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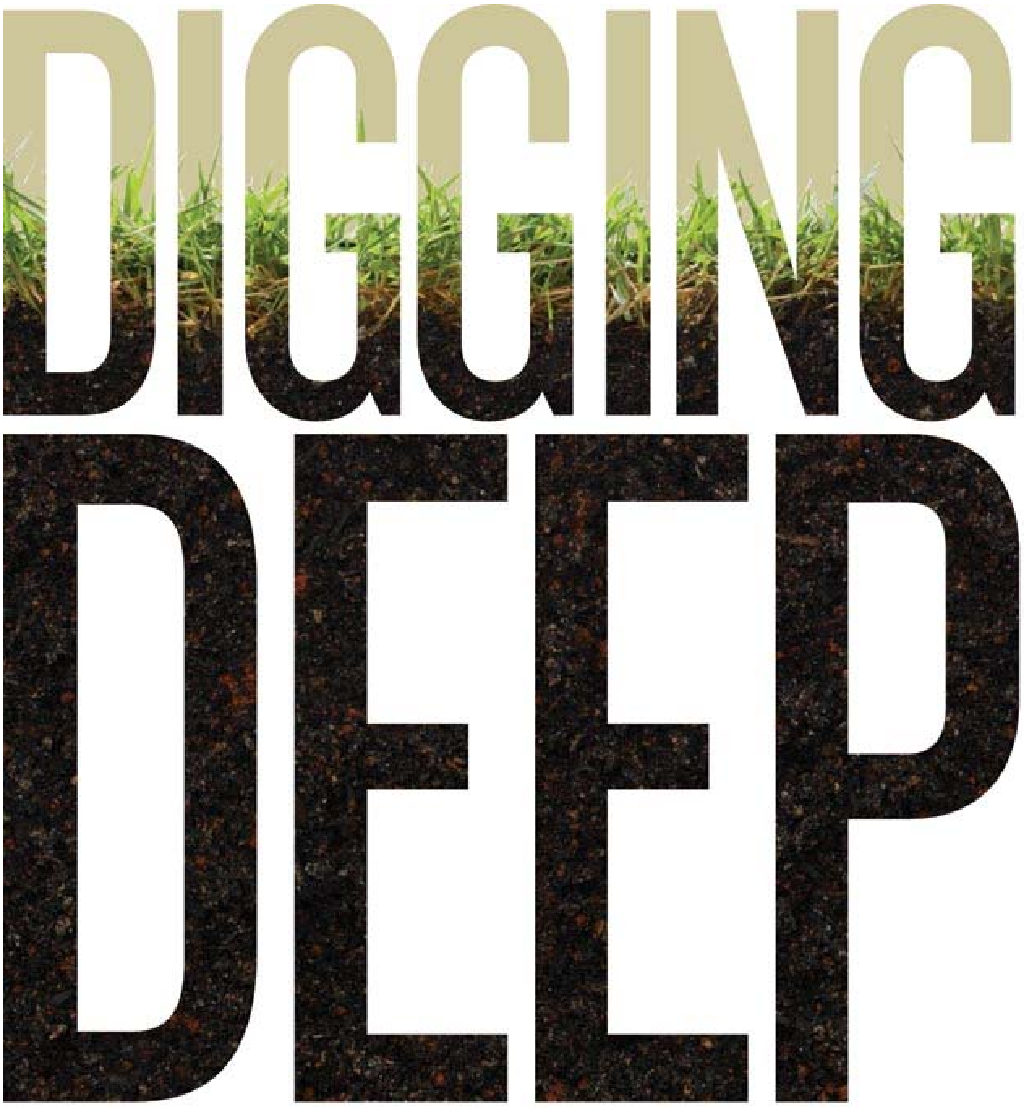
Cover Story

