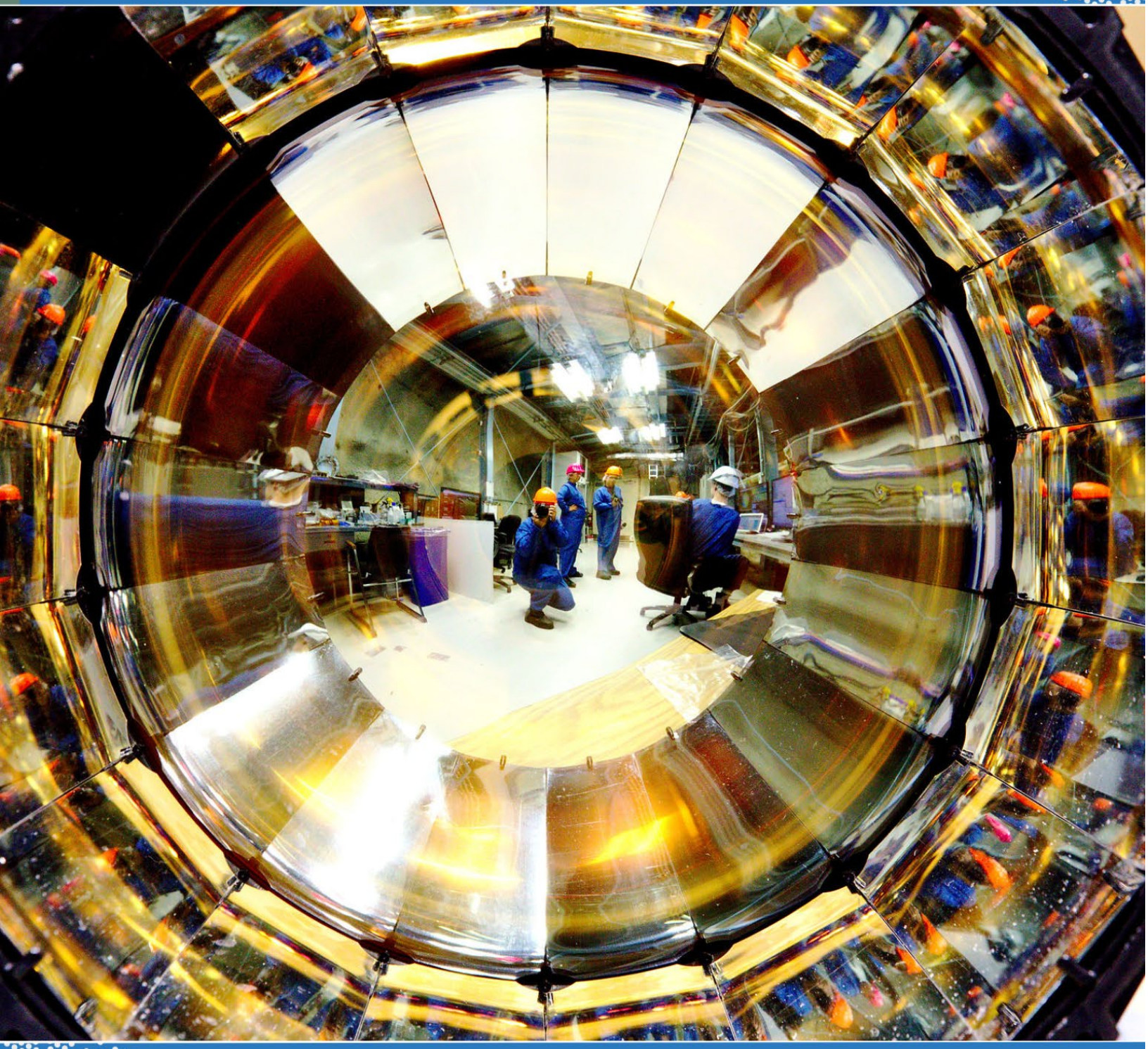
# Reaching New Heights, Deep Underground

## 2023-2029 Implementation Plan



SNOLAB

# Land acknowledgement

SNOLAB is located on the traditional territory of the Robinson-Huron Treaty of 1850, shared by the Indigenous people of the surrounding Atikameksheng Anishnawbek First Nation as part of the larger Anishinabek Nation.

We acknowledge those who came before us, and honour those who are the caretakers of this land and the waters.

# Our foundational partners

SNOLAB is the result of an alliance of six founding partners. Our five Canadian university joint venture members ensure that SNOLAB maintains an independent and effective Board of Directors. Vale provides invaluable support through access to the two-kilometre depth in its Creighton mine.

SNOLAB is sincerely grateful to our many funding partners. Their essential investments in our facilities, research capabilities, infrastructure, and operations support leading-edge discovery, physics research, and innovation for the benefit of all Canadians.

