Infrastructure Development for underground labs - SNOLAB experience

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SNOLAB Objectives

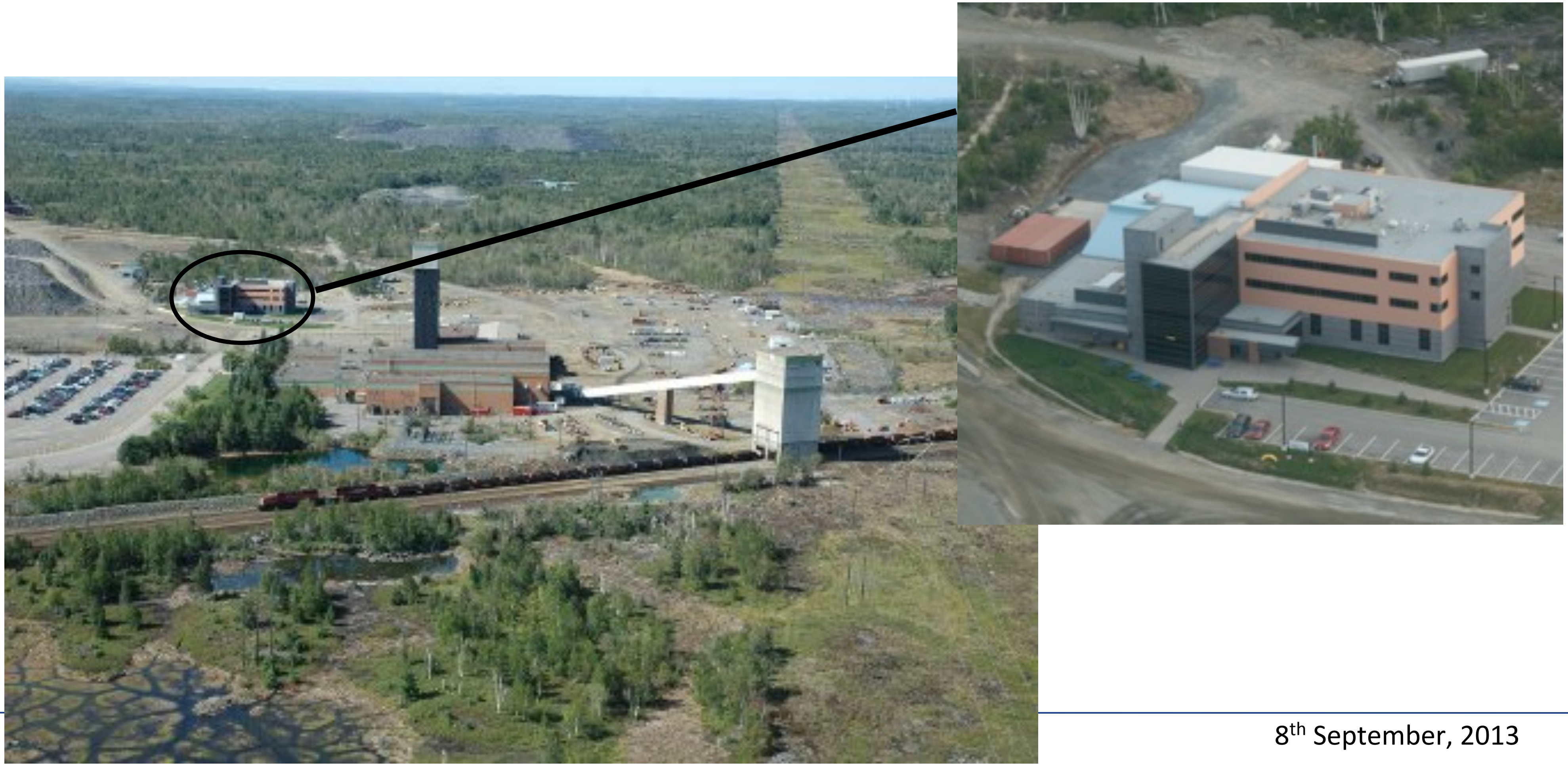
- To promote an International programme of Astroparticle Physics
- To provide a deep experimental laboratory to shield sensitive experiments from penetrating Cosmic Rays (2070m depth)
- To provide a clean laboratory
  - Entire lab at class 2000, or better, to mitigate against background contamination 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