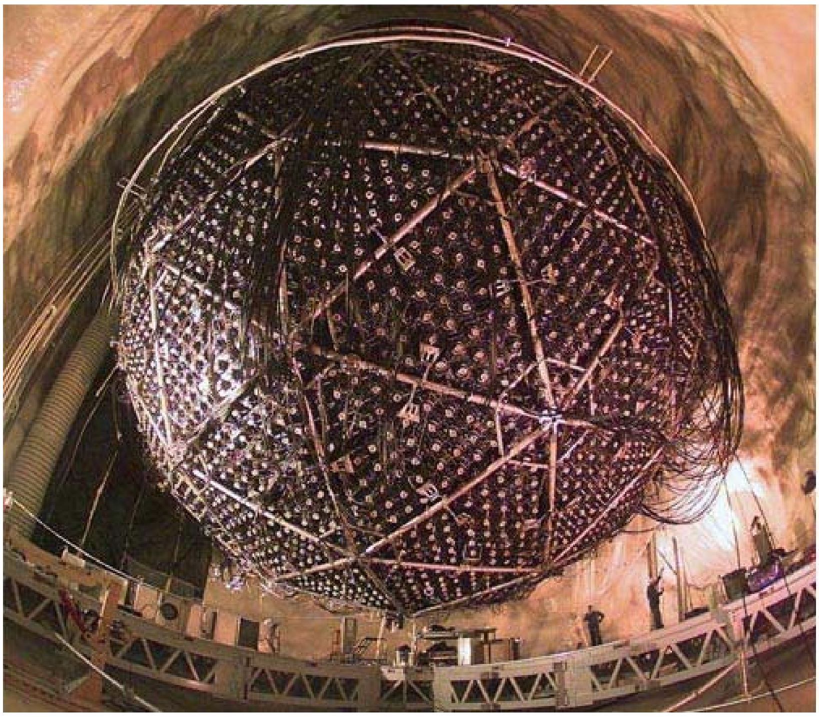


Story by *Nicolas Heffernan*

This is like no other lab in Canada.

Stepping out into a Sudbury morning at 5:30 a.m. in December in nothing but a pair of coveralls with shorts and a T-shirt on underneath is never a good idea, yet every day about a dozen researchers and 40 staff members make this trek. The 500-metre walk from the change rooms at the SNOLAB's main building to the mine building seems to take an awful lot longer than 30 seconds as the cold bites and nostrils freeze.

The heat of the building offers sanctuary from the Canadian winter and about 50 bleary-eyed people ease into benches and as they thaw and wait for the elevator.



This is like no other elevator in Canada.

As it stops to pick everyone up, half a garage door slides up – it's missing the top half with the bottom portion a solid metal fence. The "cage" has two levels with the first one packed like a sardine can with miners and scientists. It slides down 10 feet or so and the remaining stragglers come on the bottom level. Before it sets off newcomers are warned that eardrums can rupture on the way down. Pressure is good, pain is bad. The door slides down and the descent begins – 100 feet turns into 500 then 1,000 and at 2,100 feet, the elevator stops to check on the newbies. The cage is capable of plummeting the 6,800 feet in three minutes. They give the thumbs up and the elevator drops, faster now. It's like taking off in a plane on steroids. The cage rattles and shakes from side to side as it hurtles faster into the abyss. Ears start to pop. At 5,000 feet people are chewing gum maniacally and for those on their first descent, pressure is building in their chests. The elevator stops when it reaches 6,800 feet. As the door slides up, all the scientists get off and the miners continue their descent.

This is like no other hallway in Canada.

Greeting scientists as they disembark is a big sign that reads, "Be your brother's keeper" and a wave of heat that means the shorts and T-shirt under the coveralls make a lot more sense. They enter "the drift" and begin the 1.5-km trudge to the entrance of the lab with the mud trying to suck each boot off with every step. The physicists cum miners have headlamps to illuminate the dark but still have to look down as they walk to avoid the rail tracks on the uneven ground – past the chiller and the vents that purify and recycle the air every 10 minutes, to where the sewage is treated and finally, to the lab.

