 and a datalogger was installed Sept. 30, 2009.

Develop and benchmark anchoring and clamping techniques to validate measurements as rock mass behavior.

Tunneling-Induced Microseismicity at Candian URL

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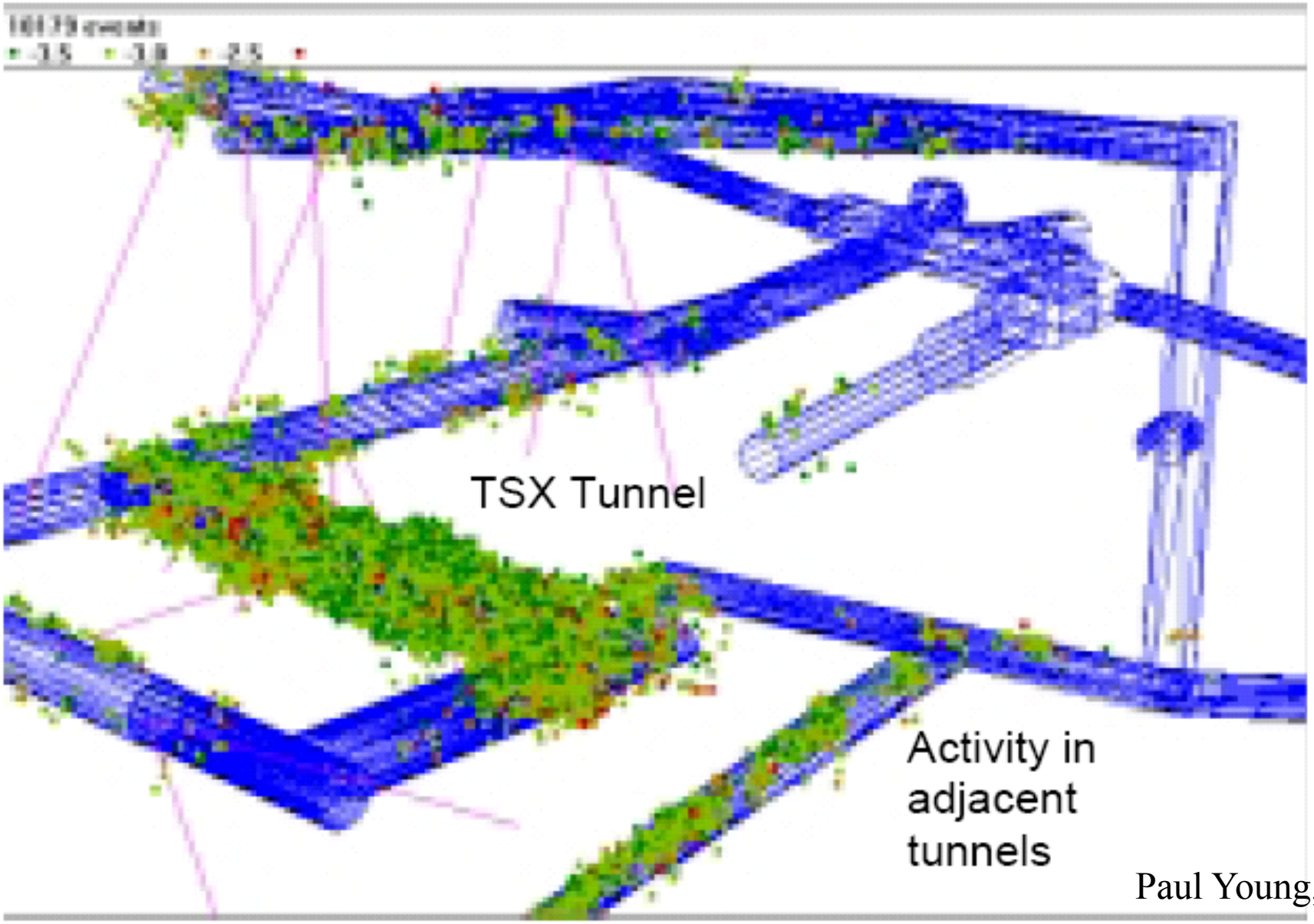

Paul Young, 1999

Create 3-D network of DST cable-- equivalent to 100s of extensometers and thermistors

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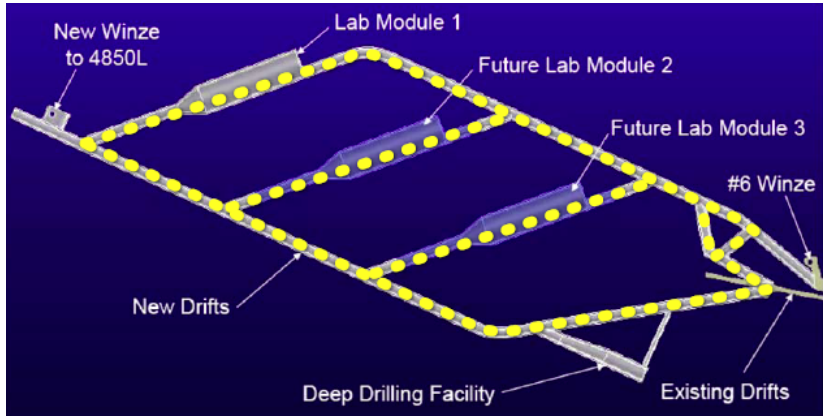