VALE

Queen's University

Carleton University

Laurentian University / Université Laurentienne

Université de Montréal

University of Alberta

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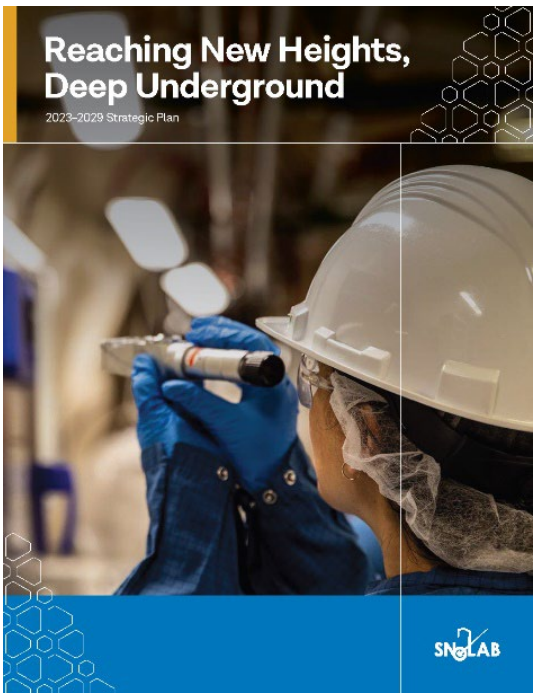
## PURPOSE OF THIS DOCUMENT

This document addresses the needs of several target audiences, including management and staff, the Board, the external community, and funding bodies.

The Implementation Plan works with the Strategic Plan, and these documents will guide SNOLABI management in prioritizing resources. This enables a sharp focus on projects that directly support and align with the strategic goals of the SNOLAB community.

The Strategic Plan is owned by the SNOLAB Board and with this Implementation Plan will serve as benchmarking documents for oversight, to assess the effectiveness and impact of the facility and of the management team. The entire SNOLAB community drives the strategic direction, and, as such, this document provides a vehicle for continued engagement and alignment with the community SNOLAB serves.




## EXECUTIVE SUMMARY

SNOLAB, the deepest-cleanest underground research facility in the world, has made Canada a leader in underground science, infrastructure, and expertise. Located two kilometres underground, SNOLAB's facility near Sudbury uses the Canadian Shield to protect experiments from the cosmic rays that constantly bombard the Earth's surface. SNOLAB's experimental spaces have the lowest cosmic radiation flux in the world and the least possible interference from radioactivity.

This unique low-radiation environment enables delivery of SNOLAB's world-class astroparticle physics research program. Working with collaborators, SNOLAB's science program explores priority questions about the evolution of the universe, particularly the role of neutrinos and dark matter. SNOLAB has also attracted experiments in life sciences, nuclear security, and quantum technology.

SNOLAB is at a pivotal point in its evolution. International demand for access to its unique environment and capabilities has grown substantially while SNOLAB has matured to meet it. The recent explosion in interest and investment around the world has intensified global competition in underground science. At the same time, it has created enormous opportunities for international collaboration. To keep

Canada and Canadians at the forefront of global science, SNOLAB must capitalize on these opportunities or risk being left behind.

By hosting and enabling the world's most advanced and sensitive underground experiments, SNOLAB:

- will bolster Canada's scientific reputation;
- attract new talent to Canada and Northern Ontario;
- train more highly skilled people;
- provide more opportunities for Canadian researchers to lead international projects; and
- generate economic benefits for Canadians.

SNOLAB's Strategic Plan for 2023-2029 will help fulfill the vision to become the leading international underground laboratory. It leverages past investments and builds on SNOLAB's strong record of achievements and recognized strengths. It supports SNOLAB's efforts to create a more equitable, diverse, and inclusive culture that welcomes the community. It also ideally positions SNOLAB to capitalize on emerging global opportunities in deep underground science.

**Three core pillars underpin SNOLAB's Strategic Plan.**

## EXCELLENT SCIENCE

*GOAL: Drive breakthrough discoveries at the frontiers of underground science.*

Canada has a strong global reputation for producing high-calibre discovery research, particularly in astroparticle and particle physics, which comprise approximately 95% of SNOLAB's scientific program. Most of the experiments SNOLAB hosts in these fields are large-scale international projects involving a host of collaborators. They aim to illuminate new insights into the particles and forces that have shaped the universe. Discoveries in either dark matter or neutrinos could have dramatic impacts on fundamental understanding of the universe. Aligning SNOLAB's science priorities with both national and international planning activities enables SNOLAB to attract the best scientists and opportunities and prepare for the future.

SNOLAB's deep underground lab offers a unique environment for driving knowledge about artificial and natural sources of radiation in the environment. That makes it well-suited to experiments in emerging underground fields such as quantum computing, nuclear forensics, and life sciences. Canada's involvement in the rapidly growing quantum technology industry is expanding. Research and testing on superconducting quantum devices in SNOLAB's low-radiation environment will provide valuable insights to advance and operate the technology. Detection of very small levels of radioisotopes can provide crucial information about external nuclear events. While SNOLAB has begun exploring and hosting experiments in these areas, it has not tapped into the full potential of these opportunities.

Enabling and delivering world-class international research projects across an increasingly diversified portfolio will accelerate progress, open new avenues of knowledge, and keep SNOLAB — and Canada — at the forefront of research excellence.

## CUTTING-EDGE INFRASTRUCTURE

*GOAL: Continuously improve our research infrastructure to remain state of the art.*

World-class infrastructure is the foundation for the development of high-impact science and technology. It includes not only physical research facilities and equipment, but also the tools, processes, technologies, and operational and engineering expertise that support experiments. As Canada's only deep underground laboratory and a major science infrastructure, SNOLAB provides a unique facility with leading-edge expertise that continues to evolve to meet the changing scientific demands of top international researchers.

