Infrastructure Development for underground labs - SNOLAB experience

Nigel Smith
Director, SNOLAB
SNOLAB Objectives

- To promote an International programme of Astroparticle Physics
- To provide a deep experimental laboratory to shield sensitive experiments from penetrating Cosmic Rays (2070m depth)
- To provide a clean laboratory
  - Entire lab at class 2000, or better, to mitigate against background contamination of experiments.
- To provide infrastructure for, and support to, the experiments
- Focus on dark matter, double beta decay, solar & SN experiments requiring depth and cleanliness.
  - Also provide space for prototyping of future experiments.
- Large scale expt’s (ktonne, not Mtonne)
- Goal has been to progressively create a significant amount of space for an active programme as early as possible.
The SNOLAB facility

- Operated in the Creighton nickel mine, near Sudbury, Ontario, hosted by Vale Ltd.
- Developed from the existing SNO detector
- Underground campus at 6800’ level, 0.27µ/m2/day
- Development funds primarily through CFI as part of a competition to develop international facilities within Canada
- Additional construction funding from NSERC, FedNOR, NOHF for surface facility
- Operational funding through NSERC, CFI, MRI/MEDI (Ontario)
- Managed as a joint trust between five Universities (Alberta, Carleton, Queen’s, Laurentian, Montréal)
  - Carleton led SNOLAB construction and facility development
  - SNOLAB formally a Queen’s Institute to provide legal entity (for Vale)
  - SNOLAB Institute Board of Directors has overall governance responsibility
Vale Creighton Mine

- Surface Facility (3100 m²)
  - Operational from 2005 - Provides offices, conference room, dry, warehousing, IT servers, clean-room labs, detector construction labs, chemical + assay lab
  - 440m² class-1000 clean room for experiment setup and tests
Facility design philosophy

- Initial underground design concept was single monolithic cavity
- Workshops held with community to determine experiment requirements
- Switched to multiple target cavities
  - Isolate experiments for background and noise control
  - Safety of large cryogenic liquid volumes: connection to raise
  - Logistics not limited by break-out into several cavities
- Utility drifts separated from target volumes (à la SNO)
- Entire facility to be maintained as a C2000 clean-room
  - Minimise potential for cross-contamination of experiments from dust introduced into lab
  - Minimise burden on experiments, trained crew for materials
  - Controlled single point access for materials and personnel, including personnel showers and change area
  - Provide proto-typing and rapid deployment capability for medium scale projects
Facility design considerations

- Seismic activity
  - Mining induced seismic activity - quasi-random
  - SNO and SNOLAB designed to 4.1 NutlI, such event seen (after completion of SNO)
  - Maximum event now taken as 4.3 NutlI

- Design criteria - seismic
  - SNO and SNOLAB in the stable hanging wall of norite
  - Exploratory core drilling performed over lab area
  - Detailed analysis of cavity and lab design stress from ITASCA
  - Lab placed outside the lifetime 5% stress boundary from mining activity
  - Orientation to give cavities along line of maximum stress
  - Secondary support: 2m rockbolts, 7/10m cables, mesh and shotcrete

- Background minimisation
  - Norite rock: 1.00 ± 0.13 % K, 1.11±0.13 ppm U and 5.56±0.52 ppm Th
  - Dust suppression required - all experimental areas shotcreted and painted to capture dust and contamination
Seismic design criteria

5% stress contour

Stress modelling for all cavities

Proposed SNO installations (approx.)

400 mm/s PPV limit

Existing SNO installations

5% $\sigma_1$ change limit

5% $\sigma_3$ change limit

Lab location outside stress boundary

Active mining horizon

Nigel J.T. Smith

CJPL Workshop, Asilomar

8th September, 2013
Underground Facilities

SNO Area: 1860 m²

SNOLAB Area: 5360 m²
## SNOLAB Space Summary

### Excavation

<table>
<thead>
<tr>
<th>Area</th>
<th>Dimensions</th>
<th>Area (m²)</th>
<th>Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNO Cavern</td>
<td>24 m (dia) × 30 m (h)</td>
<td>250²</td>
<td>9,400</td>
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<tr>
<td>Ladder Labs</td>
<td>32 m (l) × 6 m (w) × 5.5 m (h)</td>
<td>190²</td>
<td>960</td>
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<tr>
<td></td>
<td>23 m (l) × 7.5 m (w) × 7.6 m (h)</td>
<td>170²</td>
<td>1,100</td>
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<tr>
<td>Cube Hall</td>
<td>18.3 m (l) × 15 m (w) × 19.7 m (h)</td>
<td>280²</td>
<td>5,600</td>
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<tr>
<td>Cryopit</td>
<td>15 m (dia) × 19.7 m (h)</td>
<td>180²</td>
<td>3,900</td>
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### Clean Room