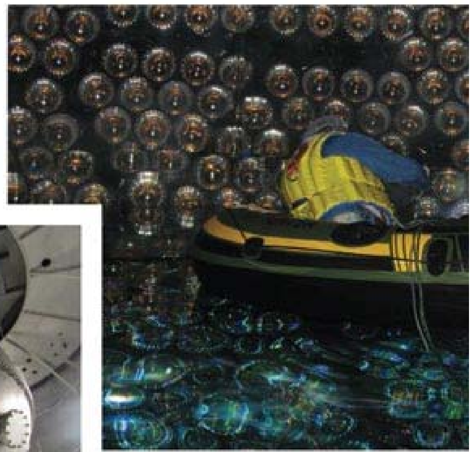
Before they're allowed entrance the scientists undergo a rigorous cleaning process: powerwashing their boots and putting them away, then stripping off all their mining gear and taking a shower before changing into new coveralls, a hairnet, hardhat, safety goggles and boots. Finally, they can get to work.

This is like no other lab in Canada.

Sudbury Neutrino Observatory

The roots of SNOLAB stretch back to 1990 when the Sudbury Neutrino Observatory (SNO), set out to solve the solar neutrino problem – the apparent discrepancy between the number of neutrinos observed emanating from the sun and what the theory estimated, with the number of detected neutrinos between one third and one half of the predicted number. Between 2001-2006, SNO conclusively proved that the solar neutrino deficit was caused by a property of the neutrino by which it changed "flavor" from the type produced by the sun (electron neutrinos) to other types (muon and tau neutrinos). The hugely successful experiment stopped taking data in 2006 and was decommissioned in 2007 but gave great credence to the value of deep underground physics laboratories. In 2002, Laurentian, Carleton and Queen's universities, and the universities of British Columbia, Guelph and Montreal, proposed the creation of an international facility called SNOLAB to the Canada Foundation for Innovation (CFI). The CFI approved the funding and with additional funds from the province of Ontario, construction began in 2004 with a new surface facility coming on line in 2005 and the expanded underground laboratory occupied in 2008. The resulting lab is now three times larger than the old SNO underground facility and is capable of housing several experiments simultaneously. Approximately $100 million has been invested by government over the life of the lab.

In addition to SNO+, the lab hosts eight other experiments exploring dark matter, neutrinos and supernovas.



But SNOLAB only hosts experiments. Canadian and international groups apply and the projects with the best science and requisite funding are chosen. The teams don't pay for rent but they pay for equipment and people. While eight SNOLAB researchers are based at the lab, 250 scientists worldwide are affiliated with an experiment at the facility. SNOLAB provides logistical support and support teams: engineers to disassemble the massive detectors so they fit on the cage and then reassemble them, cleaners to make sure everything that goes in the lab maintains the lab's Class 2000 cleanroom ranking; and a research science group that acts as an interface between the experiments and the lab to make sure the data analysis, management and collection is done at an appropriate level to allow the experiments to flourish. "One of the real strengths that we have here is the support mechanisms and people that provide additional support to the experiments when they come here, to make sure they have as good an opportunity as possible to succeed," says Dr. Nigel Smith, SNOLAB's Director.

The lab has two principal areas of focus: neutrinos and dark matter. "Dark matter is so compelling because you're actually trying to understand the basic information and basic components of the universe and how they influence the evolution of the universe," says Smith. "[Neutrinos] are obviously part of tradition here in Sudbury with the original SNO detector, but there are still many unanswered questions with neutrinos."

The lab has two principal areas of focus: neutrinos and dark matter.

This research has put Canada on the map in the astrophysics and particle astrophysics community thanks to a facility that operates at a depth and cleanliness that attracts the best projects and researchers from around the world. "In Canada we're unique; we're the only deep underground research facility so there's actually no comparison you can make. Around the world there's probably half a dozen deep underground labs doing our kind of research and the combination of our depth and cleanliness is what makes us unique even in our community," says Smith, who was conducting dark matter research in Yorkshire, England before being coming to run the facility. "SNOLAB is the place to be at the moment in our field."