As SNOLAB grows and diversifies its research portfolio and the requirements for great depth and low radiological backgrounds become even more stringent for experiments, it must continuously evaluate, expand, and adapt its infrastructure capacity, supporting technologies, and business practices. Doing so will allow SNOLAB to maintain operational excellence and high safety standards.

## SKILLED PEOPLE

*GOAL: Foster and develop diverse talent in an inclusive environment.*

People are at the heart of SNOLAB's success: its staff of researchers, technicians, engineers, and operations and corporate professionals who provide dedicated support to the experiments is hosts and the many collaborators who come to the facility to work on experiments. World-class science and research excellence requires contributions from diverse perspectives, skills, and experiences. And SNOLAB is committed to creating a culture and work environment that is safe and respectful for everyone. In 2020, SNOLAB formalized its commitment to equity, diversity, and inclusivity (EDI) by implementing an EDI Action Plan.

While significant and measurable progress has been made, there is more to do. SNOLAB's ambition is to be recognized as a world-leading laboratory in EDI best practices, setting an example for other laboratories.

Canada's economic prosperity and competitiveness depend on building and retaining a highly skilled workforce. SNOLAB contributes to Canada's talent pool by further training people by creating Highly Qualified Personnel (HQP). SNOLAB attracts talented graduate and undergraduate students, post-doctoral researchers, and technical professionals to Canada and Northern Ontario. And SNOLAB provides them with a formative work experience as members of both small and large collaborative international teams, along with unique training opportunities in underground science and creative technical innovation.

SNOLAB also helps inspire the next generation of scientists and innovators through public engagement and outreach activities. Communicating the excitement about the science at SNOLAB nurtures curiosity and scientific literacy as well as making it the go-to resource for underground science educational tools.

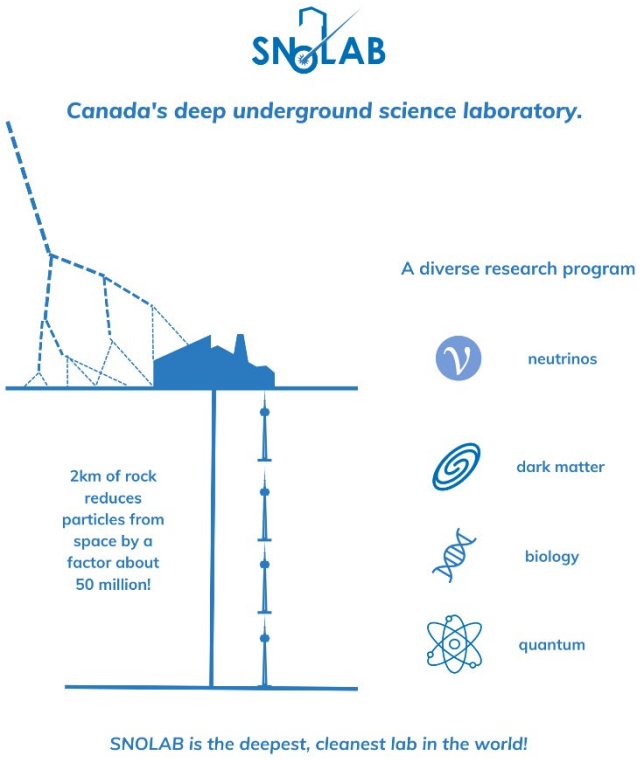
Ultra Pure Water Plant / **SNOLAB**

## SNOLAB and its user community

SNOLAB is Canada's deep underground research laboratory located in the operational Vale Creighton nickel mine near Sudbury, Ontario, Canada. At two kilometres underground, SNOLAB is the deepest-cleanest laboratory in the world. "Deepest-cleanest" meaning SNOLAB is the best shielded underground clean laboratory space with the lowest cosmic radiation in the world.

SNOLAB's depth and cleanliness provide an ideal low-radiation background environment for the study of extremely rare physical phenomena. SNOLAB's science program focuses on astroparticle physics, specifically neutrino and dark matter studies, though its unique location has allowed SNOLAB to expand its science program to include experiments in life sciences, nuclear security, and quantum technology.

SNOLAB has 5,000 $m^2$ of clean space underground for experiments and supporting infrastructure. A staff of more than 140 support the science, providing engineering design, construction, installation, technical support, operations, and corporate services expertise. SNOLAB research scientists provide expert and local support, as well as leadership, to the experiments as members of experimental collaborations.




SNOLAB is an expansion of the facilities constructed for the Sudbury Neutrino Observatory (SNO) solar neutrino experiment. Construction of SNOLAB was completed in 2011 using capital funds totalling $70 million, including an initial $38.9 million capital award from the Canada Foundation for Innovation through the International Joint Venture program. The Ontario Innovation Trust, the Northern Ontario Heritage Fund, and FedNor provided additional funds enabling construction.

Now a multi-experiment facility currently hosting more than 20 experiments in all phases of development, SNOLAB has achieved international recognition as a leading laboratory and partner of choice for deep underground science. SNOLAB serves a growing community of scientists, researchers, students, and collaborators across Canada and around the world. Currently, SNOLAB's scientific program supports more than 1,400 academic users, of which 250 are from Canadian institutions.