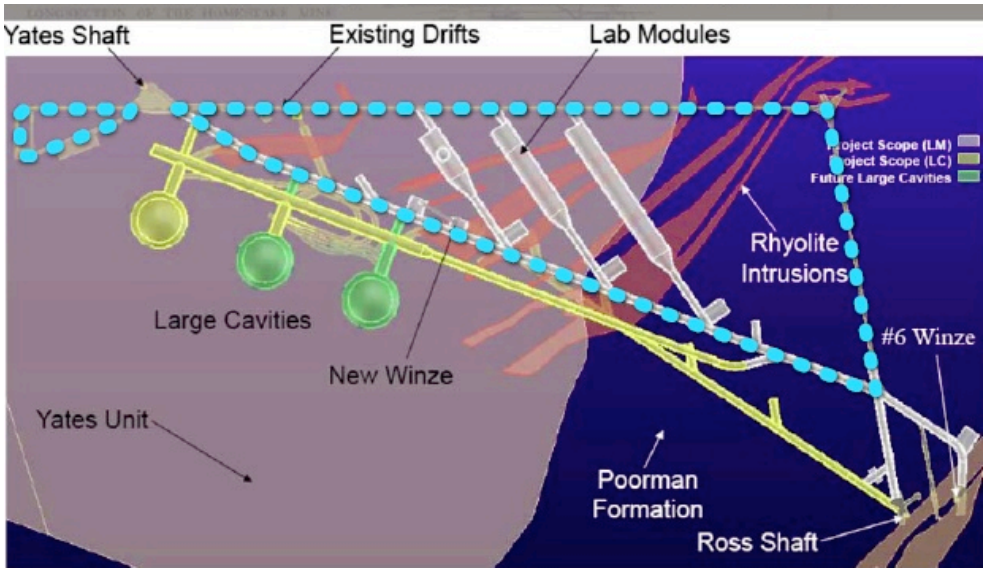

Simultaneously measure deformation and fluid-flow.

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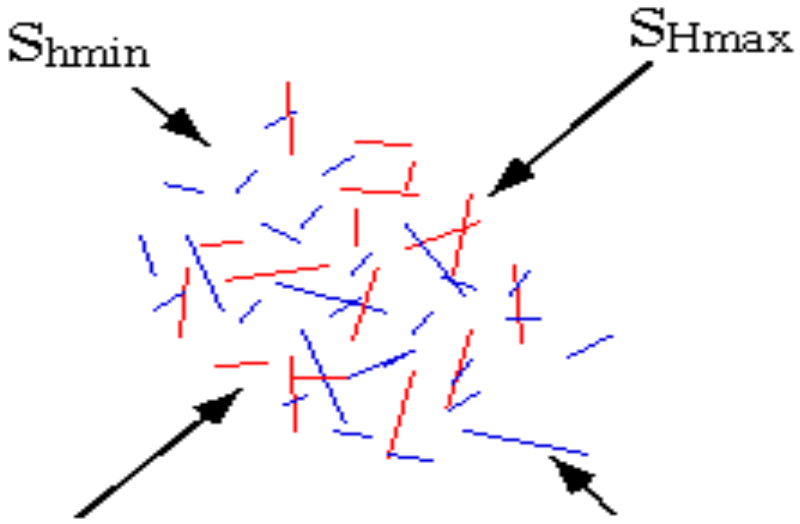
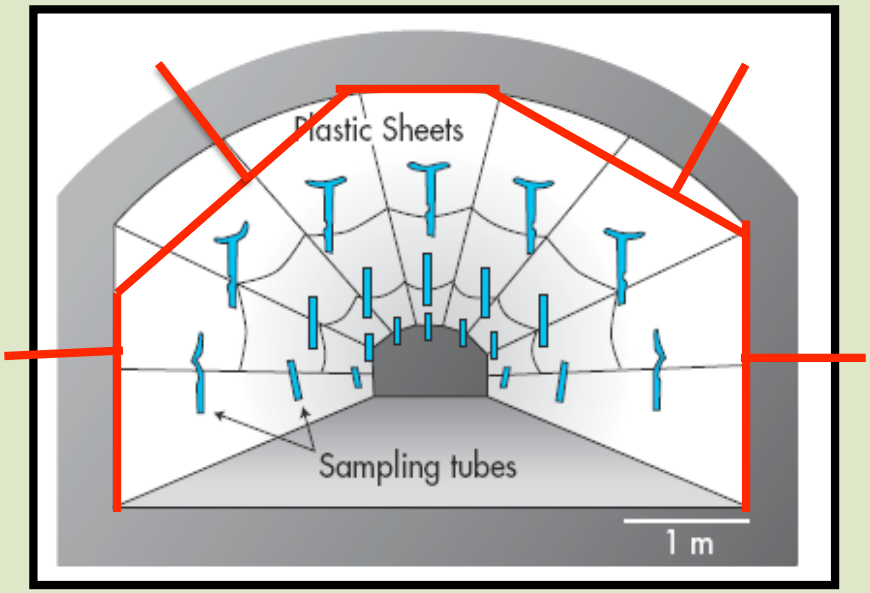
Do critically-stressed fractures dominate fluid flow?