Forget what you think you know

Everything at the SNOLAB is counterintuitive – like studying the universe two km below ground or operating a lab (with vast open spaces) as a cleanroom in an active mine. "The depth and the cleanliness are what really provide our researchers the environment in which they can do their work unhindered by the background radiation that would affect their experiments," says Smith. "The reason we're deep is to get away from cosmic rays. The reason we're clean is so that any potential contamination from natural radioactivity in such things as concrete dust doesn't interfere with the experiments, doesn't interfere with these exquisitely small signals we're looking for with the detectors."

When Smith says "radioactive," there's no need to think of impending doom.

"Everything has radiation; when I say that people think nuclear reactor," says Samantha Kuula, SNOLAB's communications officer. "This is very small amount of radiation but it makes a massive difference to these kinds of experiments."

The other reason to come so deep is to avoid all the background signals that exist on the earth's surface. Think of it as an orchestra and the snap of your fingers is a neutrino. On the surface there's a cacophony of sound: trumpets blaring and drums banging – that's all the extra cosmic and high energy gamma-rays. Quite simply, it's impossible to hear the snapping. So to study the universe, researchers have to travel to great depths and keep the environment as clean as possible. "We're not recreating what's happening on the sun," says Kuula. "The only way to detect what's happening, what's coming out of the sun is being this far underground. Because if we're on the surface all we'd be hearing is air horns and this detector would be lit up constantly, so we would never see all the small particles because all we'd see are the high-energy ones."

One of the detectors the lab has the highest hopes for is SNO+, a collaboration between Canada, the United States, the United Kingdom and Portugal, that's an extension of the original SNO experiment.

SNO+

Glance down at your thumbnail. Every second a billion neutrinos pass through it. Neutrinos are one of the most fundamental, yet least understood particles that make up the universe. They are almost unfathomably tiny. Think back to high school physics class and the atom. Think of the nucleus as a basketball in the middle of a football field, with the electrons outside the field. A neutrino would be like a grain of sand compared to everything else. On top of that they are exceptionally weakly interacting, affected only by "weak" subatomic force making it able to pass through ordinary matter as though it were not there. "Neutrinos don't interact with almost anything," says Erica Caden, a PhD student from Philadelphia working on the project. "Even here, even two kms down, neutrinos don't interact with almost anything. So to detect them we have to have these giant detectors and have them be very, very clean and very, very deep underground to shield them from other backgrounds."

SNO+ is being carried out in the largest cavern – 30 metres by 22 metres wide – at this depth in the world. Researchers changed the detection material from heavy water to a liquid scintillator because linear alkylbenzene, designed by SNOLAB scientists, is safe, inexpensive and gives off 100 times more light than water. The liquid scintillator is housed in an acrylic vessel, surrounded by 10,000 Photomultiplier Tubes (PMTs). When a neutrino interacts in the detector it creates a very minuscule spark of light which the extremely sensitive PMTs capture. The entire assembly is completely submerged in 7,000 tonnes of ultra pure water. But neutrinos are so non-interactive that the original SNO detector running in a million litres of detection material saw only 10 interactions a day. "With the linear alkylbenzene they may not see more than 10 a day but they're going to get more data from those 10," says Kuula.

(Left) Erica Caden and Richie Bonaventure, two American students working on SNO+.

SNO+ will be able to make precision measurements of different parts of the solar neutrino spectrum, furthering our understanding of the solar fusion mechanisms and ultimately the evolution and fate of the sun. The main goal of the experiment is to search for neutrinoless double beta decay; a rare process that researchers know exists but has never seen. It would reveal whether neutrinos are their own antiparticles – so the antimatter neutrino – and potentially the absolute neutrino mass. "The neutrino is the only possibility to be its own antiparticle. All other particles are too large or too complex," says Caden. The experiment is also exploring geoneutrinos as a way to measure the total amount of heat produced in the Earth from radioactivity.

Caden sought out Laurentian University as a post doc for this opportunity. "I wanted to work on SNO+ and be at SNOLAB and be at the centre of the [other] experiments that are here, either running or under construction, to be surrounded by scientists all day," she says. "I love it. This is my dream job. It's so cool to be here."

The experiment is not yet operational. Caden and the team are taking the first steps to beginning the data collection process by filling the acrylic vessel with water to test the electronics on the PMTs that haven't been in use since 2006. "They haven't been wet in a

DID YOU KNOW?