A truly international facility, users of the laboratory represent numerous scientific collaborations based at 128 institutions across 24 countries. Working together enables SNOLAB to harness the expertise of academic, industry, and government partners and to focus resources on the advancement of research, discovery, and societal impact.

Engagement within this user community has enabled training of more than 1,700 HQP to date, including Ph.D. students, M.Sc. students, scientists, post-doctoral fellows, technicians, and engineers. These skilled personnel acquire hands-on experience and learning in SNOLAB-supported projects and apply this knowledge to future positions in academia and industry.

Canada has a strong record of achievement in particle physics, which is an exciting field on the forefront of discovery. Almost half of the Nobel Prizes in Physics awarded since 2015 have been in astrophysics or astroparticle physics, the study of the intersection of particle physics with astronomy and cosmology. The 2015 prize was awarded to Arthur B. McDonald, Director of the SNO experiment, a major astroparticle physics experiment to which many Canadian and international scientists contributed.

Particle physics thrives on international cooperation. Large collaborative teams of scientists from all over the world design and build the most promising experiments to make major discoveries. The Canadian and international particle physics communities have prioritized research on key astroparticle physics questions that underground experiments may answer, including: What is the nature of the dark matter in the universe? What kind of particle is the neutrino? The answers will give insight into both the evolution of the universe and the foundational principles underlying all of physics.

Over the timeframe of this plan, research programs on these questions are expected to engage thousands of scientists and require hundreds of millions of dollars to develop, build, and operate extremely sensitive, large-scale experiments that require great underground depth and low backgrounds. The increasing sensitivity of experiments will drive the demand for access to SNOLAB and meeting this demand will in turn advance Canadian scientific leadership in deep underground science. SNOLAB has recently committed space to a next-generation tonne-scale neutrinoless double beta decay experiment. Examples of such projects that used SNOLAB to baseline their conceptual designs are nEXO and LEGEND-1000. SNOLAB also has the capacity to host a next-generation large-scale dark matter experiment, and the community is presently considering alternative designs and concepts for such programs in the future.

Recent strategic investments in research infrastructure at SNOLAB and in world-leading astroparticle talent at Canadian universities have placed Canada at the forefront of underground science. SNOLAB is a world-class, deep underground facility that gives Canada a competitive advantage: SNOLAB offers access to extremely deep, clean halls for experiments capable of hosting kilo-tonne scale projects; access to expert scientific, technical, and administrative support; and access to the technologies that enable low radiological backgrounds. This is a unique combination within the global community of deep underground facilities.

These capabilities support researchers to build underground experiments, to study extremely rare phenomena, and deliver world-class science in a highly productive way. These capabilities enable a world-class science program that is currently focused on neutrino and dark matter investigations — and these capabilities are attracting internationally renowned scientists and experiments from across Canada and around the world.

SNOLAB has adopted a bold vision to capitalize on these opportunities to build on Canada's scientific strengths, its strategic investments, and the demand from the international community, thereby, positioning Canada to lead, contribute to, and benefit from major scientific discoveries. By hosting and enabling the world's most advanced underground experiments, SNOLAB will bolster Canada's scientific reputation, attract new talent to Canada, and provide more opportunities for Canadian researchers to take leadership roles in international projects.

The following sub-sections explore the Canadian and international landscape in more detail.

## SNOLAB and Canada

Canada has an opportunity to lead the world in addressing some of the most fundamental questions remaining in this major international field of research. These questions are at the top of the international lists of topics in physics, cosmology, and astronomy and can only be addressed by major investments in experiments in an underground laboratory. These experiments are presently under development by significant international teams of scientists and will necessitate international investment at historic levels. Success in these experiments will certainly extend Canada's global scientific reputation while building Canada's scientific capacity.

Two major scientific puzzles centre on some of the most difficult-to-detect substances in the universe: dark matter and neutrinos. Mysteries at the heart of each of these phenomena are key drivers for the current and future SNOLAB scientific program.

Dark matter is a non-luminous form of matter present in the early and modern cosmos. Astronomical observations tell us that it usually outnumbers normal atomic matter by 5-to-1 at just about any scale of observation: the local Milky Way galaxy, other individual galaxies, clusters of galaxies, and even in the pattern of light left over from the Big Bang. Dark matter seems possessed of properties that make it a unique challenge, even compared to other particles like neutrinos. SNOLAB's dark matter program is home to current and proposed experiments using a range of materials (argon, helium, fluorine, silicon, and germanium) to induce a reaction when struck by a dark matter particle. A key effort in this program is to assess and suppress confounding effects due to cosmic ray and terrestrial radiation.

Neutrinos are weakly interacting elementary particles. They have been the source of multiple Nobel Prizes and have secrets to yield while also providing insights into other cosmic phenomena. They are readily produced by many sources — the Sun, nuclear reactors, atomic decay, dying stars, and even the core of the Earth — of interest to current and future programs at SNOLAB. However, we have yet to

reveal key features of neutrinos such as their exact masses. Studying this class of particle at SNOLAB will yield insights into the lives and deaths of stars, nuclear monitoring, and fundamental aspects of nature.

