Overview and capabilities of SNOLAB

Nigel Smith
Director, SNOLAB

Overview

- The current SNOLAB facility
  - Objectives
  - Current status
  - Facility design philosophy and considerations
  - Space availability for hosting additional experiments
  - Construction and operations costs
  - SNOLAB support capabilities
  - Operational models
- Future expansion possibilities
  - Technical
  - Political
- Current science programme

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/m^2/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 (Ontario)
- Managed as a partnership between four Universities (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 has overall governance responsibility

SNOLAB Overall Status

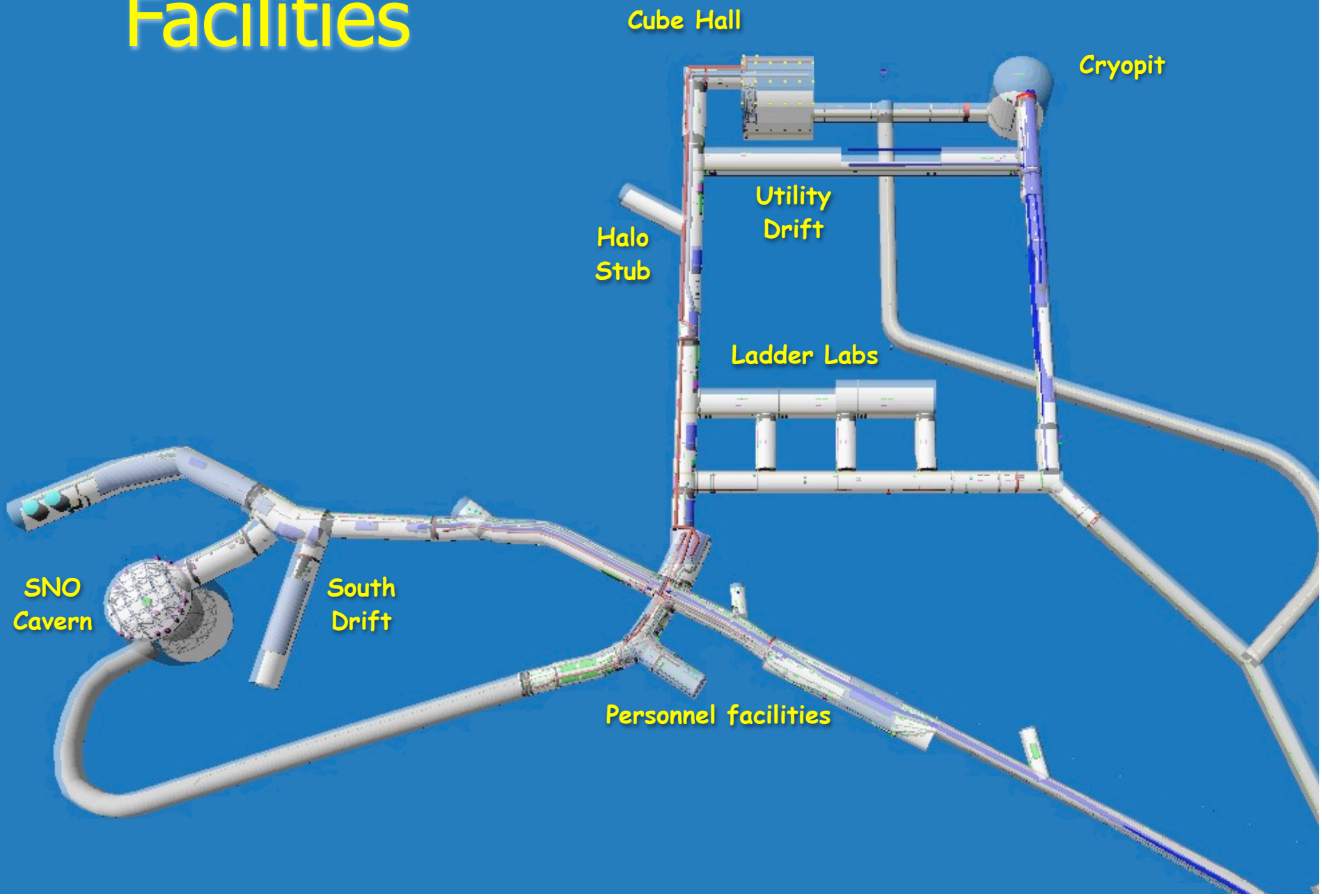
- Surface Facility (3100 m^2)
  - Operational from 2005 - Provides offices, conference room, dry, warehousing, IT servers, clean-room labs, detector construction labs, chemical + assay lab
  - 440m^2 class 1000 clean room for expt setup
- Underground Construction (Cube Hall, Cryopit, Ladder Labs)
  - Phase I excavation complete and outfitting began June 2007.
  - General outfitting in Phase I areas complete 2009, final clean 2010.
  - Phase-II excavation complete June 2008
  - Phase-II integration complete 2011, final clean underway.
  - SNO cavity, Cube Hall and Ladder Labs hosting and developing experiments.
- Experimental Programme
  - Relocation / continued operation of DEAP-1 & PICASSO-III (and EXO-gas R&D).
  - New experiment deployed: COUPP-4
  - Construction support for HALO, SNO+, DEAP-3600, MiniCLEAN
  - Current allocations to: PICASSO-III, DEAP-I, SNO+, DEAP-3600, MiniCLEAN, SuperCDMS TF, SuperCDMS, COUPP, HALO.
- Operational funding currently secured to 2013

Surface Facilities

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
- 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

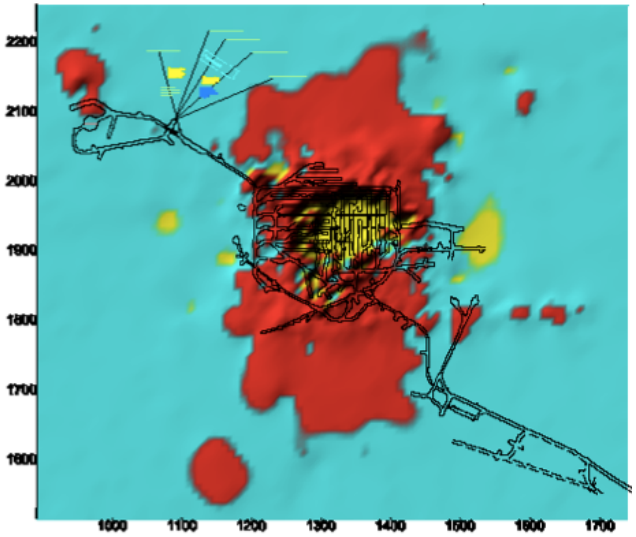
Underground Facilities



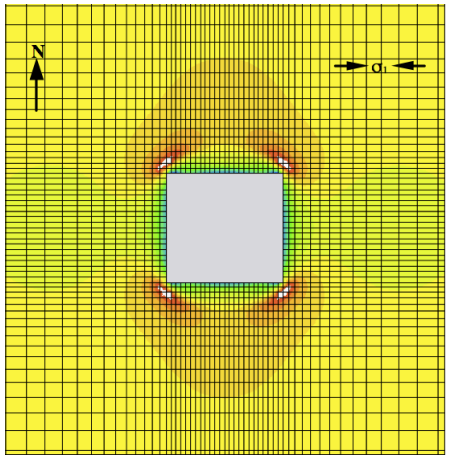
Facility design considerations

- 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

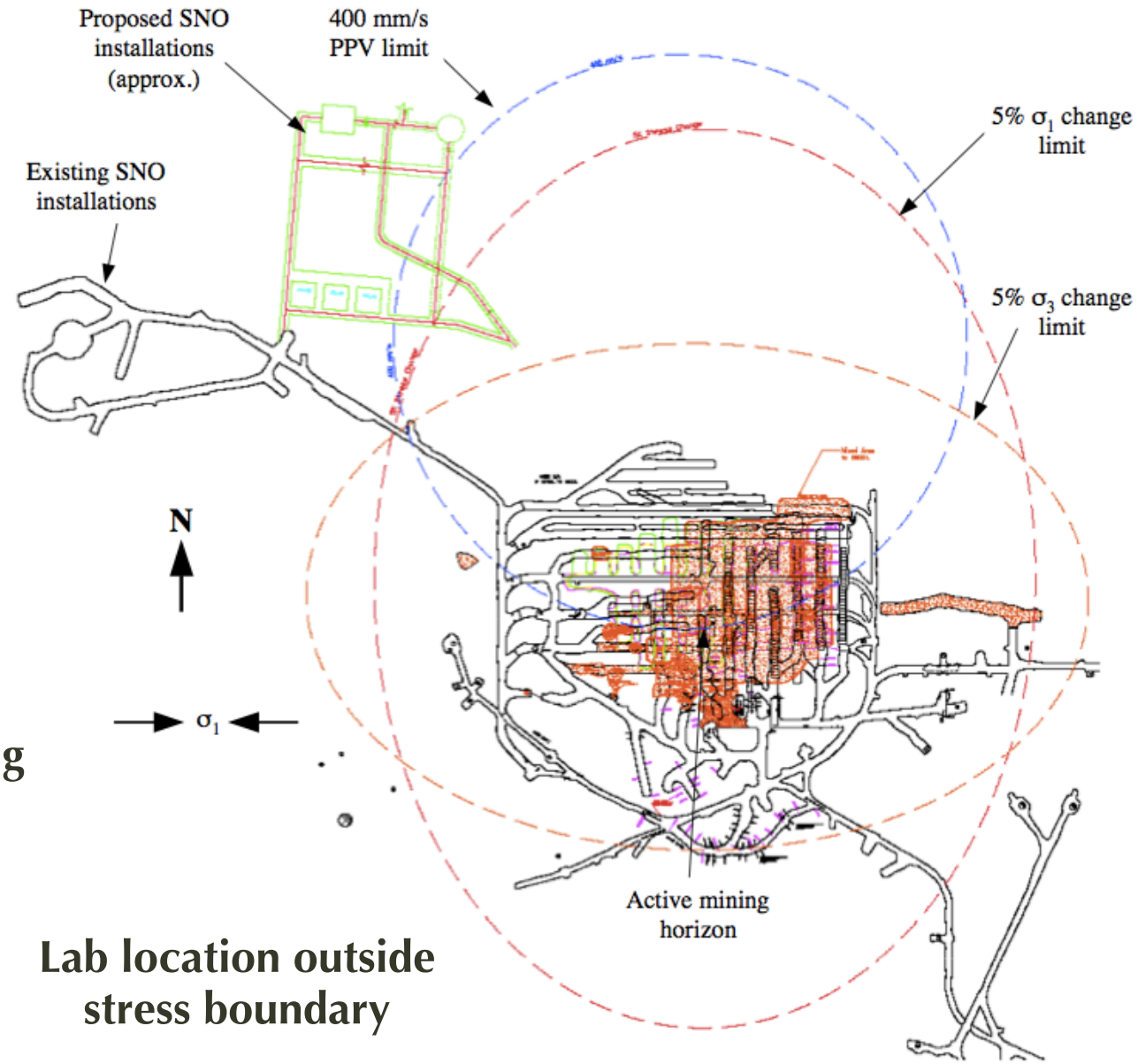
Seismic design criteria



5% stress contour



Stress modelling for all cavities



Lab location outside stress boundary

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)
  - 150kW (++?) Generator planned
- 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)

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/m^3)
  - No direct radon suppression in air intakes
  - Cover gas used (LN_2 boil-off) on detector systems
  - Ventilation (make-up vs recirculation) minimises radon emission from walls
- H_2S
  - 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