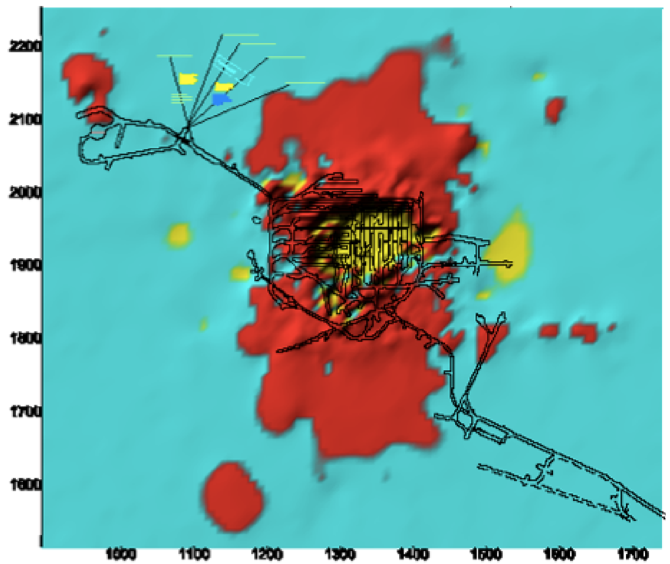
Facility design philosophy

- 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

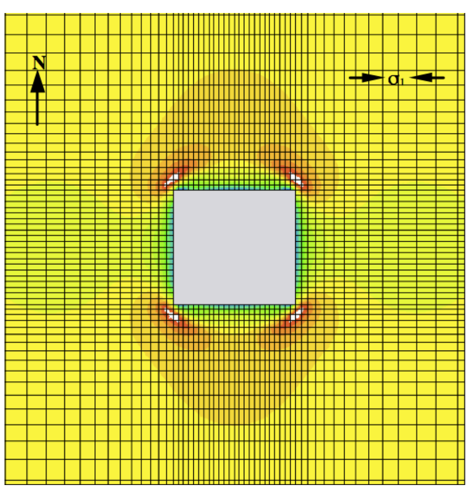
Facility design considerations

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

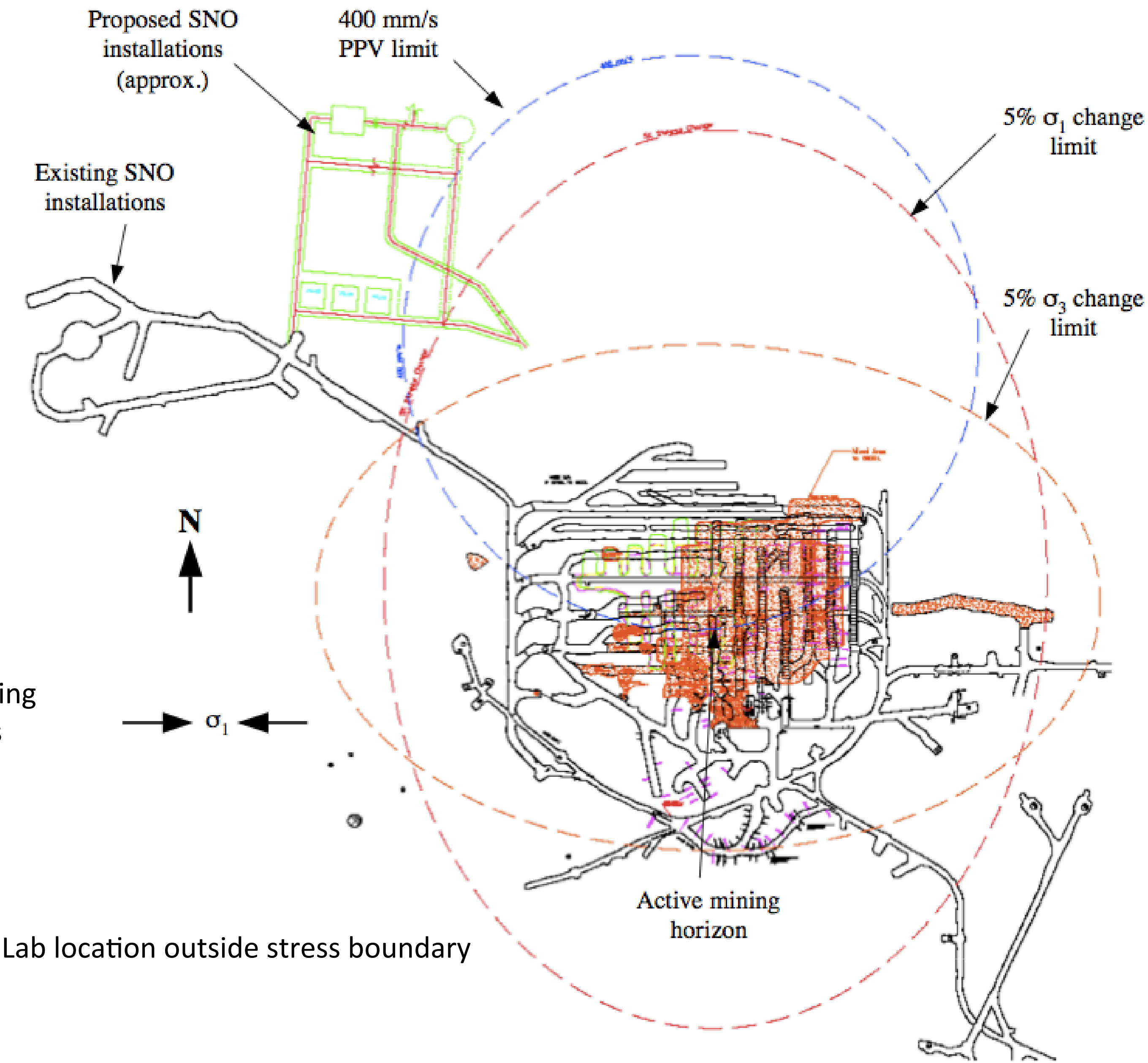
Seismic design criteria



5% stress contour



Stress modelling for all cavities