- The PMTs used on the SNO+ experiment are so sensitive that if someone was standing on the moon holding a candle and the earth was dark it could detect the light.
- Geranium detectors are used to detect background radiation on everything at SNOLAB. The lab had to send rope back to the manufacturer because it was too high in potassium. There is currently no other use for the rope in the world.
- The lab undergoes construction projects such as drilling into the rock, drywalling, etc., and runs a machine shop while maintaining its cleanroom status.
- Every experiment has "a fingerprint budget." Potassium is in sweat, it's salty and potassium breaks down into radioactive daughters. These experiments have a fingerprint budget of five. It means there can only be enough potassium from five fingerprints in the entire experiment from beginning to end or that's too much radiation for the experiment to handle.
- Your body feels 25 to 30 per cent more pressure at 6,800 feet, making a day underground tiring until your body gets used to it.
- The lab is so clean there is only one gram of dust in the entire laboratory – enough to cover the head of a loonie.
- In order to do repairs to SNO+ workers use an inflatable boat and lower themselves into the cavern.
- Experiments are surrounded by ultrapure water, made in the lab's own water plants. The water is so clean – stripped of all the ions, salts, minerals, etc., that it's actually corrosive and would dehydrate a person.

would dehydrate a person.

long time… so we're going to turn them up, put 3,000 volts on them and see if they explode," says a smiling Richie Bonaventure, another American PhD student working on the experiment. The team hopes to have SNO+ collecting data by the end of 2014.

Other experiments

SNO+ is not the only experiment under way. There are eight other experiments underway or under construction, with space for one more still not allocated. COUPP, DEAP 1, DEAP 3600, DAMIC and PICASSO are studying dark matter; EXO and miniCLEAN are studying neutrinos; HALO is studying supernova. "There are tweaks I would like to add but fundamentally, things are pretty awesome," says Smith. "We're in a situation where we have our initial science program coming on… We're at a point where we're still attracting new projects and going through the process of selecting those new projects. So it's an exciting period in our field and it's an extremely exciting period for SNOLAB as we start contributing to the field. At the moment I'm pretty pleased with where we are."

Back to reality

At the end of a shift, everyone signs out and goes back to the changerooms where they dump their lab clothes in bins to be washed in underground facilities and put their mining gear back on. In the hallway outside, those with boots insufficiently cleaned find a chastising note inside.

Stepping into the drift again, it's easy to forget you're still in an active mine. On the way back, traffic is particularly bad with two trucks reversing down the drift and some construction creating a blockage, causing painful flashbacks to a Toronto commute. At the cage, boots are powerwashed again and the wait for the ride back to the surface begins. The cage is packed again but this time flies upward at full speed, without the pressure of the decent.

Stepping out into the brilliant sunshine after being underground all morning is blinding and the walk in a frigid Sudbury afternoon in coveralls with only shorts and a T-shirt underneath is still never a good idea but after spending five hours in the SNOLAB the cold doesn't seem to bite as much and it doesn't matter that your nostrils are frozen.

Now I know why about a dozen researchers and 40 staff members make this trek.