Chiller


Chiller


Lab Entry
6800

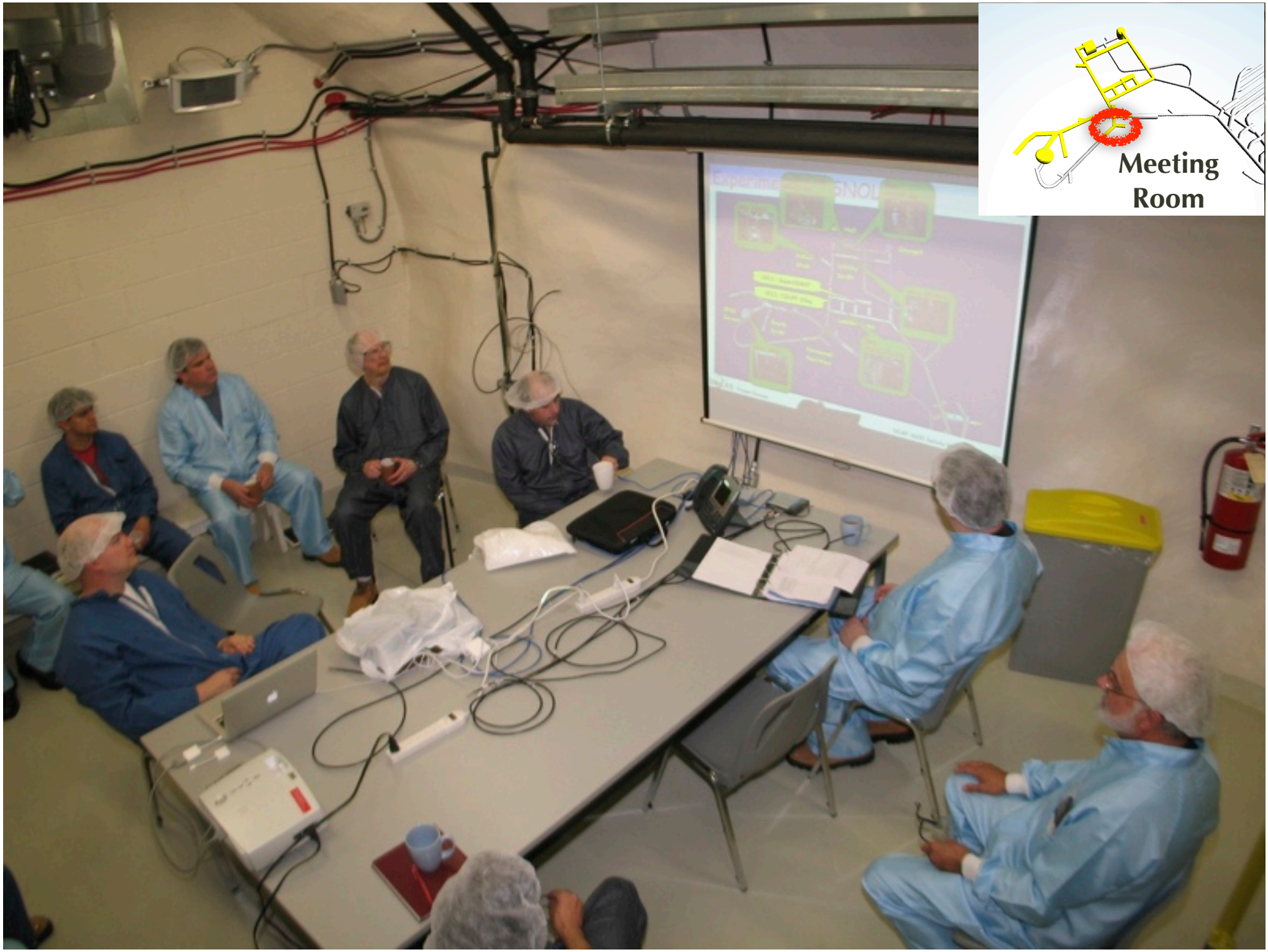

Lab Entry


Lab
Entrance


Personnel
Facility

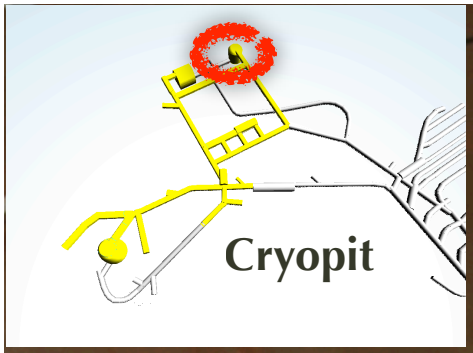

Lab
Entry


Galley/
Refuge


Meeting
Room


Cryopit
Access

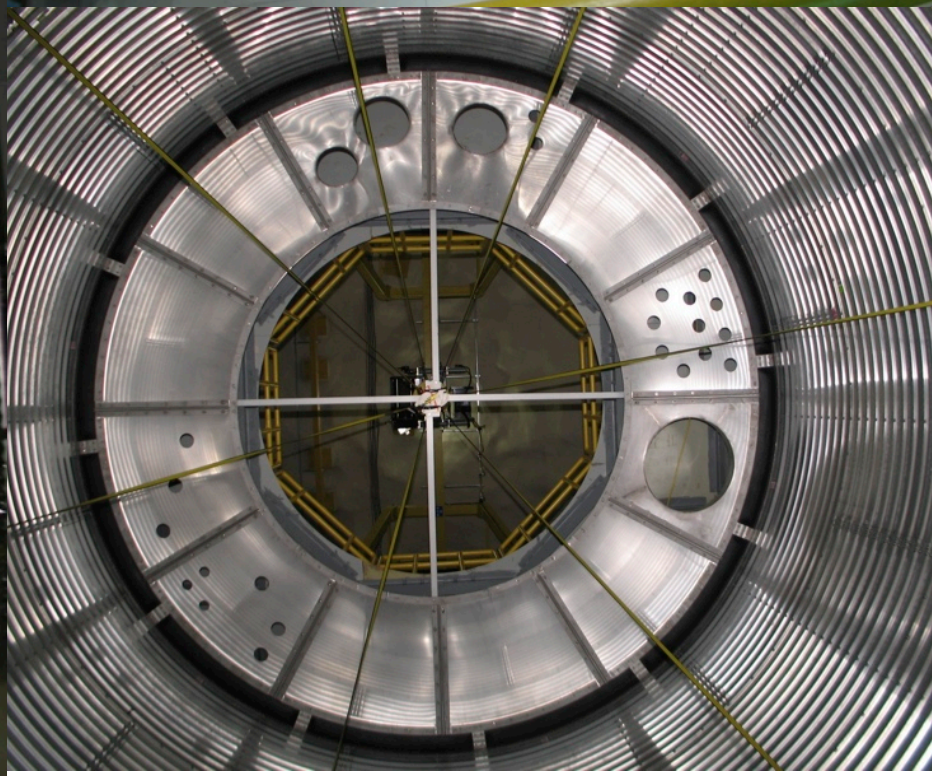

Cryopit


Cryopit


DENKA-LIFT


Cube
Hall


Cube
Hall




Cube
Hall

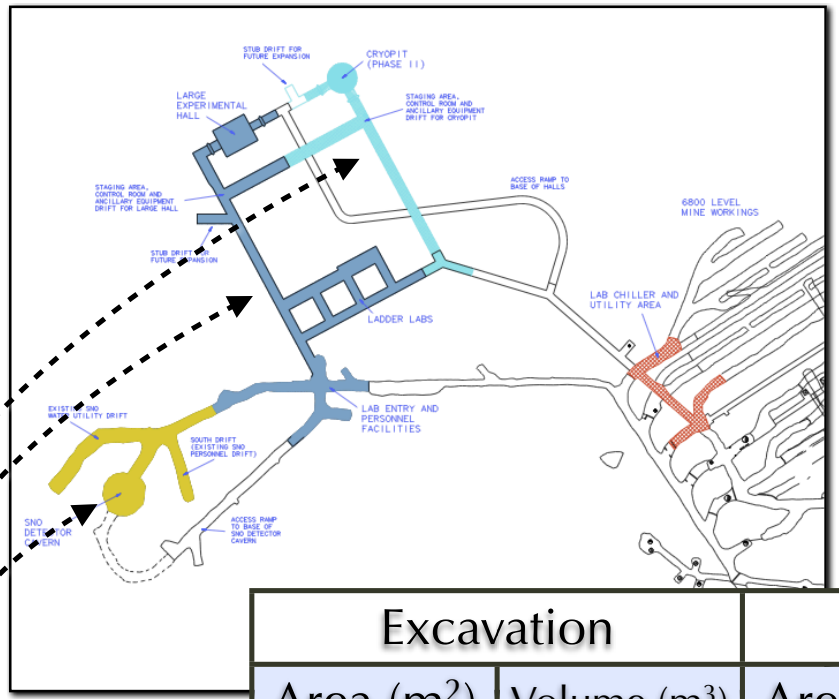

Ladder
Labs


Utility
Drift


Ladder
Labs


R&D 'J'
Drift

SNOLAB Space Summary

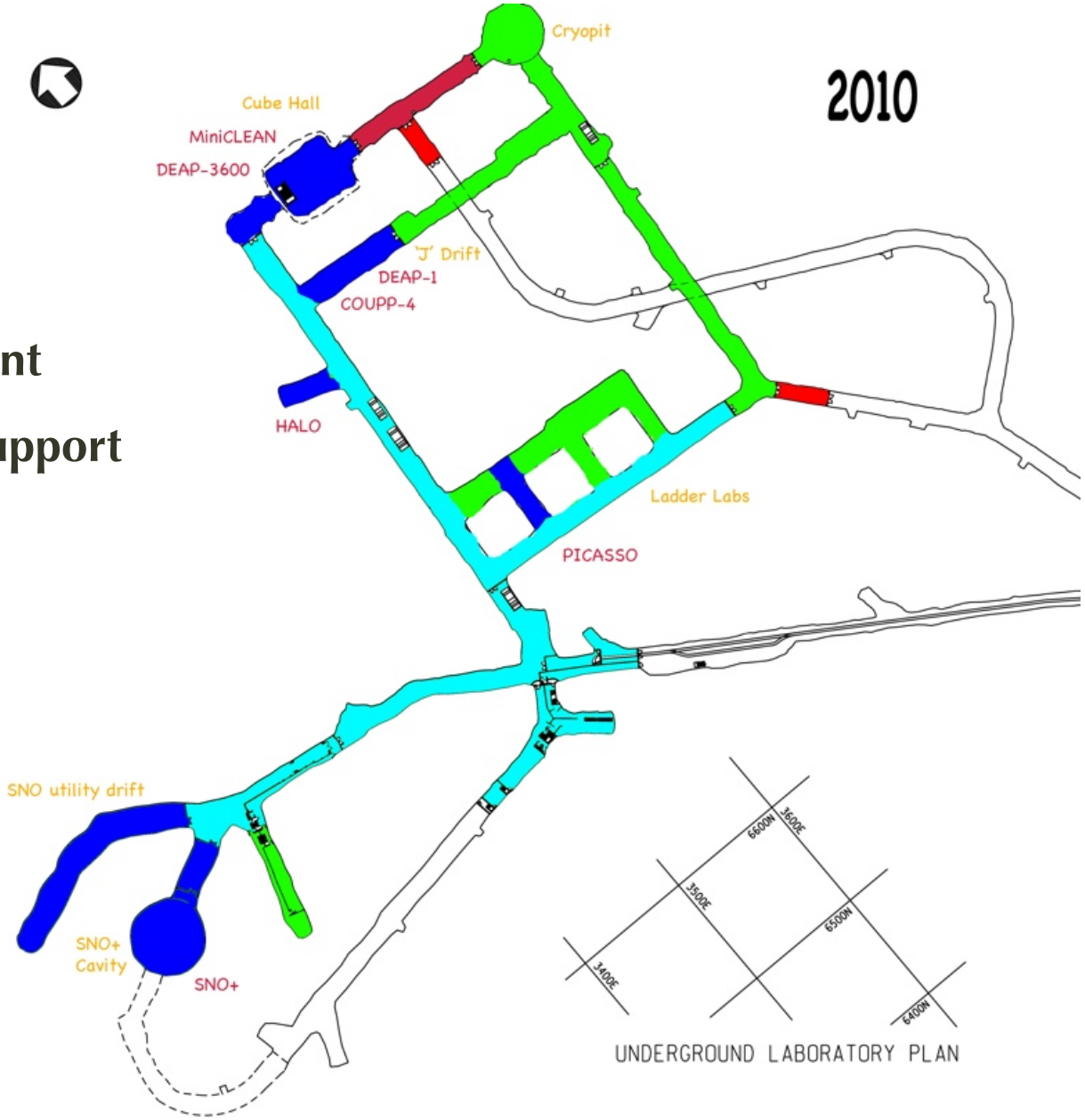


Area	Dimensions	Area	Volume
SNO Cavern	24m (dia) x 30m(h)	250m^2	9,400 m^3
Ladder Labs	32m(l)x6m(w)x5.5m(h)	190m^2	960 m^3
	23m(l)x7.5m(w)x7.6m(h)	170m^2	1,100 m^3
Cube Hall	18.3m(l)x15m(w) x 19.7m(h)	280m^2	5,600 m^3
Cryopit	15m(dia) x 19.7m(h)	180m^2	3,900 m^3