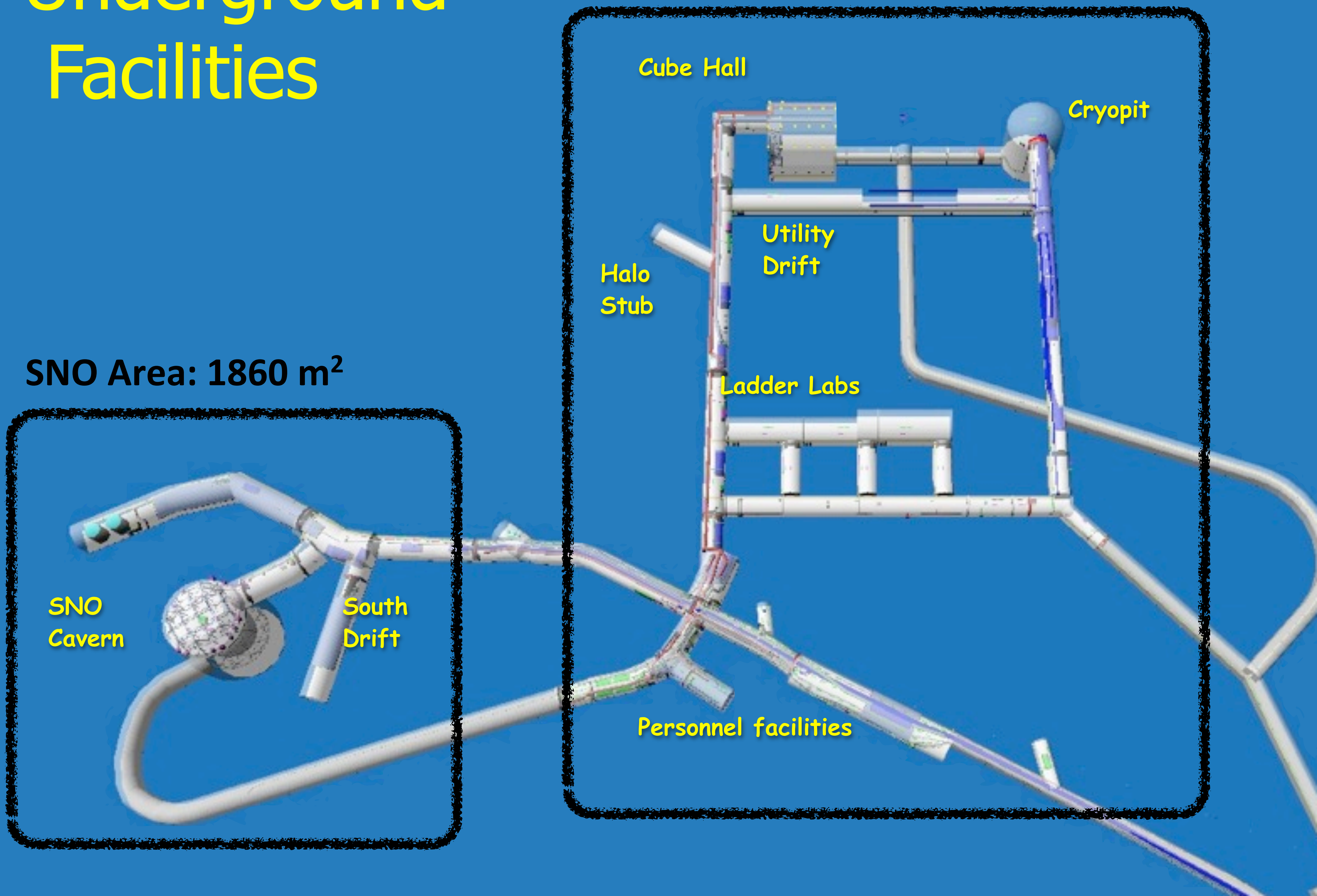


Lab location outside stress boundary

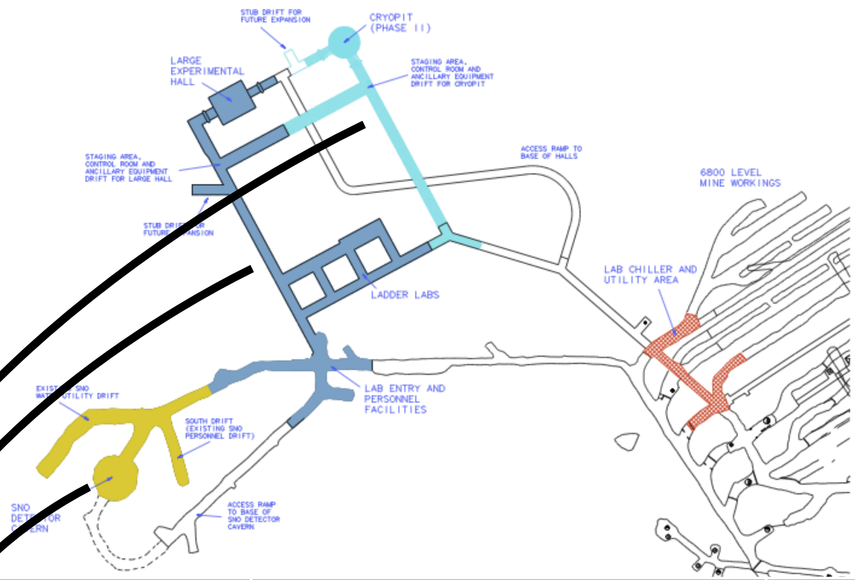
Underground Facilities

SNOLAB Area: 5360 m^2

SNO Area: 1860 m^2



SNOLAB Space Summary



Area	Dimensions	Area	Volume
SNO Cavern	24m (dia) x 30m(h)	250m^2	9,400 m^3
Ladder Labs	32m(l)x6m(w)x5.5m(h)	190m^2	960 m^3
	23m(l)x7.5m(w)x7.6m(h)	170m^2	1,100 m^3
Cube Hall	18.3m(l)x15m(w) x 19.7m(h)	280m^2	5,600 m^3
Cryopit	15m(dia) x 19.7m(h)	180m^2	3,900 m^3

	Excavation		Clean Room		Laboratory	
	Area (m2)	Volume (m3)	Area (m2)	Volume (m3)	Area (m2)	Volume (m3)
Original SNO Areas	1860	16500	1130	13300	750	11700
+Phase I	6070	38750	3900	29750	2430	23700
+Phase II	7220	46650	4940	37250	3060	29550