Fiber-Optic Sensor Network



Synergistic Measurements

- Tiltmeter arrays: Fiber-optic strain measurements are complemented by borehole tiltmeter and long-baseline (100-m) water-level tiltmeters.
- Seismic arrays: FBG strain sensors sampling rate can go up to 1 kHz and be related to measurements by microseismicity arrays.
- Stress measurements: Fiber-optic strain measurements are complemented by in situ stress measurements to model rock-mass behavior.
- LIDAR: Fracture and anisotropy analysis over scales of 100s of meters can provide rock-property inputs to models

Future Work – Load a small room

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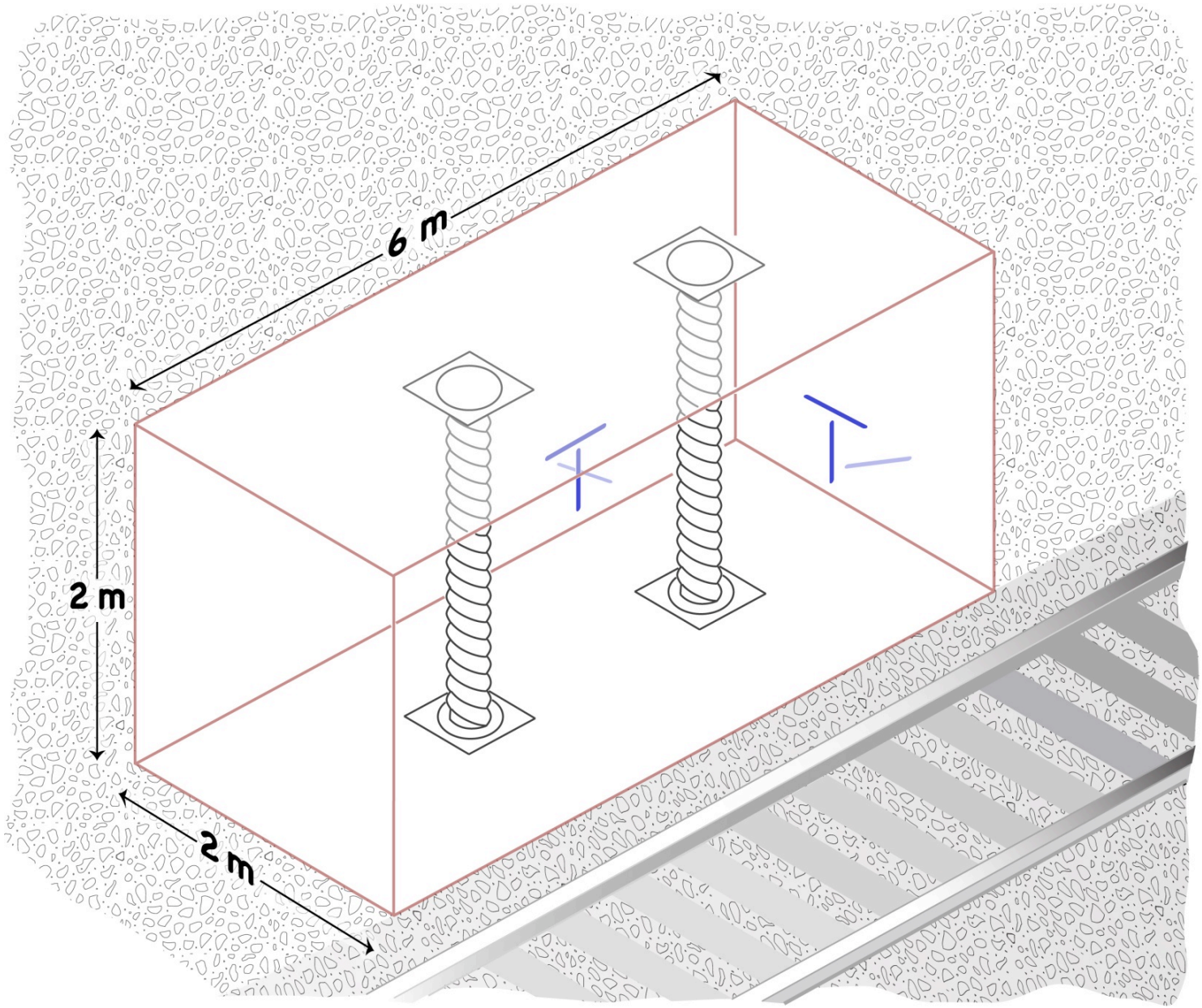