	Excavation		Clean Room		Laboratory	
	Area (m^2)	Volume (m^3)	Area (m^2)	Volume (m^3)	Area (m^2)	Volume (m^3)
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

SNOLAB Space Evolution

- Available
- Experiment
- Utility/Support
- Access



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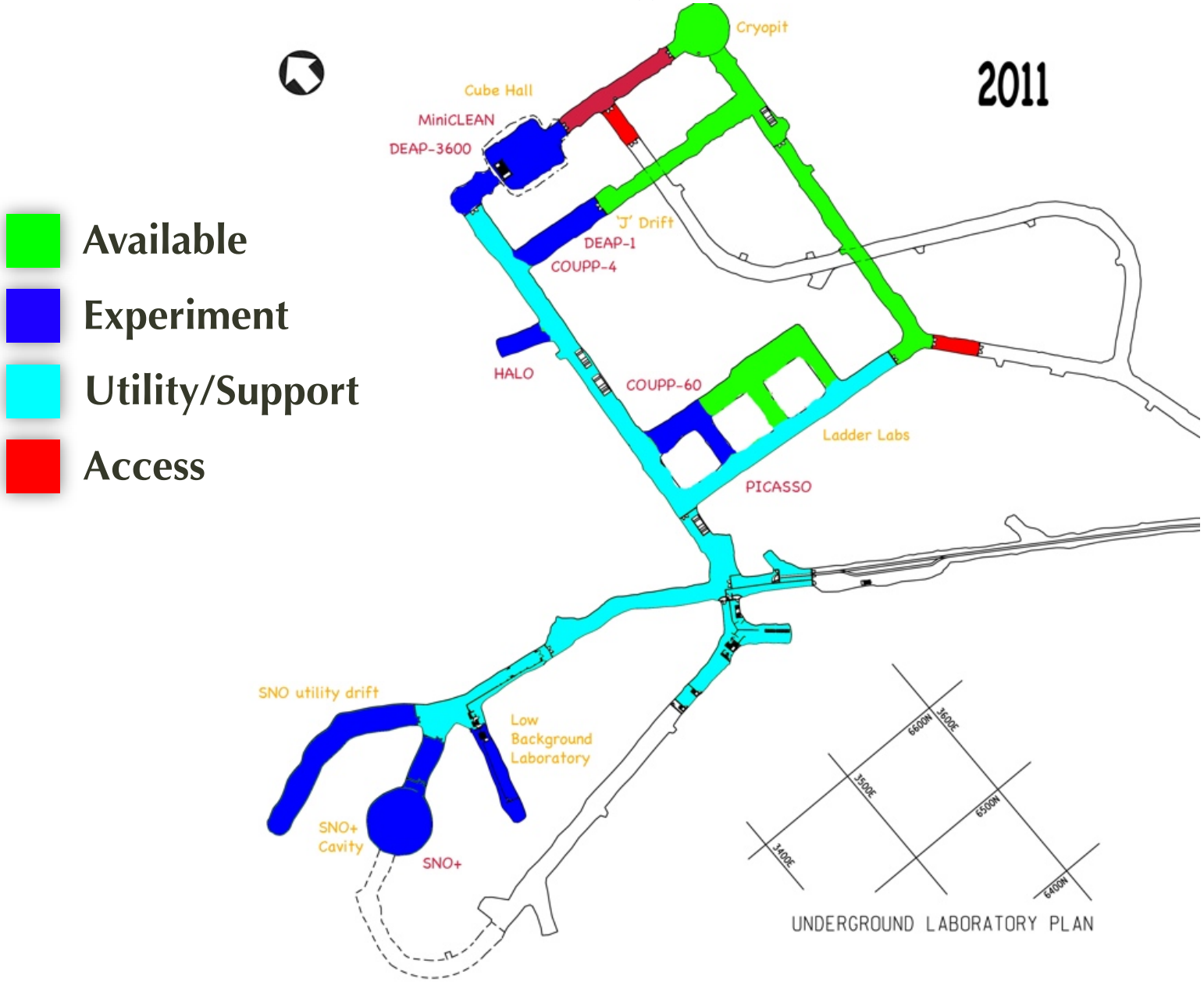

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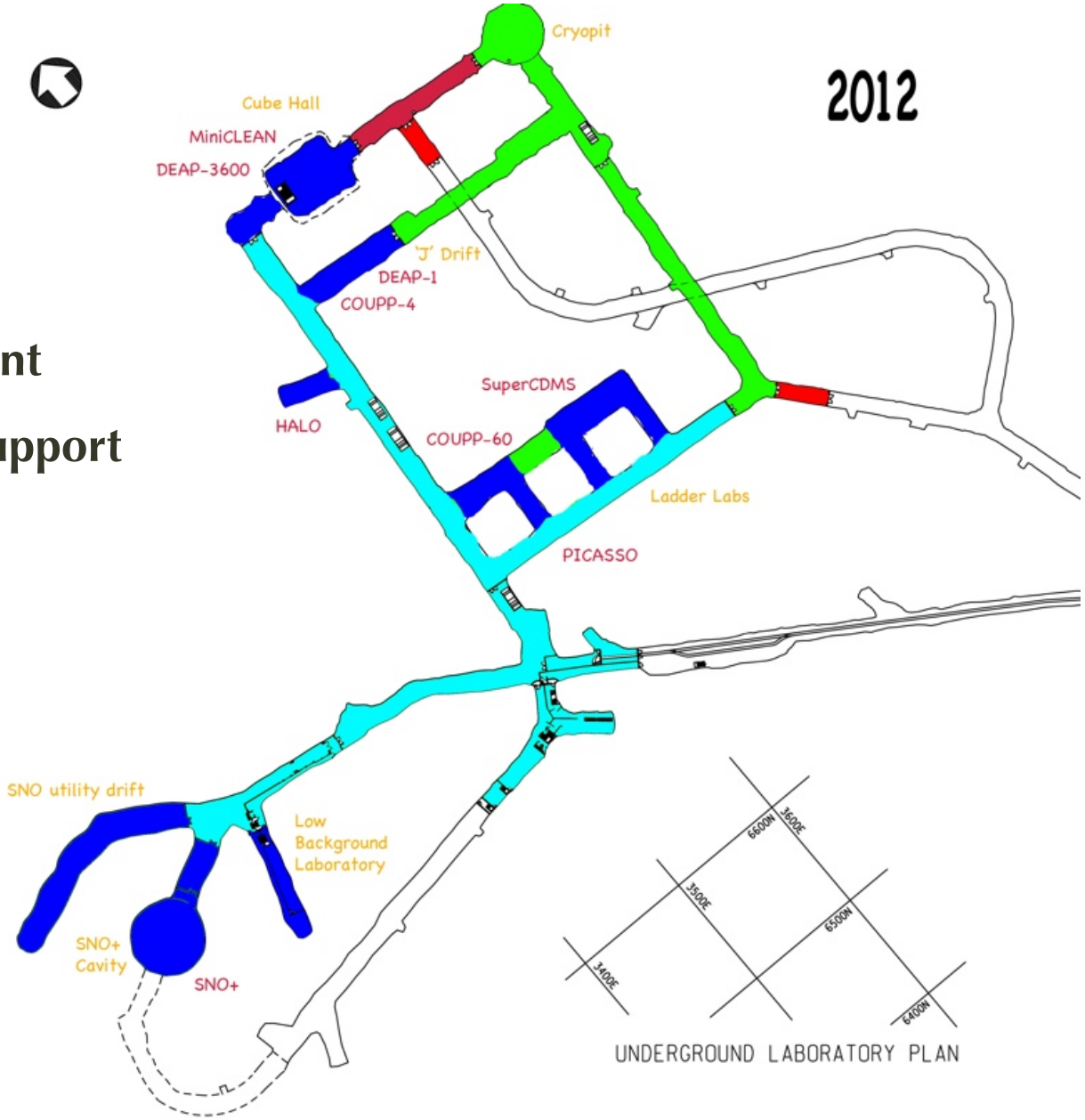

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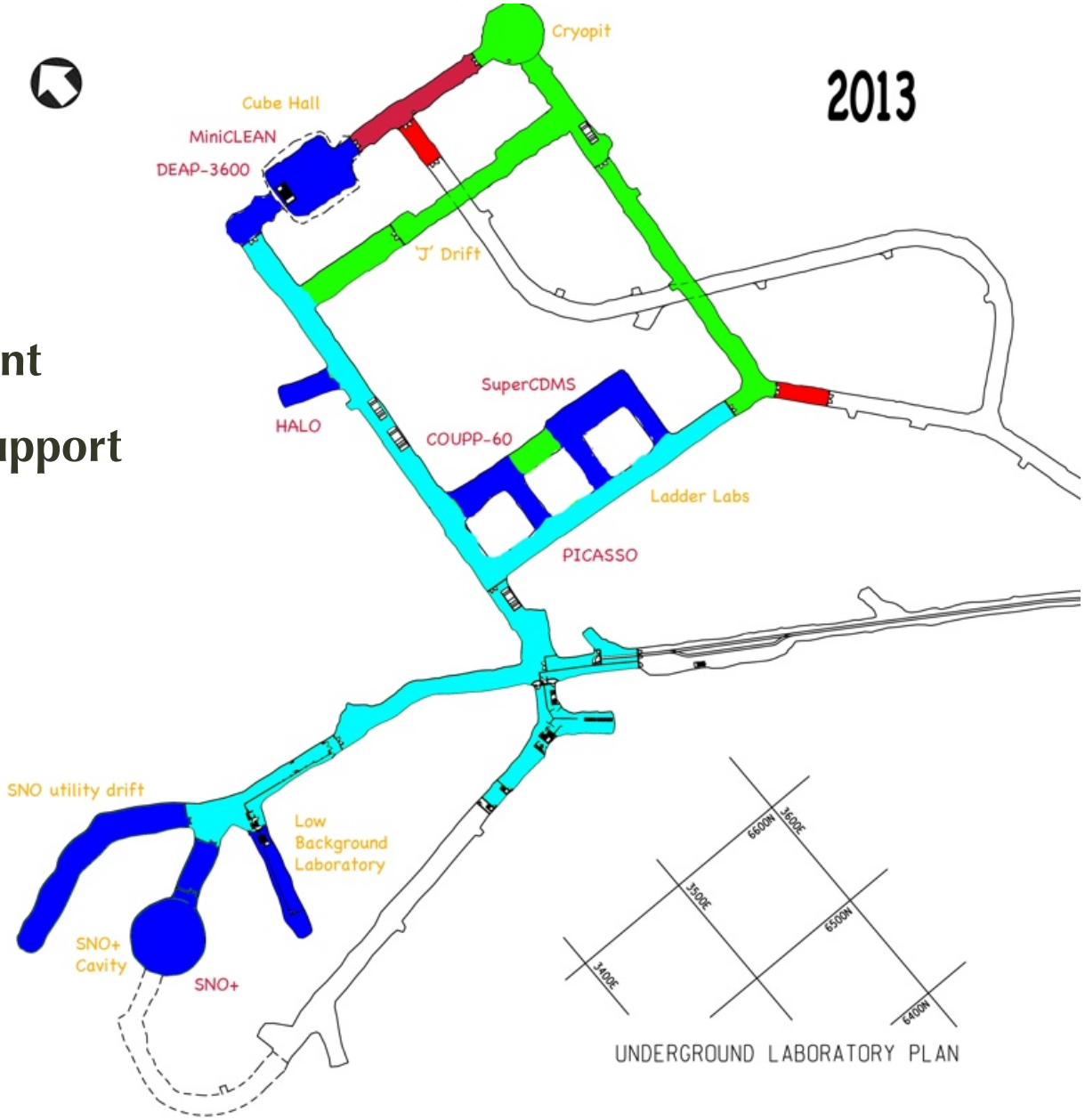