<table>
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<th>Area</th>
<th>Volume (m³)</th>
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<td>Original SNO Areas</td>
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<td>+Phase II</td>
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### Laboratory

<table>
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<th>Area</th>
<th>Volume (m³)</th>
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<tr>
<td>Original SNO Areas</td>
<td>11,700</td>
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<tr>
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<td>2,3700</td>
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<tr>
<td>+Phase II</td>
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</table>
Facility Services

- **Ventilation**
  - 100,000 cfm mine air flow to laboratory, mainly used for cooling of chillers
  - 10% make-up air fed in lab - 13 air handling units in lab
  - Maintains pressure differentials for cleanliness
  - 10 air changes/hour nominal; 5 air changes/hour in cavities

- **Cooling**
  - 1 MW cooling capability from 5 cooled water units delivering 10°C water to the laboratory. 100kW from rock in steady state (42°C base)
  - 20% utilised at present with minimal expt. load

- **Power distribution**
  - 3-phase 13.8 kV fed to facility
  - Stepped to 3-phase 600V (total 2000 kVA); Upgrade underway to 3000 kVA
  - 150kW (++) Generator planned + switch-over infrastructure

- **Water**
  - Utility water derived from mine water
  - UPW as a general capability for experiments (150l/min 183 kΩm)
  - Waste disposal through mine systems (except sewage - STP)
Facility Services

- Gases / Liquids
  - Bottle transport used for gases; dewar transport for LN2
  - Discussion on liquefaction underground (but purity issue for cover gas systems)

- Networking
  - Switching to single mode fibres underway
  - 100Mbit through shaft; upgrade to Gbit once fibres switched

- Low Background Assay and calibrations
  - Co-ax and well Ge detectors available
  - X-ray fluorescence for cleanliness assay

- Workshops
  - Surface machine shop; surface chem labs; surface electronics shop
  - Underground clean room workshop and chem labs in construction

- ‘Hot’ Lab
  - Dedicated surface lab at Laurentian University for ‘hot’ work
  - Encapsulation of sources; production of radiological spikes

- Other services
  - GPS timing
Experiment design considerations

- **Transport**
  - Cage size: 3.7 m x 1.5 m x 2.6 m, slinging for larger objects

- **Seismic mitigation**
  - Design criteria now 4.3 Nuttli, following 4.1 event in SNO
  - Forcing function applied to experiment designs - maximum velocity 800 mm/s at 5 Hz

- **Pressure**
  - Air pressure is 25% higher than atmospheric
  - Excursions during ventilation changes and crown blasts (up to 3% seen)
    - managed through baffling and blast doors
    - design pressure for experiments up to 20 psi

- **Radon (~130 Bq/m3)**
  - No direct radon suppression in main air intakes
  - Surface (compressed) air used to provide low(er) radon air to specific areas
  - Cover gas used (LN2 boil-off) on detector systems
  - Ventilation (make-up vs recirculation) minimises radon emission from walls

- **H2S**
  - Long term exposure to mine air showed deposition of CuS on SNO electronics
  - Suppression is now installed in the air handling units
Additional Information

- SNOLAB Users Handbook
  - (Outdated (2006) but still relevant
- Geo-tech Reports
  - Forcing function for 4.3 Nuttli event
- “The Construction and Anticipated Science of SNOLAB” Duncan, Noble & Sinclair
  - Ann. Rev. of Nucl. & Part. Science (60) 163-180, 2010
Support for Experiments

- Through a staff of ~55, SNOLAB Provides technical and administrative support to SNOLAB experiments:
  - design, construction, operations
  - background assay, science support
  - materials transport, cleaning, EH&S, training, procurement
- The Research team members can act as collaborators on experiments, providing operational and scientific support
- Infrastructure support is provided through development of shielding systems, mechanical supports, access, EH&S, etc.
- Services provided as standard to experiments includes life safety, power, ventilation, compressed air, ultra-pure water, liquid nitrogen, IT and networking
- Vale provide materials transport through the shaft, maintain the safety of the infrastructure, regulatory checks, etc.
  - SNOLAB currently has 50-80 people underground regularly, 3 dedicated cages
  - Cages integrated into Vale operations effectively (eg SNO D2O movement)
  - Double shifts maintained regularly
SNOLAB Operations costs

- Staff complement ~60
  - Cost ~$4M/yr
  - Note: additional support from University partners so NOT full project staff costs
  - 24hr/day operations not assumed