For example, the search for neutrinoless double beta decay ($0\nu\beta\beta$) is one of the most compelling challenges in particle physics today. The discovery of neutrinoless double beta decay could shed light on the absolute neutrino masses and on their mass hierarchy. SNOLAB is at the forefront of this scientific priority with the SNO+ science program and the capability to host a future tonne-scale neutrinoless double beta decay experiment.

SNOLAB's unique location makes it an ideal site to advance research in other fields of science in addition to astroparticle physics, such as biology and chemistry. The FLAME genomics program has studied how the increased pressure at two kilometres underground affects metabolism. The REPAIR bioinformatics experiment is examining what effects, positive or negative, an extremely low-background environment has on cells and organisms at a genetic level.

Cryogenic Underground Test facility (CUTE) / **SNOLAB**

Another adopter of SNOLAB's unique location is quantum technology. Recent developments in such technologies, driven by sensing and computing applications, bring new challenges. These involve understanding and mitigating the sources of quantum-state decoherence. The underground environment facilitates the design of new experiments that will employ quantum sensors to explore the fundamental make-up of the Universe. Astroparticle physics research is poised to be an early adopter of the newest quantum technology, and SNOLAB-hosted research may both advance quantum technology broadly and result in fundamental physics breakthroughs.

Such collaborations place SNOLAB and Canada at the leading edge of fundamental physics and underground science today. Maintaining that prominence will require Canada to host future large-scale multinational experiments with clear scientific advantages and substantial economic and technological effects. The opportunities provided by SNOLAB will enable Canada to be a global leader in astroparticle physics and deep underground science. The pursuit of these projects will test SNOLAB's physical and technical capacity.

In addition to attracting substantial international investment in Canada, these major projects will train a next generation of scientists in "evidence-based decision making," a role for which SNOLAB is well positioned to lead.

## SNOLAB produces the skilled labour of tomorrow

Recent surveys indicate SNOLAB alumni are putting their science and technology skills to work solving real-world problems, creating economic value in software, finance, logistics, manufacturing, and retail sectors, or are advancing social goals in clean energy, security, and public health.[1]

In addition to universities, SNOLAB alumni are strongly represented in:

- professional and technical services (e.g. technology start-ups, engineering consulting);
- Scientific research and development (e.g. national labs, Defense Research and Development Canada, TRIUMF);
- software & e-commerce (e.g. Google, Amazon);
- manufacturing (e.g. ICT devices, aerospace);
- finance (e.g. investment banks); and
- public administration (e.g. Health Canada).

SNOLAB attracts the best students and trains a future generation of leaders for Canadian society. The pressure for innovative technological developments in frontier experiments has contributed to advances in everyday life. Examples include improved PET scanning devices based on novel light sensors and measurements that provide strong confirmation of nuclear fusion calculations in the Sun relevant to fusion power devices under development on Earth.

Frontier science provides Canadian students with valuable training. These skilled people in turn enhance Canada's technological leadership, a key driver of the economy. SNOLAB alumni are entrepreneurs, heads of teams of highly qualified people, or expert professionals. They are leading their organizations in developing technology, evaluating scientific information, interpreting complex data, and applying the resulting insights.

## SNOLAB as an economic powerhouse

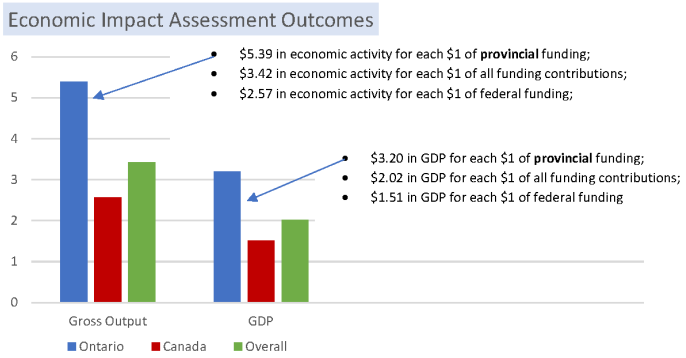
Since 2015, federal and provincial investments in SNOLAB have totalled more than $161 million, including more than $129 million from the Government of Canada and $32 million from the Province of Ontario.[2]

An economic impact assessment demonstrates that the total gross economic activity generated by SNOLAB's operating expenditures over the past six years and the forecasted economic activity over the next six years is estimated to be $456.6 million.

[1] *SNOLAB Alumni Study; TVB Associates Inc; November 2022*[1] *SNOLAB Alumni Study; TVB Associates Inc; November 2022*
[2] *SNOLAB – Economic Impact Assessment; KPMG; May 2023*

For the same 12-year period, SNOLAB has and will:

- contribute $252 million to Ontario's Gross Domestic Product (GDP), and $275 million to Canada's GDP;
- support approximately 2,200 person-years of employment; and
- introduce close to $200 million in labour related income to Canada.




Every dollar invested in SNOLAB by the province has yielded $3.20 in GDP in Ontario and $5.39 in total economic activity in Ontario. This compares favourably to a return of $1.51 in GDP and $2.57 in economic activity for every federal dollar invested in SNOLAB.

Furthermore, every $1 million invested in SNOLAB creates 29 person-years of employment in Ontario.