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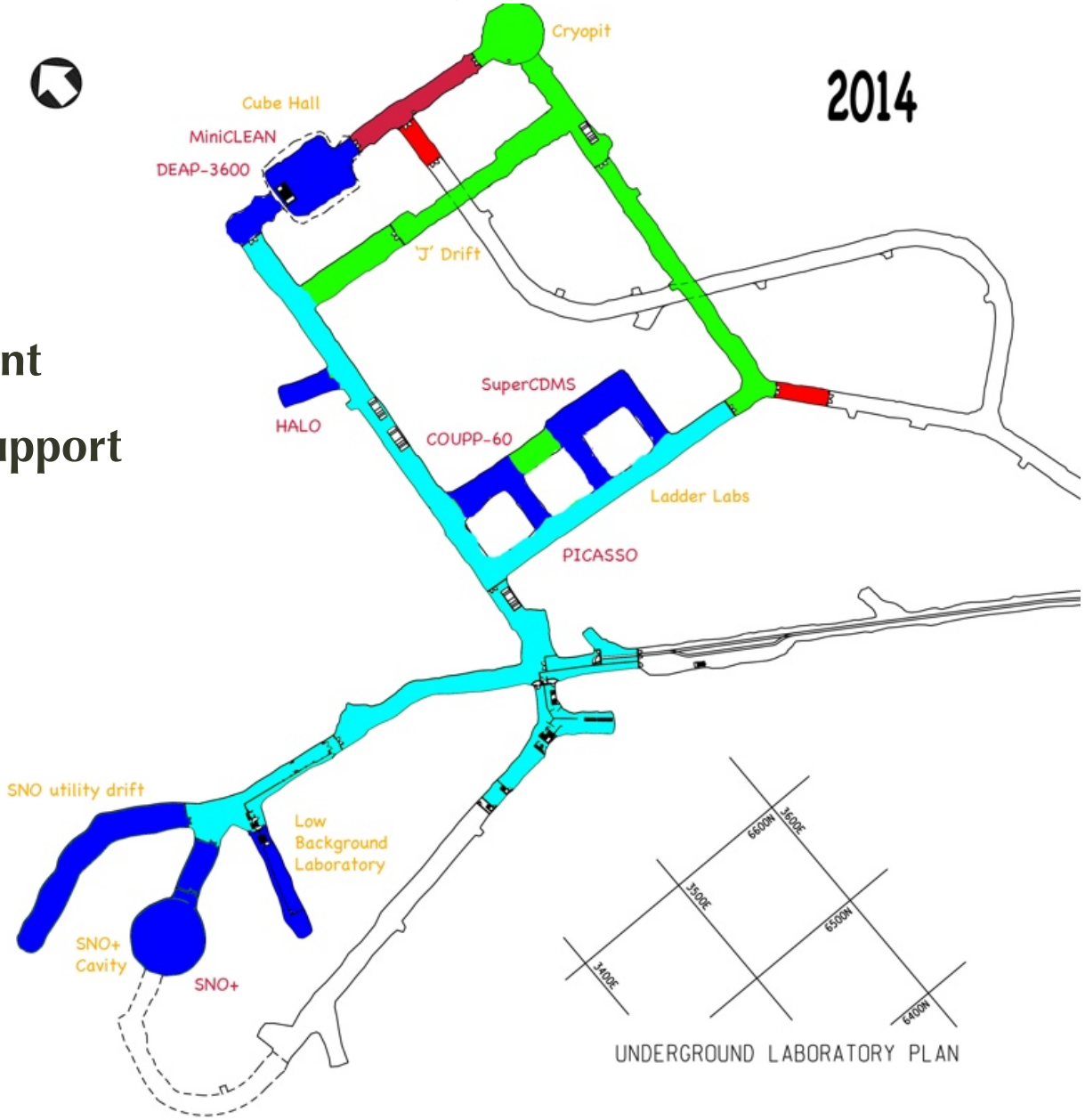

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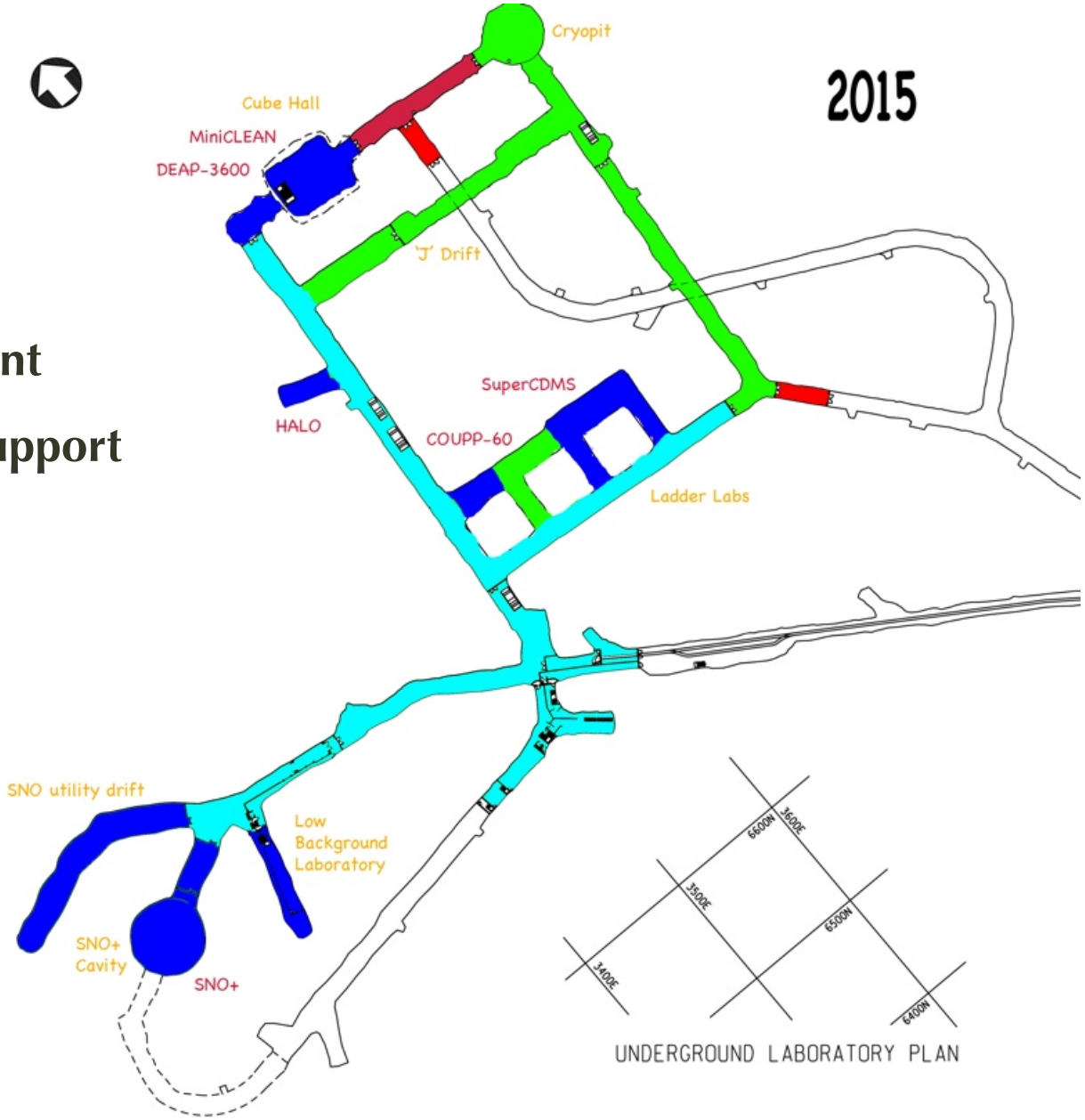

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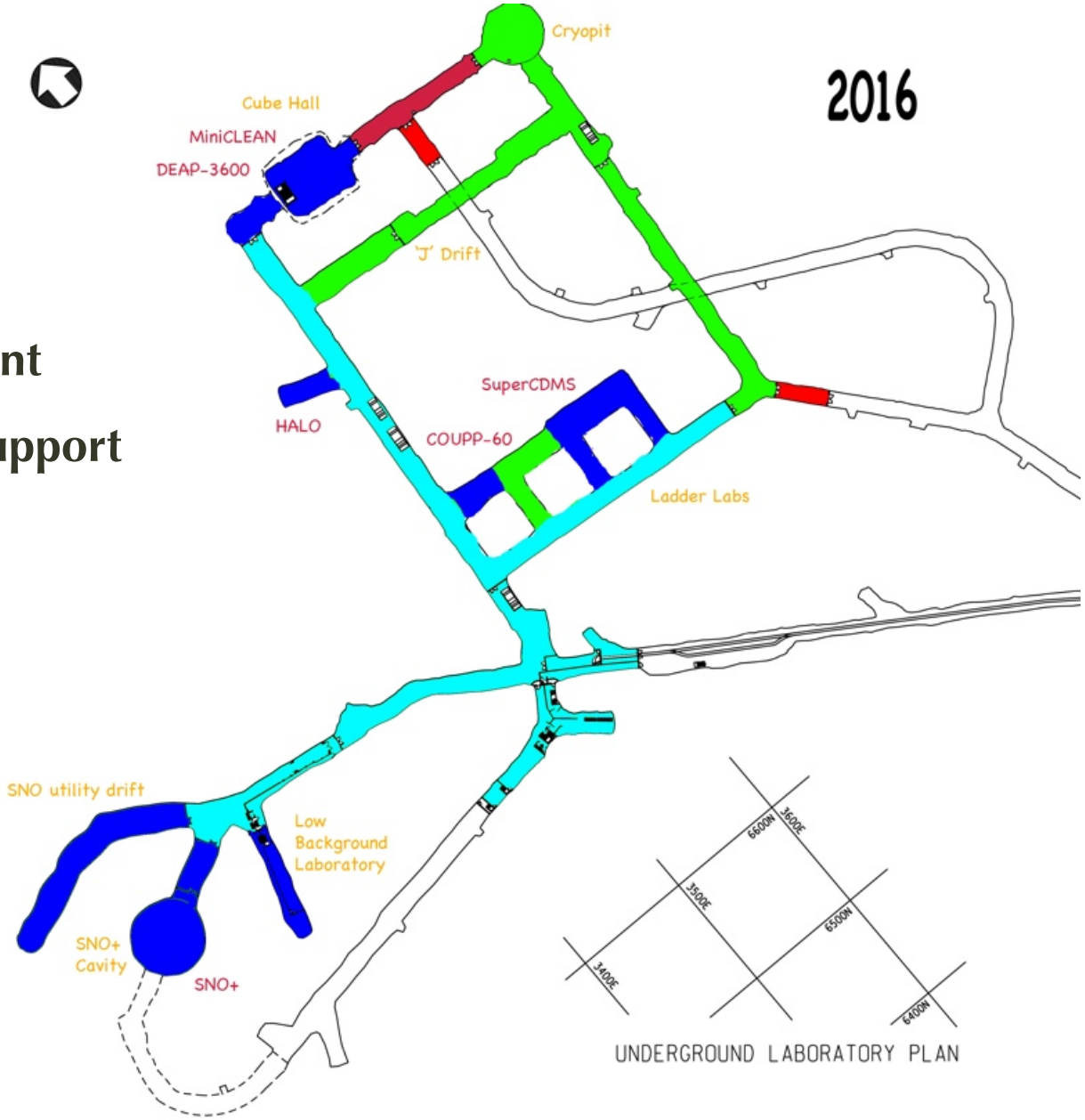