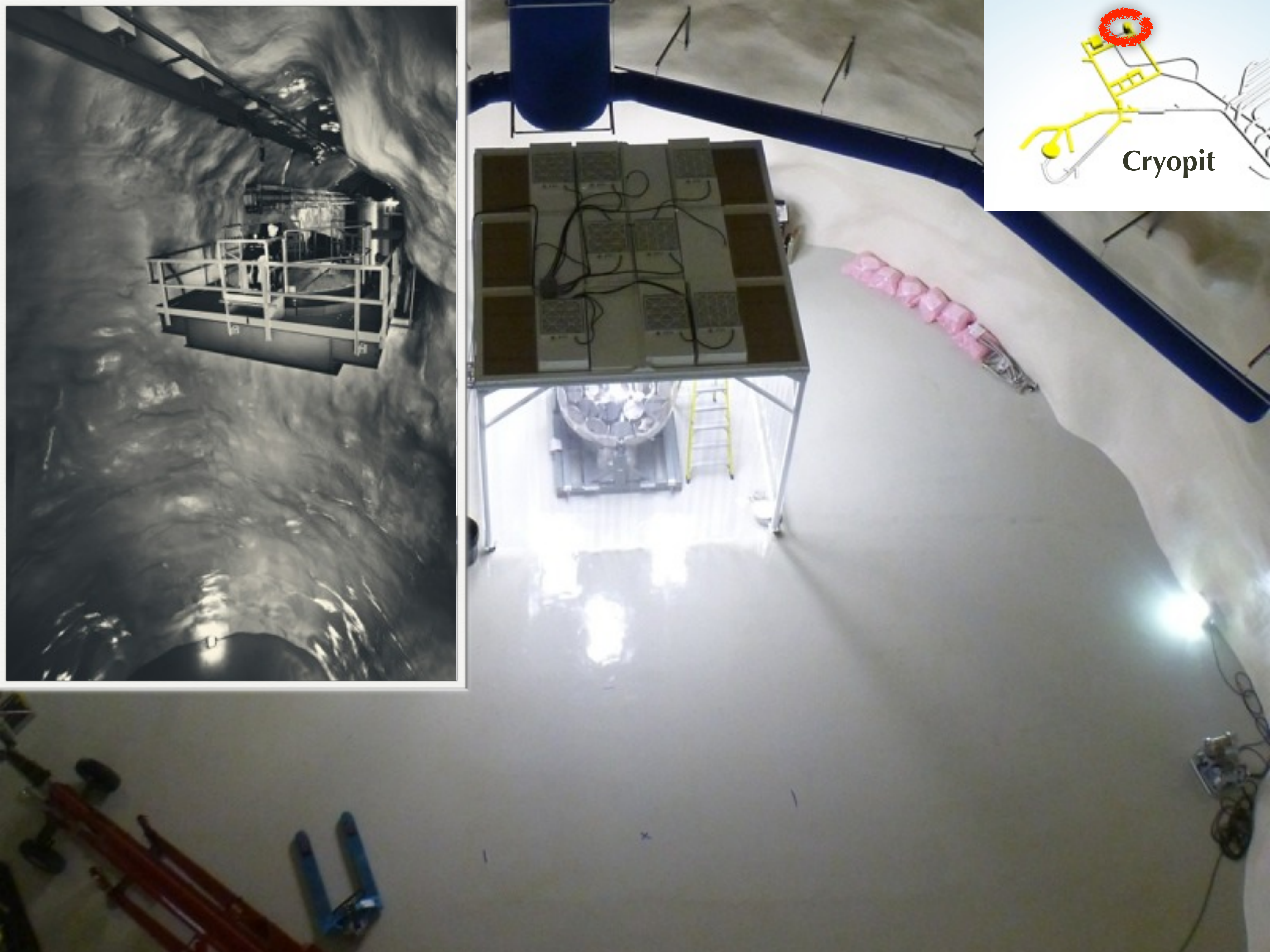

Chiller


6800
Lab Entry


Lab Entry


Lab
Entrance


Personnel
Facility


Cryopit

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

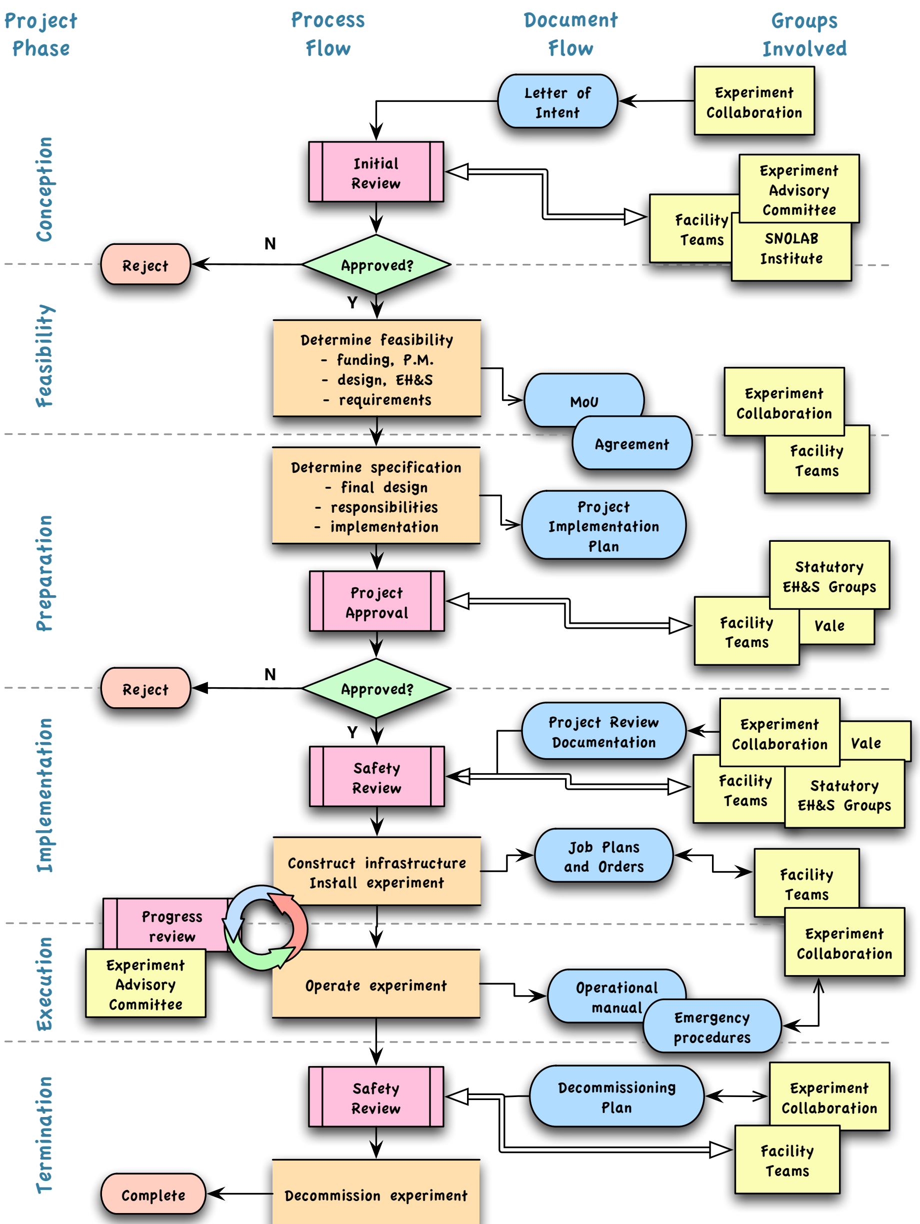
- Staff complement ~60
  - Cost ~$4M/yr
  - Note: additional support from University partners so NOT full project staff costs
  - 24hr/day operations not assumed
- Non-staff
  - Cost currently ~$3M/yr
  - Includes Vale charges ~$1M
- Project cash costs currently ~$7M/yr
- "In-kind"
  - If mining operations 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.