## SNOLAB science partners

Partnerships and collaborations with Canadian universities and other large research facilities are essential to maximize Canada's competitive advantage and make the most efficient use of resources invested in astroparticle physics and related fields.

SNOLAB has grown strong partnerships with TRIUMF, Canada's particle accelerator centre, at both the management and technical levels. TRIUMF specializes in large detector development and construction, naturally augmenting the capabilities of SNOLAB. TRIUMF is involved in light detector development for nEXO, the data acquisition system (DAQ) for DEAP-3600 and SuperCDMS, light guide and sensor development for DEAP-3600, and electronic testing and calibration system for SNO+. TRIUMF's project management process is also aligned with that of SNOLAB to ensure strong synergy on common projects. TRIUMF also contributes to experiment reviews, and engages in national big science discussions, initiatives, and events.

The McDonald Institute (MI) hosted by Queen's University is a hub for astroparticle physics research and an important partner in aligning the Canadian research community to enable current and future experiments. SNOLAB is working with MI to expand the pool of research expertise in Canada, create an intellectual hub for experimental astroparticle research at SNOLAB, and provide resources to enable detector development in the field of underground astroparticle physics.

The Perimeter Institute (PI), Canada's renowned research centre for theoretical physics, conducts theoretical research vital to the experimental program at SNOLAB. Recently SNOLAB has partnered with PI to study how ionizing radiation affects the coherence of individual qubits and how it causes correlated errors that are problematic for quantum error correction. PI is also a strong partner in

education and outreach initiatives. For example, SNOLAB has collaborated with PI on the development of Canada's next generation of physicists through its support of the International Summer School of Young Physicists. SNOLAB also engages PI on matters related to governance, operations, advocacy, and science policy.

The Canadian Light Source (CLS) in Saskatoon is a synchrotron radiation source and the "brightest light" in Canada, used by scientists to get detailed information about the structural and chemical properties of materials at the molecular level. As a fellow Major Research Facility (MRF), SNOLAB works closely with CLS on national science opportunities and challenges, advocacy, project management, and operational issues. This helps to create a more collective, cohesive, and unified voice for science in Canada, increasing influence and stimulating action.

Health Canada's Radiation Protection Bureau partners with SNOLAB utilizing the Low Background Counting Facility (LBCF). This facility at SNOLAB provides services in low background counting using several instruments, including gamma counting using ultra-low background germanium detectors, alpha counting using an XIA alpha counter, passive radon emanation, radon and thoron measurements with electrostatic counters, alpha-beta counters, X-ray Fluorescence (XRF) spectrometry and general gamma spectroscopy, and LBCF staff also consult on low background materials and experiments. The SNOLAB LBCF is also used to verify compliance with the International Comprehensive Nuclear Test Ban Treaty.

The collective and complementary physics research capabilities and expertise provided by SNOLAB and the partners discussed above provide a solid foundation on which to consistently grow the talent required to provide Canada with a truly global advantage in the rapidly evolving field of sub-atomic physics and related underground scientific disciplines. A direct example of this is the TRISEP summer school for graduate students in particle and astroparticle physics, annually organized in rotation by SNOLAB, TRIUMF, and the Perimeter Institute.

These national linkages are essential to consistently enhance the research capabilities that differentiate Canada on the global science stage. These key relationships enable SNOLAB to:

- deliver a world-leading science program, with national and international collaborations, at the forefront of global research;
- make educated decisions about the world-class infrastructure and capabilities required to achieve research objectives, maintain a leading-edge science program and laboratory, and maximize usage by researchers;
- stay apprised of key research needs, opportunities, and directions in the dynamic and competitive field of physics;
- identify and help researchers to capitalize on new and unexpected opportunities in physics and other scientific disciplines;
- disseminate and promote key research findings to academia and other members of the research community.

By working together as an integrated and collaborative community within this environment, Canada's physics community will be well-positioned to exercise influence and generate new opportunities that will benefit generations to come.


SNO+ Scintillator Plant / **SNOLAB**

# SNOLAB science program

Over the past decade, SNOLAB has transitioned from a single-experiment site to a multi-experiment facility. Astroparticle and particle physics are the central science disciplines, comprising about 95% of SNOLAB's scientific program. Most of the experiments are international projects aiming to discover dark matter or deliver foundational insights into neutrino properties. Other avenues of research, both existing and emerging, include life sciences, quantum technology and nuclear security.

## DARK MATTER

**DAMIC** (DArk Matter In CCDs) uses CCDs (charged coupled devices) to detect dark matter interactions. The silicon CCDs are electrical circuits made up of many capacitors, which are extremely sensitive to small changes in energy. When a dark matter particle interacts, that energy change can be measured, creating a signal in the data. DAMIC is supported by 11 institutions in six countries.

**DEAP-3600** (Dark Matter Experiment using Argon Pulse) uses a vessel of liquid argon to look for dark matter. When argon atoms are excited by particle interactions, they produce ultraviolet light. This light is then detected by sensors surrounding the vessel and analyzed to determine what caused it. DEAP-3600 is supported by 18 institutions in six countries.