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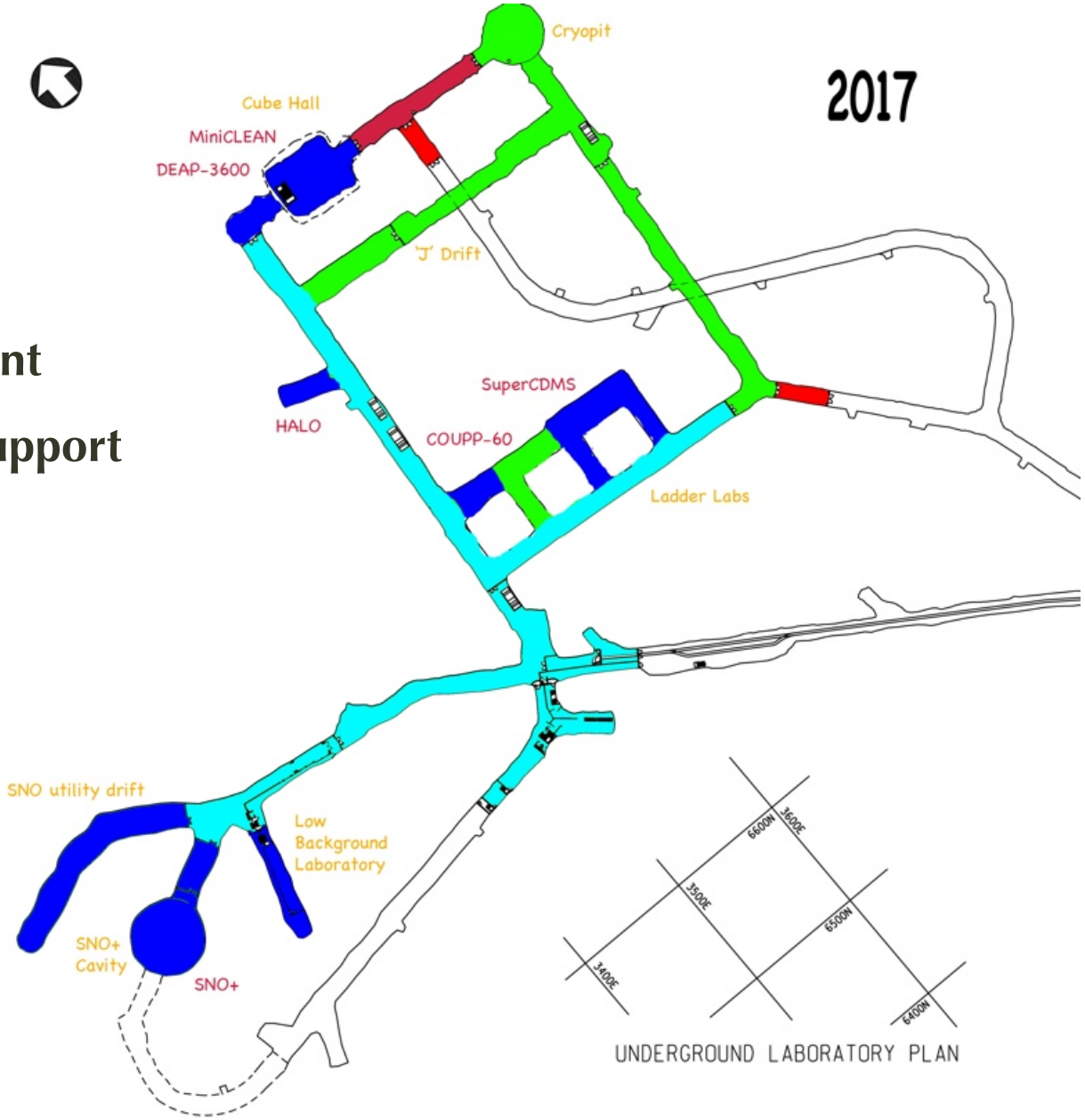

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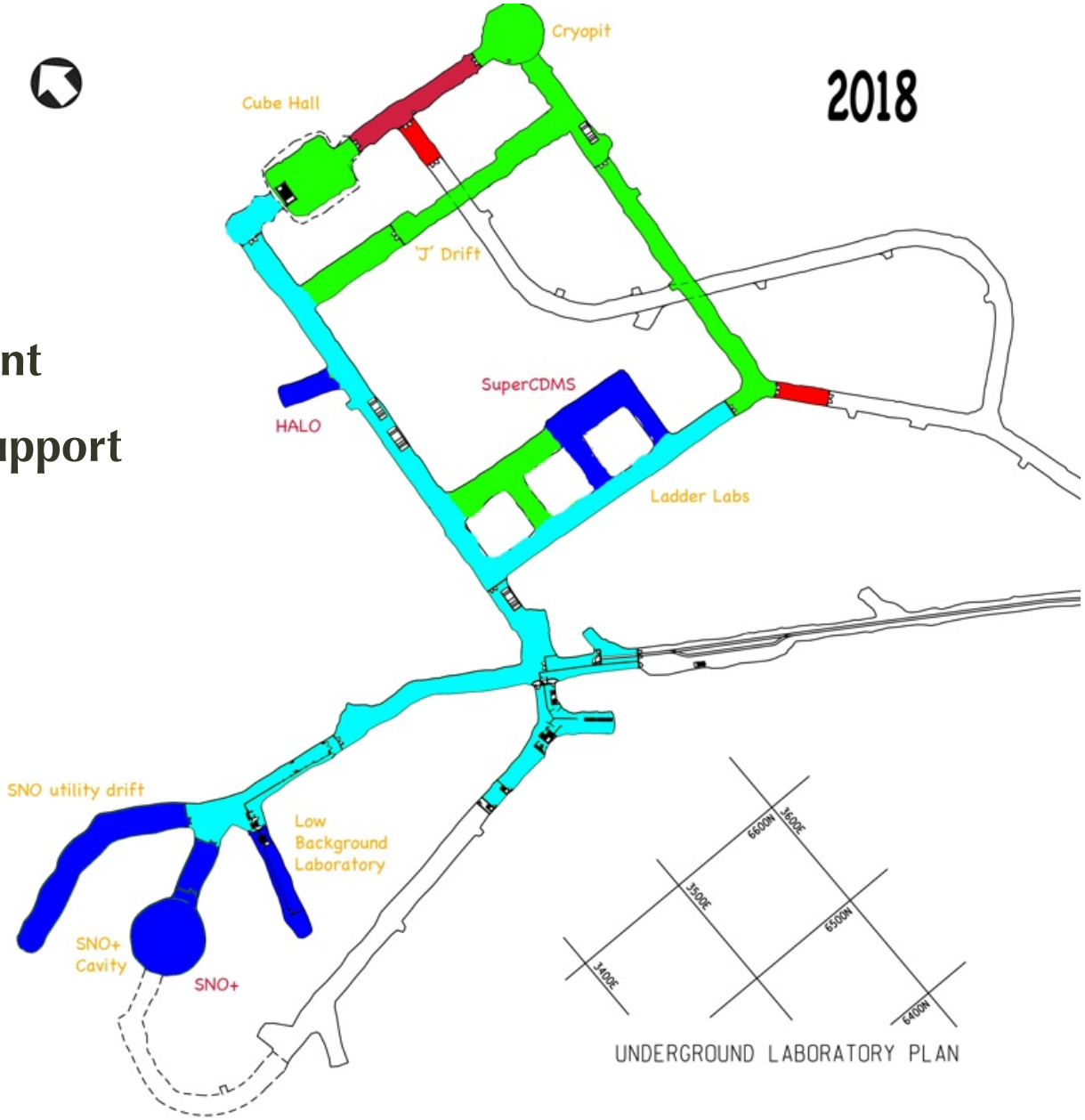

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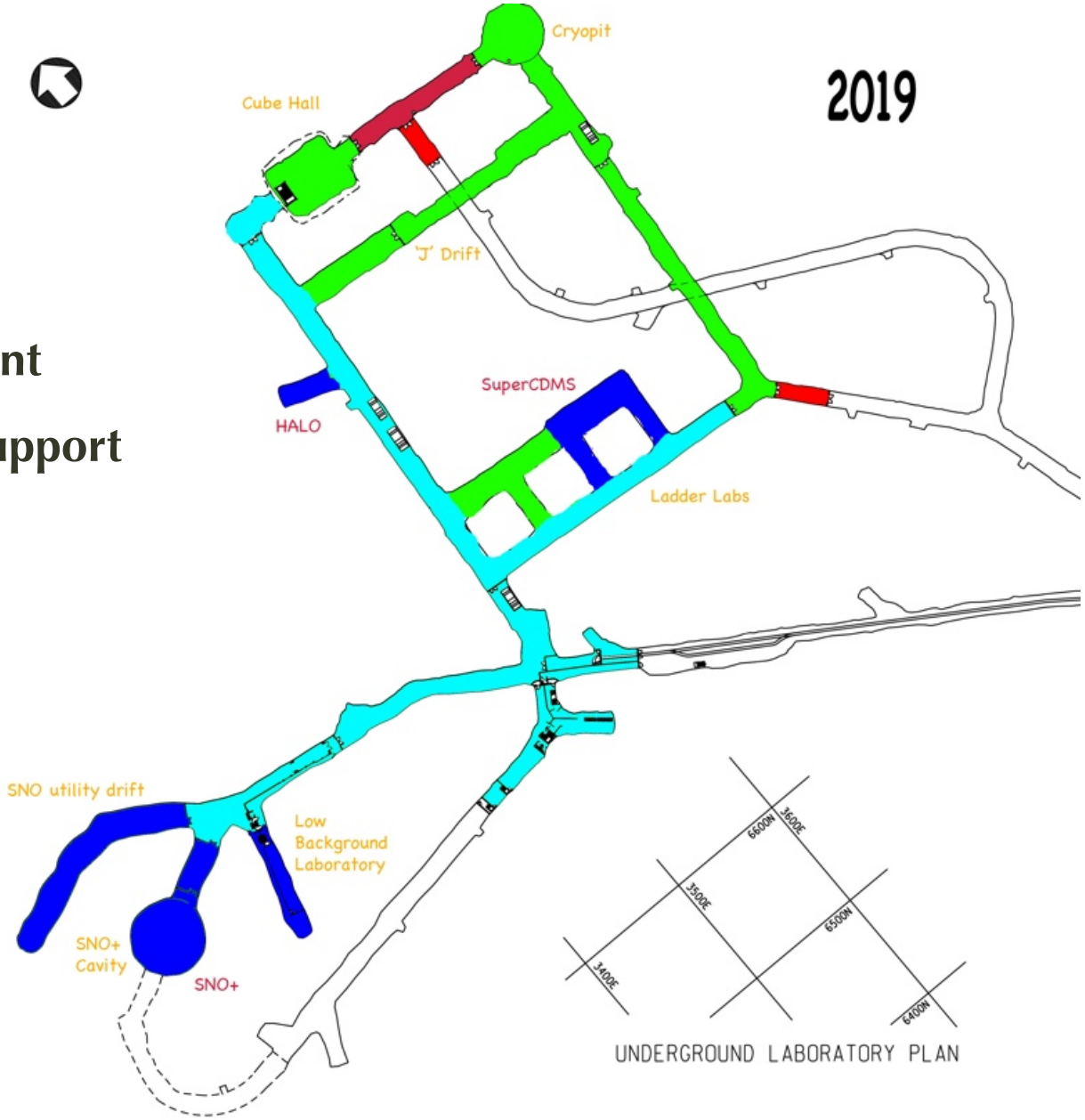