Future Work – Monitor a large room

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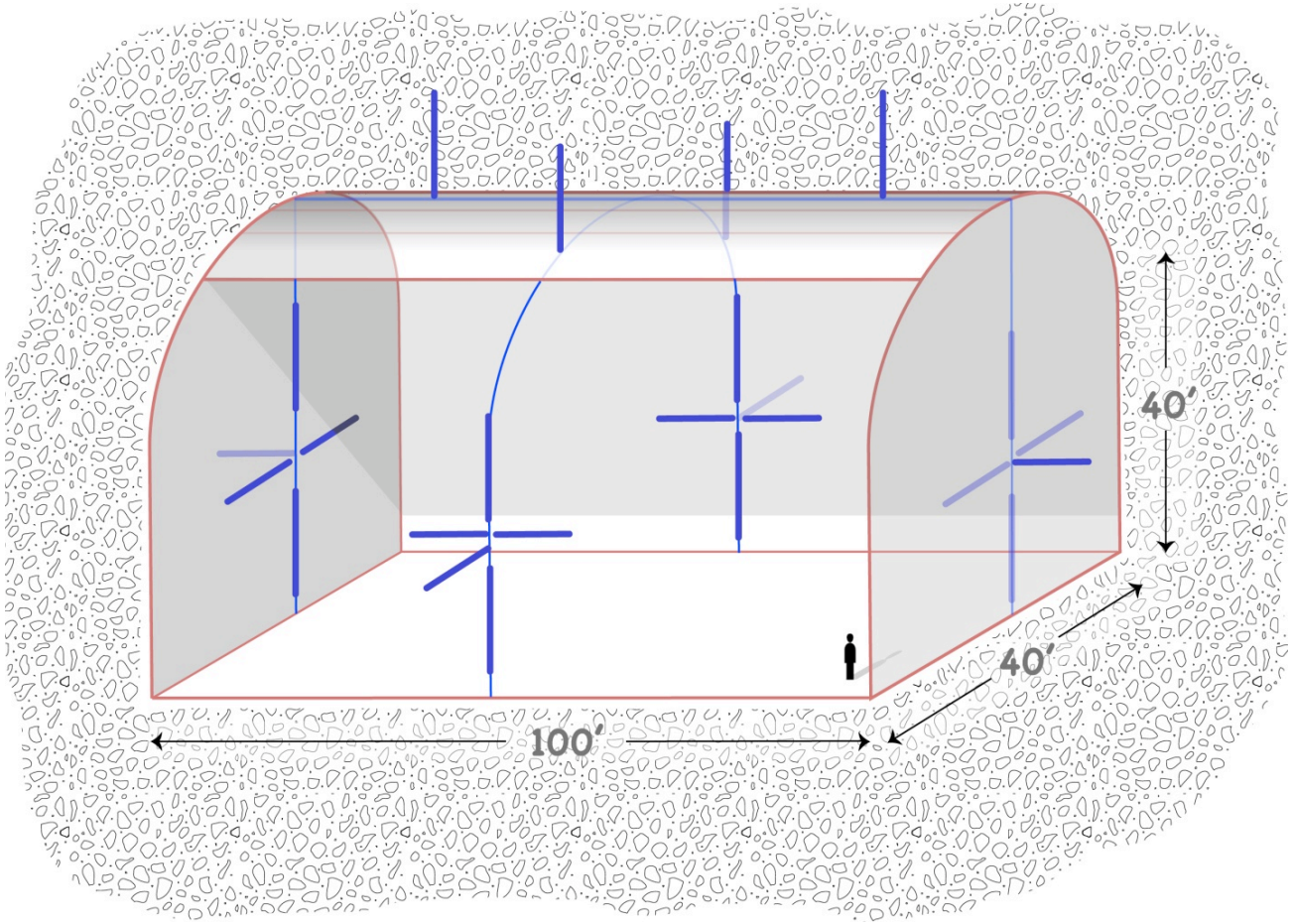
Install fiber-optic sensors at 4850L behind drifting to LUX/ Majorana laboratory and in the cavity (without significantly impeding the work schedule). Combine with geological mapping and LIDAR to model results in terms of rock properties of Yates Fm.



Future Work – Monitor the cable bolts in water Cherenkov cavities

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