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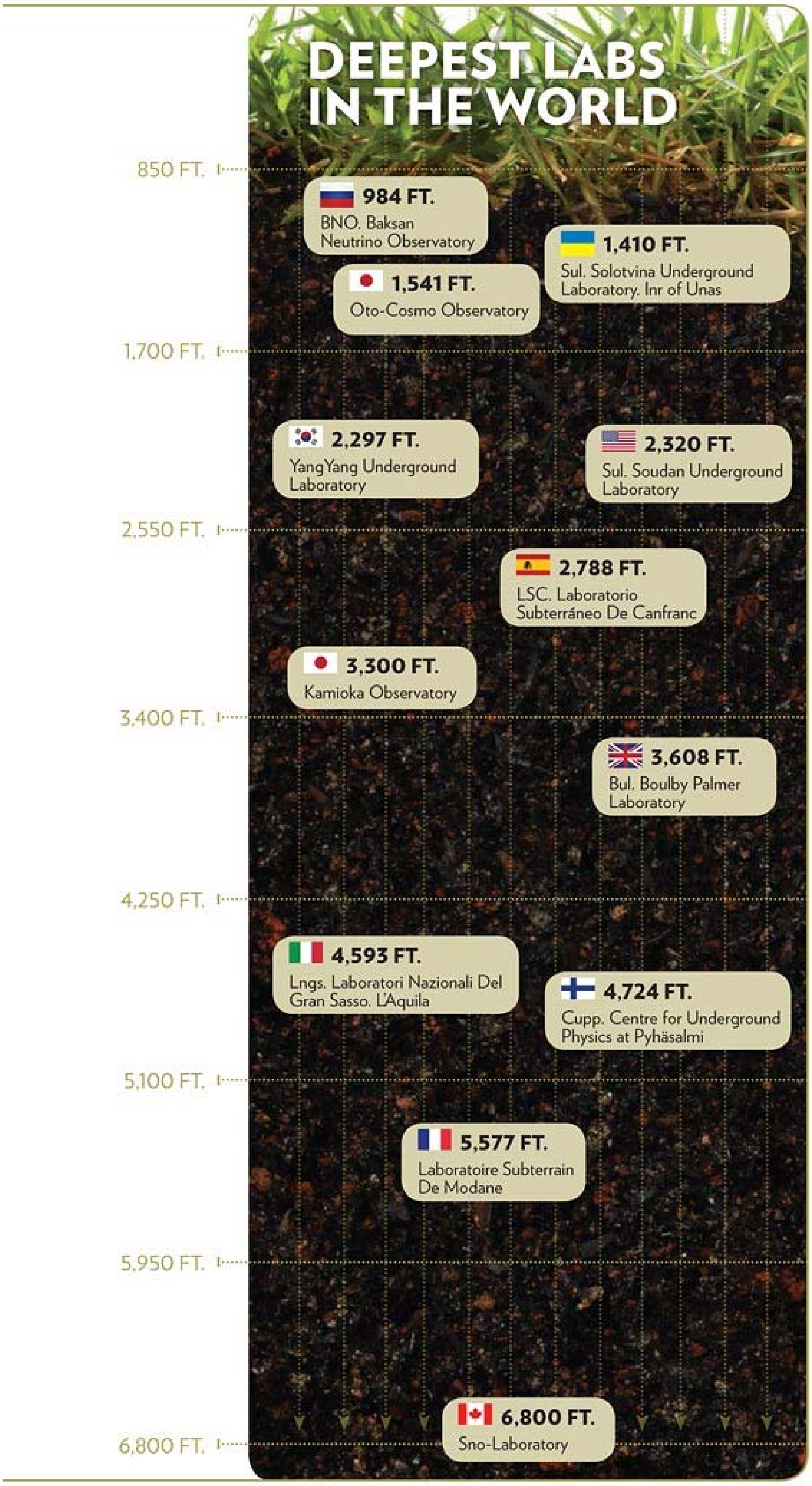
DEEPEST LABS IN THE WORLD
850 FT.
984 FT.
BNO. Baksan Neutrino Observatory
1,410 FT.
Sul. Solotvina Underground Laboratory. Inr of Unas
1,541 FT.
Oto-Cosmo Observatory
1,700 FT.
2,297 FT.
YangYang Underground Laboratory
2,320 FT.
Sul. Soudan Underground Laboratory
2,550 FT.
2,788 FT.
LSC. Laboratorio Subterráneo De Canfranc
3,300 FT.
Kamioka Observatory
3,400 FT.
3,608 FT.
Bul. Boulby Palmer Laboratory
4,250 FT.
4,593 FT.
Lngs. Laboratori Nazionali Del Gran Sasso. L'Aquila
4,724 FT.
Cupp. Centre for Underground Physics at Pyhäsalmi
5,100 FT.
5,577 FT.
Laboratoire Subterrain De Modane
5,950 FT.
6,800 FT.
Sno-Laboratory
6,800 FT.

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