- Non-staff
  - Cost currently ~$3M/yr
  - Includes Vale charges ~$1M

- Project cash costs currently ~$7M/yr

- “In-kind”
  - If mining operations ceased, the equivalent contribution from Vale estimated ~$7-10M/yr:
    - Hoist, materials, service infrastructure, EH&S, drift maintenance, collar services, water+ventilation
  - University support ~$1M/yr
SNOLAB operational model

- For current facilities
  - Traditional NP “free-at-the-point-of-access” model
  - Canadian support for baseline operations of the facility, including life safety, power, ventilation, materials handling, compressed air, UPW, IT and networking
  - Experiments charged for additional ‘non-standard’ costs: significant transport, high power usage, significant gas/nitrogen
  - Experiments responsible for clean-room beyond C2000
  - Infrastructure negotiated: capital expected from experiments

- Based on current planned programme
  - If additional experiments incorporated immediately then additional installation and construction support would be required through the experiment for infrastructure
Project Lifecycle Planning

- Project lifecycle and interaction with facility well-defined
  - Structures and agreements under development
  - Q.A. under development
- International Experiment Advisory Committee (Stew Smith chair) helps to define programme
- H&S reviews integral to development and deployment
  - SNOLAB
  - Vale (if req’d)
- Workshop based approach to updated programme needs
  - e.g. material production/machining underground
SNOLAB Science Programme
Current programme:
Dark Matter at SNOLAB

- Noble Liquids: DEAP-I, MiniCLEAN, & DEAP-3600
  - Single Phase Liquid Argon using pulse shape discrimination
  - Prototype DEAP-I completed operation. Demonstration of PSD at 108.
  - Construction for DEAP-3600 and MiniCLEAN well advanced.
  - Will measure Spin Independent cross-section.

- Superheated Liquid / Bubble chamber: PICASSO, COUPP
  - Superheated droplet detectors and bubble chambers. Insensitive to MIPS radioactive background at operating temperature, threshold devices; alpha discrimination demonstrated;
  - COUPP-4 operation completed; PICASSO-III currently operational, COUPP-60 construction completed, in commissioning;
  - Measure Spin Dependent cross-section primarily, COUPP has SI sensitivity;
  - New world leading sensitivity published in 2012.

- Solid State: DAMIC, SuperCDMS
  - State of the art CCD Si / Ge crystals with ionisation / phonon readout.
  - DAMIC operational;
  - CDMS Currently operational in Soudan facility, MN. Next phase will benefit from SNOLAB depth to reach desired sensitivity.
  - Mostly sensitive to Spin Independent cross-section.
Current programme: 0νββ and neutrino at SNOLAB

- **SNO+**: 130Te $\rightarrow$ 130Xe + e- + e-
  - Uses existing SNO detector. Heavy water replaced by scintillator loaded with 130Te. Modest resolution compensated by high statistical accuracy.
  - Requires engineering for acrylic vessel hold down and purification plant. Technologies already developed.
  - Will also measure
    - solar neutrino pep line (low E-threshold)
    - geo-neutrinos (study of fission processes in crust)
    - supernovae bursts (as part of SNEWS)
    - reactor neutrinos (integrated flux from Canadian reactors)

- **EXO-gas**: 136Xe $\rightarrow$ 136Ba++ + e- + e-
  - Ultimate detector aim = large volume Xe Gas TPC
  - Developing technique to tag Ba daughter. Electron tracking capability.
  - Development work at SNOLAB surface facility

- **HALO**: Dedicated Supernova watch experiment
  - Charged/neutral current interactions in lead
  - Re-use of detectors (NCDs) and material (Pb) from other systems
  - Operational May 2012
  - Will form part of SNEWS array
# The SNOLAB Science Programme

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- **Current**: DEAP-I, COUPP-4, COUPP-60, PICASSO-III, DAMIC (Dark Matter) and HALO, EXO-Gas (Neutrino).
- **2013+**: DEAP-3600, MiniCLEAN, (Dark Matter) and SNO+ (Neutrino).
- **2014+**: SuperCDMS (Dark Matter) and EXO Prototype (Neutrino).

Diagram:
- **Cube Hall**
- **Cryopit**
- **Unallocated as yet (MC use now)**
- **SuperCDMS Test Facility**
- **Halo Stub**
- **Utility Drift**
- **Ladder Labs**
- **SNO+**
- **SNO Cavern**
- **South Drift**
- **PUPS**
- **PICASSO-III**
- **DEAP-3600 MiniCLEAN**
- **COUPP-4**
- **COUPP-60**
- **SuperCDMS**
- **Low Background Tests**

**Personnel facilities**
A dungeon horrible, on all sides round...
No light; but rather darkness visible...

Paradise Lost - Milton (1668)