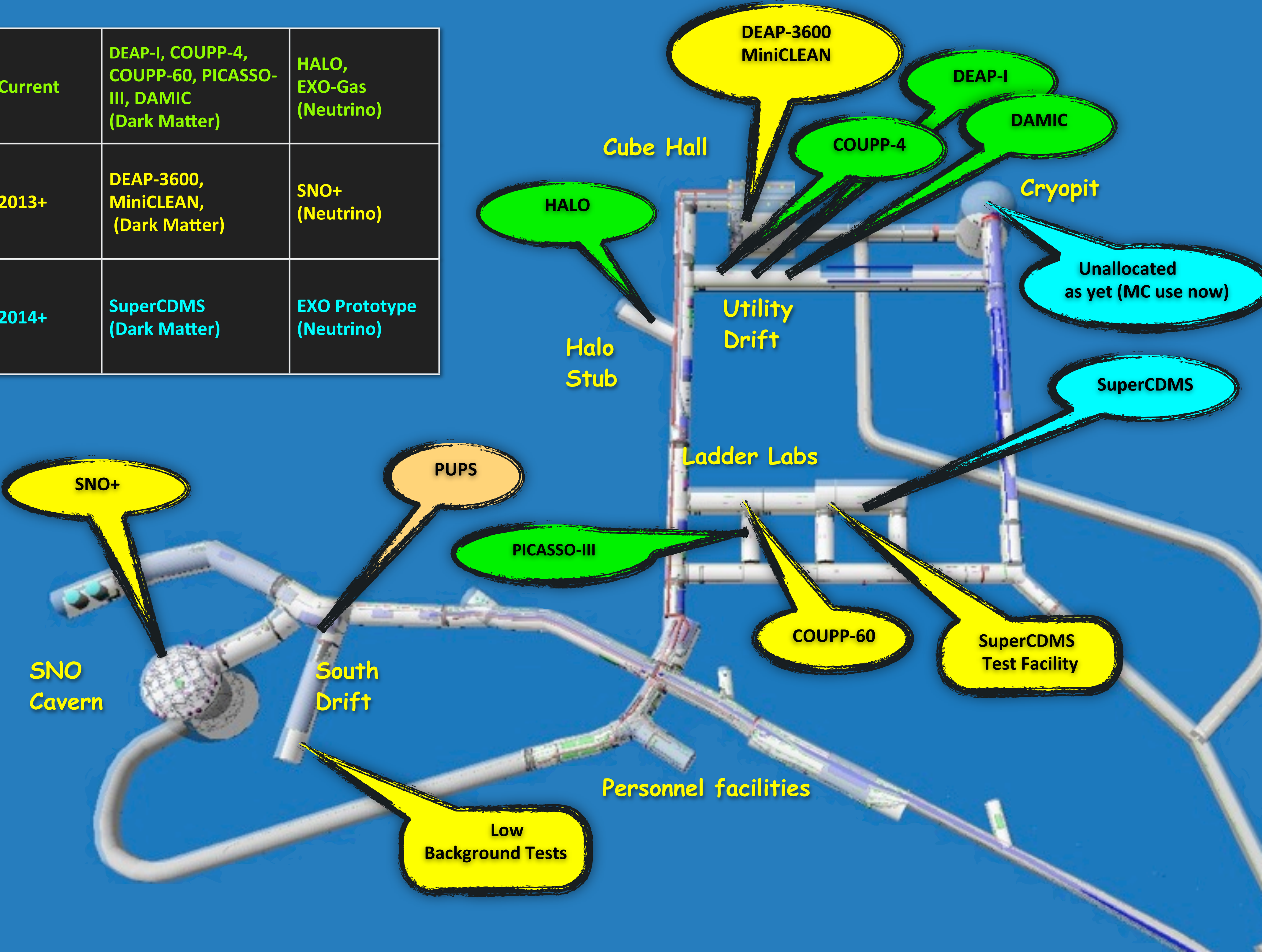
Current programme: 0νββ and neutrino at SNOLAB

- SNO+ : 130Te → 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 → 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

Experiment	Solar ν	0νββ	Dark Matter	Supernova ν	Geo ν	Other	Space allocated	Status
CEMI						Mining Data Centre	Surface Facility	Proposal
COBRA		√					Ladder Labs	Request
COUPP-4			√				J'-Drift	Operational
COUPP-60			√				Ladder Labs	Construction
DAMIC			√				J'-Drift	Operational
DEAP-1			√				J'-Drift	Operational
DEAP-3600			√				Cube Hall	Construction
EXO-gas		√					Ladder Labs	Request
HALO				√			Halo Stub	Operational
MiniCLEAN			√				Cube Hall	Construction
PICASSO-III			√				Ladders Labs	Operational
PUPS						Seismicity	Various	Completed
SNO+	√	√		√	√		SNO Cavern	Construction
SuperCDMS			√				Ladder Labs	Request
U-Toronto						Deep Subsurface Life	External Drifts	Completed

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




A dungeon horrible,
on all sides round...
No light; but rather
darkness visible...
Paradise Lost - Milton (1668)