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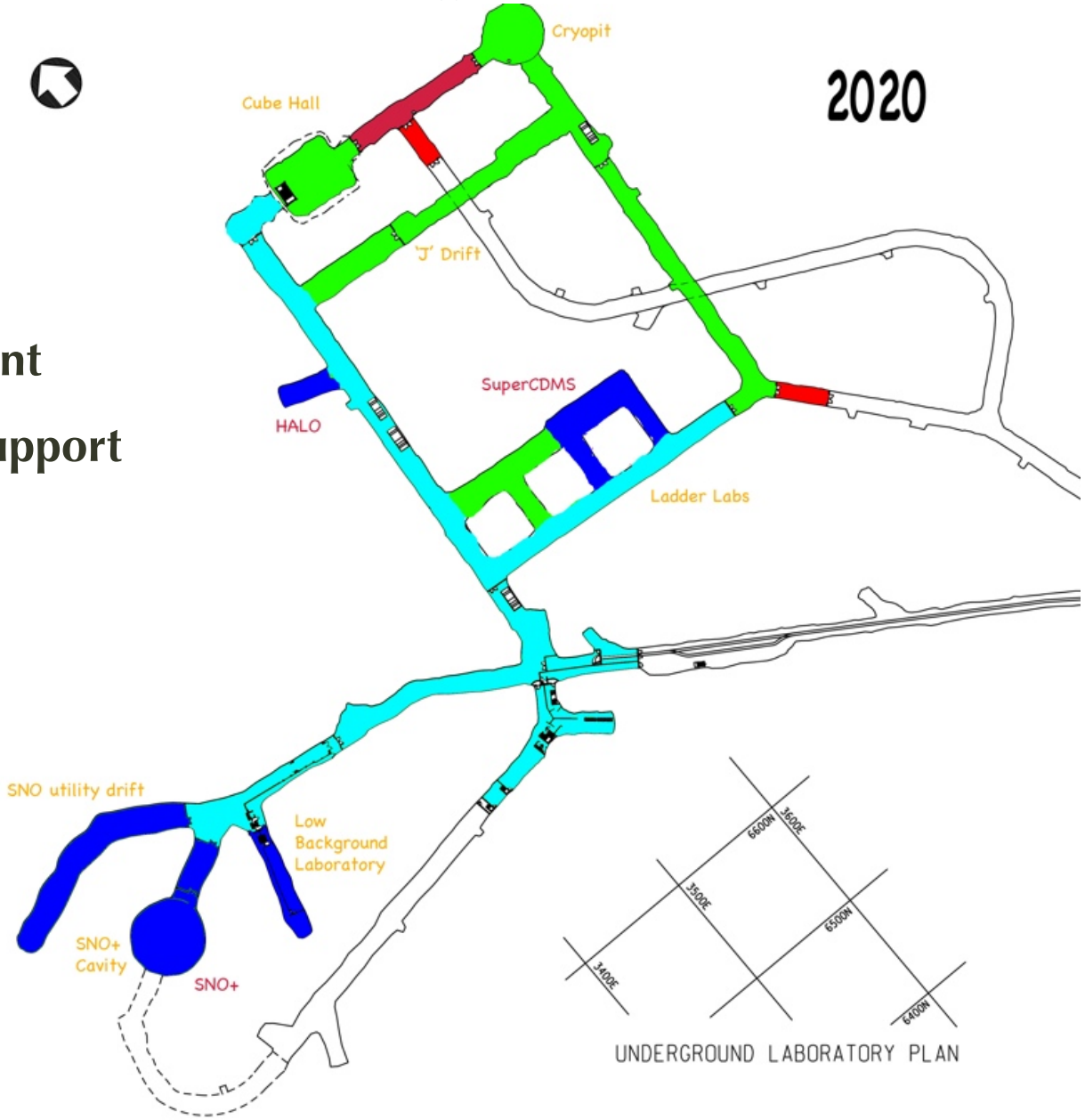

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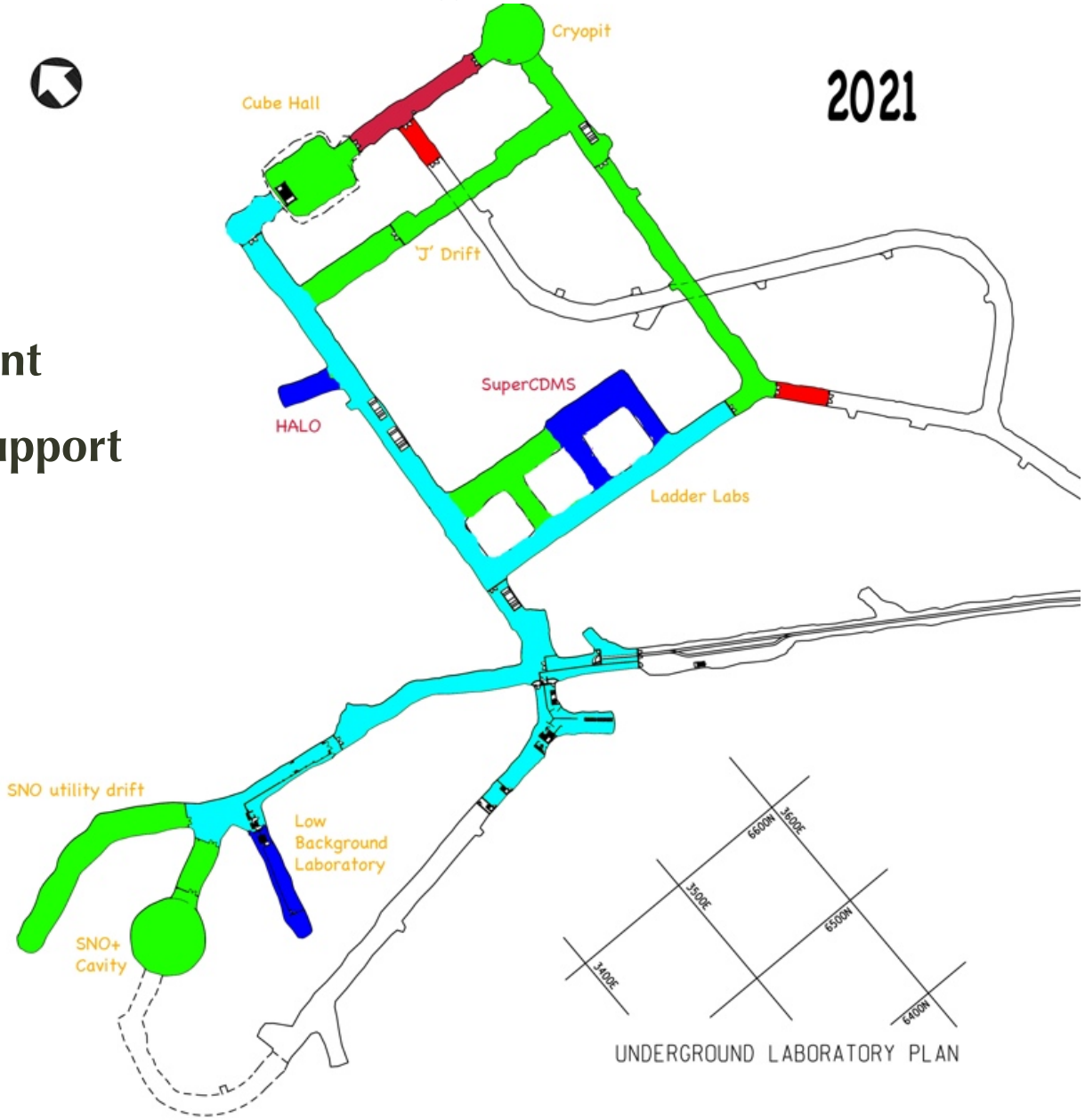


Support for Experiments

- 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 people underground regularly, 3 dedicated cages
  - Cages integrated into Vale operations effectively (eg SNO D_2O movement)

SNOLAB Construction Costs

- SNO costs (~$80M) included both detector and development of SNO facility
- Surface facility (~$10M)
- Two phases to new underground development
  - Phase I: Cube Hall, Ladder labs and service drifts (~$31M)
  - Phase II: Cryopit access drifts (~$15M)
- Total cost $63M (2004CA)

	Cost ($k)
▼ SNOLAB	62,924
▼ Underground Laboratory	31,516
Project Management	4,467
Exploration/Geotech	212
Excavation	12,127
Construction	12,503
Vale Services	2,207
▼ Cryopit Development	14,561
Engineering / PM	720
Excavation	9,541
Services extensions	4,301
► Underground Infrastructure	2,043
► Operations	3,511
► Research Equipment	1,679
▼ Surface Facilities	9,614
Project Management	889
Surface Building	8,480
Laurentian Facilities	244

SNOLAB Construction Costs

- Excluding the SNO area (i.e. new developments)
- Total cost for underground development ~$50M
  - breakdown given below for volume and surface area
- Alternative metric is ~85 ktonnes rock excavated
  - 40% hoisted; 60% used as road-bed by Vale

	$V(m^3)$	$A(m^2)$	$\$k/m^3$	$\$k/m^2$
Experimental	17,900	2,300	2.8	21.7
Clean Room	24,300	3,900	2.1	12.9
Excavation	30,100	5,300	1.7	9.3

SNOLAB Operations costs

- Staff complement ~55
  - Cost ~$4M/yr
  - Note: additional support from University partners so NOT full project staff costs
  - Final staff complement expected ~60
    - 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