**NEWS-G** (New Experiments With Spheres – Gas) uses a spherical copper vessel filled with a noble gas to search for dark matter. When a particle enters the sphere, it ionizes some of the gas, generating electrons. A sensor in the middle of the sphere held at a high voltage attracts the electrons, creating a charge that can be measured. NEWS-G is supported by 11 institutions in five countries.

**OSCURA** (Observatory of Skipper CCDs Unveiling Recoiling Atoms) is a next generation dark matter detector combining the strengths of both DAMIC and SENSEI. OSCURA plans to scale the skipper-CCD to a 10 kg experiment. OSCURA will bring together the groups at SNOLAB working on skipper-CCDs for the development of the largest dark matter experiment based on this technology. OSCURA is supported by 14 institutions in six countries.

**PICO-40** is a bubble chamber designed to look for dark matter. The fluid in the bubble chamber is superheated, so when a particle interacts, it boils and creates a bubble. This bubble is captured on camera and microphone, and studying it can tell scientists about the particle that caused it. PICO is supported by 17 institutions in seven countries.

**PICO-500** will be a next generation dark matter detector building upon the principle demonstrated by previous bubble chamber experiments. This larger detector will have an active volume of about 250litres and will use a synthetic quartz vessel, similar to that used by PICO-40. The design of PICO-500 is being finalized and construction of the experiment will begin soon. PICO is supported by 17 institutions in seven countries.

**SENSEI** (Sub-Electron-Noise Skipper CCD Experiment Instrument) uses skipper CCDs to search for dark matter. When a particle interacts, it causes a small energy change which is captured by the CCD. The

CCDs have millions of pixels, and SENSEI is able to count every electron within a pixel, leading to incredibly accurate measurements with no background noise. SENSEI is supported by six institutions in three countries.

**SBC** (Scintillating Bubble Chamber) will be designed to detect both dark matter and coherent elastic neutrino-nucleus scattering. Using a target volume primarily composed of argon, the nucleation signal from electron recoils, which is the limiting factor for low-threshold studies in bubble chambers, is suppressed, allowing for the exploration of new parameter space. The SBC collaboration is supported by 12 institutions in three countries.

**SuperCDMS:** (Super Cryogenic Dark Matter Search) is a second generation low-mass dark matter experiment that uses silicon and germanium crystals at cryogenic temperatures. The detectors sense both crystal lattice vibrations and ionization generated within the detectors. SuperCDMS is supported by 24 institutions from five countries.

## NEUTRINOS

**HALO** (Helium And Lead Observatory) uses lead blocks and helium to detect neutrinos. HALO is part of SuperNova Early-Warning System (SNEWS), a group of detectors around the world that alert astronomers to neutrino bursts associated with supernovae that arrive before the light does. The warning system can direct telescopes to the location of the supernovae it can be directly observed. HALO has 12 partner institutions in four countries.

**LEGEND-1000** (Large Enriched Germanium Experiment for Neutrinoless ββ Decay) would be the largest germanium neutrinoless double beta decay experiment every constructed. LEGEND-1000 will involve more than 50 institutions from around the world.

**nEXO** (next Enriched Xenon Observatory) will be a 5-tonne liquid xenon experiment designed to measure the rare neutrinoless double beta decay. nEXO will involve 31 institutions in eight countries.

**SNO+** uses 780 tonnes of liquid scintillator to detect neutrinos. When a neutrino hits the detector it creates charged particles. When these particles hit the scintillator, it will give off light which is detected by thousands of sensors surrounding the vessel. SNO+ is supported by 21 institutions in six countries.

**SNO+ Te** is the next phase of SNO where the liquid scintillator will be loaded with tellurium, enabling the detection of neutrinoless double beta decay, extremely rare decays in which the nucleus emits two electrons and zero neutrinos.

## LIFE SCIENCES

**FLAME** (Flies in a Mine) is an experiment studying the biological effects of spending time working deep underground, specifically at higher pressure, using fruit flies. Findings from FLAME could be used to improve health outcomes for people working underground. FLAME is a collaboration four institutions in two countries.

**REPAIR** (Researching the Effects of the Presence and Absence of Ionizing Radiation) investigates the effect of very low background radiation levels on living organisms. It studies cancer risk and DNA changes in human cells, and whole-organism development and growth in lake whitefish embryos. REPAIR is a collaboration of five institutions in two countries.

### NUCLEAR SECURITY

The **CTBT** (Comprehensive Nuclear Test Ban Treaty) was adopted by the United Nations General Assembly with basic obligations banning detonation of nuclear explosions. SNOLAB partners with Health Canada in the detection of very small levels of radioisotopes that can provide crucial information about nuclear events, thereby aiding national and international security interests.

### QUANTUM TECHNOLOGY

SNOLAB is partnering with the United States of America Army Research Office, the Institute for Quantum Computing (IQC) at the University of Waterloo, and Chalmers University of Technology in Sweden to investigate the impact of radiation and cosmic rays on quantum technologies. SNOLAB's extremely low background radiation environment and advanced cryogenics capabilities make it an ideal place to conduct valuable controls on quantum bits, or qubits, which hold information at the quantum level. SNOLAB's next generation dark matter experiments also promise to be early adopters of quantum technology.