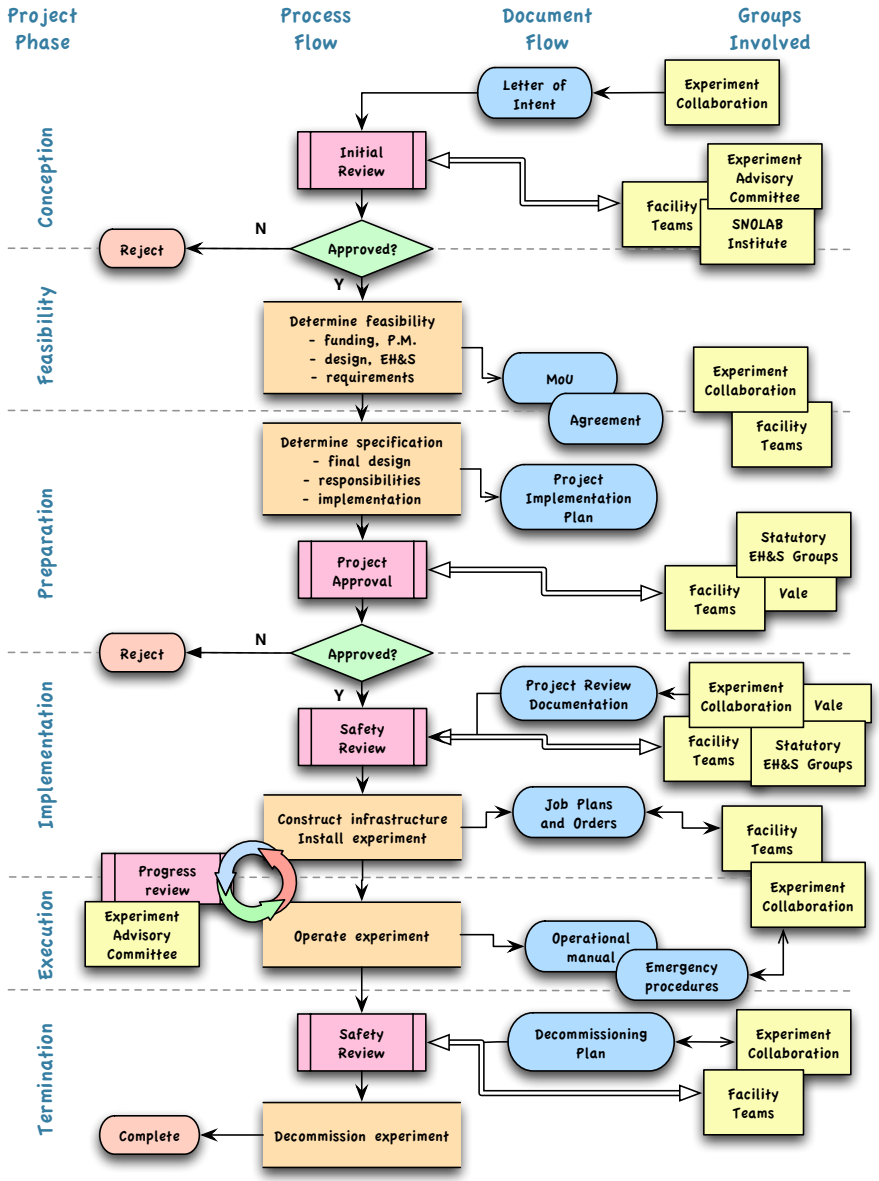
Group	FTE
Directorate	2.0
Directorate Office	7.0
Design Engineering	3.0
Information Technology	2.0
Facility Operations	17.1
Installation	6.3
Process Operations	5.5
Project Engineering	1.0
Scientific Research	6.5
Scientific Support	3.0
TOTAL	**53.4**

SNOLAB operational model

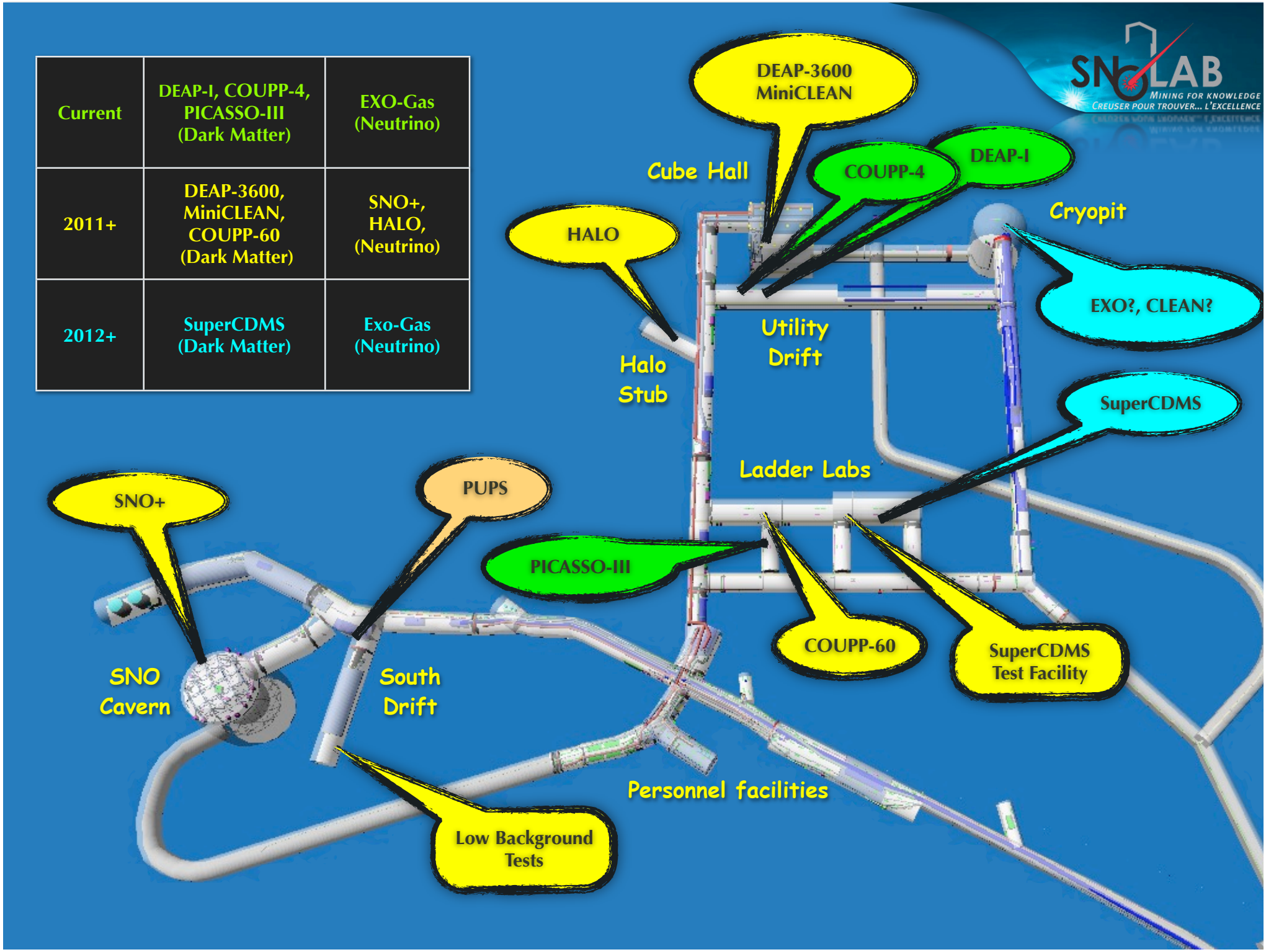
- For current facilities
  - Traditional NP "free-at-the-point-of-access" model
  - Canadian support for baseline operations of the facility, including life safety, power, ventilation, materials handling, compressed air, UPW, IT and networking
  - Experiments charged for additional 'non-standard' costs: 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

SNOLAB Project Lifecycle

- Project lifecycle and interaction with facility well-defined
  - Structures and agreements under development
  - Q.A. under development
- International Experiment Advisory Committee (Stew Smith chair) used to help define programme
- H&S reviews integral to development and deployment
  - SNOLAB
  - Vale (if req'd)



Current	DEAP-I, COUPP-4, PICASSO-III (Dark Matter)	EXO-Gas (Neutrino)
2011+	DEAP-3600, MiniCLEAN, COUPP-60 (Dark Matter)	SNO+, HALO, (Neutrino)
2012+	SuperCDMS (Dark Matter)	Exo-Gas (Neutrino)



Additional development

- Is there scope for additional development at SNOLAB, either 6800′ or elsewhere?
  - Yes, but the current strategic plan assumed no immediate development for the next 5 years at least
  - This does **not** preclude such
  - Vale have already indicated willingness to discuss
- Non-technical issues
  - Funding sources and agreements
  - Operational model agreements
  - Agreement with Vale on development scope

Technical Requirements

- Where?
  - 6800′ exploits current infrastructure, but requires management of development not to impact current facility and projects
  - Other level? Access to lower levels possible, support infrastructure in place from Vale
  - Further geotechnical studies needed to define capability. Larger cavities had not been investigated and modelled in current facility, but rock mass is well understood and stable hanging wall
- Connection to current clean room
  - Requires separation and will impact current ops
  - SNOLAB was developed with SNO operational
  - Lost time ~5 days, most planned power transitions
- Ventilation and power upgrades?
  - Separation of facilities incur additional costs

Additional development

- Timeline?
  - Driven by experiment need - when are these cavities needed?
  - Components required: negotiation, geo-tech, design, excavation, outfitting
  - Historical: Overall SNOLAB development was six years from start to completion, but experiment deployment during this time occurred.
    - 4 years excavation, 2 years outfitting concurrent, 2 years to clean room concurrent
- Cost?
  - Historical validated costs for SNOLAB experimental volume (i.e. to clean room status): ~$3k/$m^3$
  - Scaling may not be linear if constraints imposed by access through shaft or total underground workforce, or through economy of volumetric scaling

Experimental Programme

Experiment	Solar nu	0nuBB	Dark Matter	SuperNovae	Geo nu	Other	Space allocated	Status
SNO+	√	√		√	√		SNO Cavern	Underway
PICASSO-III			√				Ladders Labs	Underway
DEAP-1			√				J'-Drift	Underway
DEAP-3600			√				Cube Hall	Underway
MiniCLEAN			√				Cube Hall	Underway
HALO				√			Halo Stub	Underway
PUPS						Seismicity	Various	Completed
SuperCDMS			√				Ladder Labs	Request
EXO-gas		√					Ladder Labs	Request
COUPP			√				Ladder Labs	Underway
DarkSide			√				Ladder Labs	Request
COBRA		√					Ladder Labs	Request

Current programme: Dark Matter at SNOLAB

- Noble Liquids: DEAP-I, MiniCLEAN, & DEAP-3600, DarkSide
  - Single Phase Liquid Argon uses pulse shape discrimination. Two-phase (DarkSide)
  - Prototype DEAP-I operational in SNOLAB now, relocated to 'J' Drift. Successful demonstration of PSD and test bench for DEAP/CLEAN design/operations and background assessment.
  - Construction for DEAP-3600 and MiniCLEAN underway. Full DEAP-3600 capital funding granted (with SNO+)
  - 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
  - PICASSO currently operational in SNOLAB, relocated to Ladder Labs, demonstration of alpha rejection and test bench for scale-up of detector volumes.
  - COUPP-4kg deployment completed, 60kg summer this year.
  - Will measure Spin Dependent cross-section primarily, COUPP has SI sensitivity
- Solid State: SuperCDMS
  - State of the art Ge crystals with ionisation and phonon readout.
  - Currently operational in Soudan. Next phase will benefit from SNOLAB depth to reach desired sensitivity. Test facility in Ladder Labs under development.
  - Mostly sensitive to Spin Independent cross-section.

Current programme: 0νββ at SNOLAB

- SNO+ : $^{150}Nd \rightarrow {}^{150}Sm + e^- + e^-$
  - Uses existing SNO detector. Heavy water replaced by scintillator loaded with ^{150}Nd. Modest resolution compensated by high statistical accuracy.
  - Requires engineering for acrylic vessel hold down and purification plant. Technologies already developed.
    - SNO Cavity: repairs to cavity liner and modification of detector support to hold down the Acrylic Vessel for liquid scintillator.
    - SNO Utility Room: Excavation of pit for liquid scintillator purification system.
  - Capital funding received June 2009, turn on fall 2010.
- EXO-gas : $^{136}Xe \rightarrow {}^{136}Ba^{++} + e^- + e^-$
  - Ultimate detector aim = large volume Xe Gas TPC
  - Developing technique to tag Ba daughter. Electron tracking capability.
  - Development work at SNOLAB surface facility

Current programme: Natural neutrino sources

- SNO+ :
  - 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)
- HALO: Dedicated Supernova watch experiment
  - Charged/neutral current interactions in lead
  - Re-use of detectors (NCDs) and material (Pb) from other systems
  - Shielding partial re-use of PICASSO-II water cubes
  - Installation underway, completion by summer 2011
  - Will form part of SNEWS array

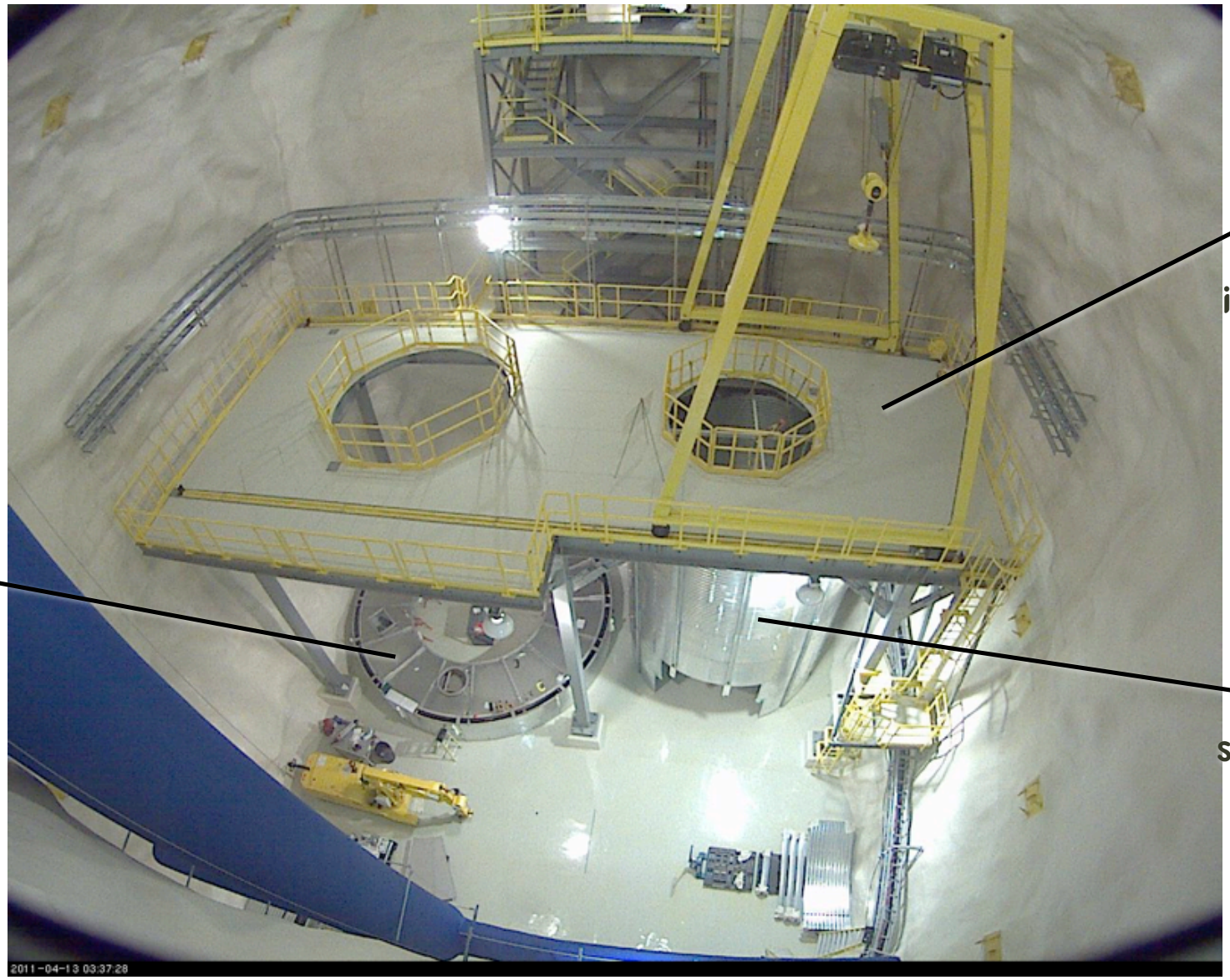
SNO+ Developments

Protection umbrella constructed underneath SNO+ AV and PSUP for floor repair and anchor point installation

Process system design advanced, inc. EH&S
Cavity work approved, underway - construction of 'umbrella', hold-down ropes, anchor points, AV cleaning, ...

Excavating a larger space in the SNO+ Utility room to accommodate the liquid scintillator process systems.

Cube Hall - DEAP/miniCLEAN



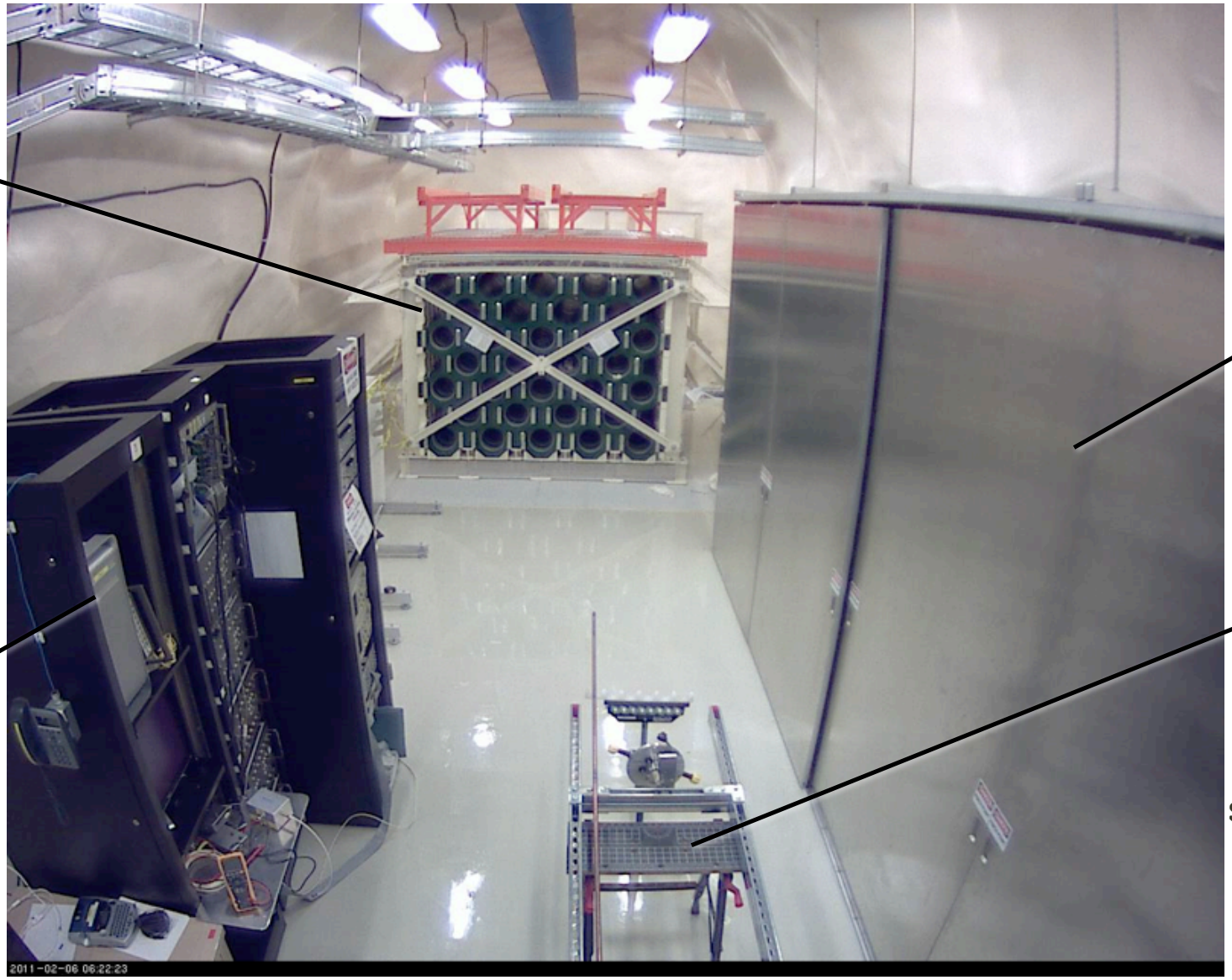
DEAP-3600 MiniCLEAN deck & infrastructure

DEAP-36000 water shielding tank

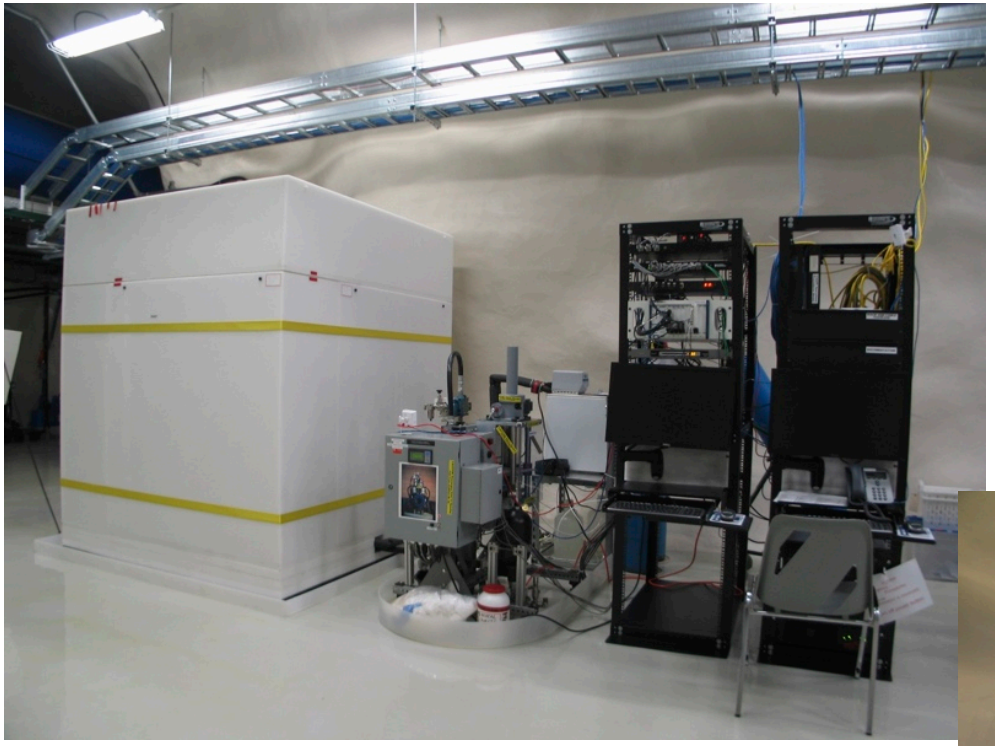
MiniCLEAN water shielding tank assembly

Ladder Labs - PICASSO

HALO


Target lead stack
NCD Racks (filled)
NCD DAQ (under refurb)
NCD Cutter
Water/Poly shielding box production
2011-02-06 08:22:23

'J'-Drift: R&D + rapid deployment



COUPP-4 bubble chamber, showing water tank shielding stack, pressure carts, DAQ racks

Relocation of DEAP-I completed. DEAP-I now operational again, backgrounds tests COUPP-4 deployed during summer 2010 from Fermilab - background limited

DEAP-I in the 'J'-Drift, showing water cube shielding and purifier stack

Summary

- SNOLAB facility is now fully integrated as a clean room, with fine cleaning of Phase-II underway
  - Experiment deployment has been on-going for dark matter, double beta and neutrino projects
- Current SNOLAB facilities contain three main experimental cavities which become available on a variety of timescales
  - These cavities available for international projects
  - non-monolithic for 3G detectors defined in design workshops
- New cavities or excavations are not precluded
  - Requires dialogue with experiments and funding agencies