## Local partners

SNOLAB has developed a strong partnership with Vale that extends beyond the physical location of the laboratory at its Creighton Mine. Vale is a multinational mining powerhouse with extensive expertise in underground operations, technical capabilities, and regulatory requirements. This expertise benefits SNOLAB in the form of operational support and services for SNOLAB's underground infrastructure and systems. The major in-kind contributions Vale provides to SNOLAB are valued at more than $13 million per year, including the use of the mine site for SNOLAB's surface and underground facilities. This contribution represents substantial support for fundamental science.

SNOLAB has grown to become a vibrant member of the Sudbury community and partners with institutions including the Northern Ontario School of Medicine, Laurentian University, Cambrian College, Collège Boréal, the City of Greater Sudbury, and the Greater Sudbury Chamber of Commerce. In addition, Science North, an interactive science centre in Greater Sudbury and the second largest science centre in Canada, is a valuable partner for educational and public engagement.

SNOLAB also partners with local vendors, suppliers, consultants, and contractors in the design, construction, and operations of the plants and projects. The unique challenges for implementation at SNOLAB, both in the cutting-edge science and the underground location, can trigger innovative and

collaborative solutions with these local partners. These interactions can grow the technical capabilities and marketable prestige and expertise of these local partners.


DEAP-3600 / **SNOLAB**

# The international landscape

The global particle physics landscape is highly dynamic and competitive with increasingly ambitious quests for scientific discovery. The infrastructure, technical, and project management expertise and investment required to successfully conduct world-class particle physics research is becoming increasingly complex, diverse, and costly. This is catalyzing the need for increased collaboration and aggregation of resources both nationally and internationally. It is only through such collaboration that increasingly ambitious and grand scientific objectives can be achieved, and that research program gaps can be addressed.

The underground science community continues to expand and evolve at a rapid rate. As the demand for underground scientific capabilities continues to increase, new facilities and expansions to existing sites are continuing emerge.

## OVERVIEW OF EXISTING AND PLANNED UNDERGROUND SCIENCE LABORATORIES

SNOLAB has become a leading laboratory and research collaborator within the growing global network of underground research facilities. The following table provides an overview of 16 global underground laboratories and associated attributes such as depth, shielding, size and status.

*Table 1. Overview of existing and planned underground laboratories. The data are collected from publications (where available) as well as facility or public investor websites.*

| Site | Country | Depth (m) | Muon Flux ($\mu/m^2/s$) | Radon ($Bq/m^3$) | Size[3] | Status |
|---|---|---|---|---|---|---|
| **ANDES** | Chile & Argentina | 1750 | $5 \times 10^{-5}$ | - | - | Planned[4] |
| **Baksan (BNO)** | Russia | 1550 | $3 \times 10^{-5}$ | 40 | 3,000 $m^3$ | Operating[5] |
| **Boulby (BUL)** | United Kingdom | 1100 | $4 \times 10^{-4}$ | <3 | 4,000 $m^3$ | Operating[6] |
| **CallioLab** | Finland | 1,444 | $1.1 \times 10^{-4}$ | <20 | 120 $m^2$ | Operating[7] |
| **Canfranc (LSC)** | Spain | 800 | $4.3 \times 10^{-3}$ | 100 | 1,250 $m^2$<br>10,000 $m^3$ | Operating[8] |
| **Jinping (CJPL-II)** | China | 2400 | $3.5 \times 10^{-6}$ | 40 | 7,280 $m^2$<br>330,000 $m^3$ | Operating[9] |

*Continued on Page 21 …*

[3] Volumes and areas of laboratory space are provided where available.
[4] Estimated flux, https://andeslab.org and Physics Procedia, Volume 61, 2015, Pages 534-541
[5] https://www.inr.ru/eng/ebno.html and estimate from K3MNeT muon flux model (Eur.Phys.J.C 80 (2020) 2, 99)
[6] https://www.boulby.stfc.ac.uk/Pages/home.aspx and e-Print: 2212.07037 [hep-ex]
[7] https://calliolab.com/ and Physics of Particles and Nuclei, Volume 49, pages 769–773, (2018)
[8] https://lsc-canfranc.es/en/home-2/ and Eur.Phys.J.C 79 (2019) 8, 721
[9] https://cjpl.tsinghua.edu.cn/column/Experiments and Chin.Phys.C 45 (2021) 2, 2

| Site | Country | Depth (m) | Muon Flux ($\mu/m^2/s$) | Radon ($Bq/m^3$) | Size[10] | Status |
|---|---|---|---|---|---|---|
| **Gran Sasso (LNGS)** | Italy | 1400 | $3.4 \times 10^{-4}$ | 80 | 180,000 $m^3$ | Operating[11] |
| **INO** | India | 1200 | $1 \times 10^{-4}$ | - | - | Planned[12] |
| **Kamioka** | Japan | 1000 | $1.5 \times 10^{-3}$ | 80 | | Operating[13] |
| **Modane (LSM)** | France | 1400 | $4.6 \times 10^{-5}$ | 15 | 3,500 $m^3$ | Operating[14] |
| **PAUL** | South Africa | 1400 | - | <150 | 640 $m^2$<br>10,240 $m^3$ | Proposed[15] |
| **SNOLAB** | Canada | 2070 | $3.1 \times 10^{-6}$ | 130 | 5,000 $m^2$<br>37,241 $m^3$ | Operating |
| **Stawell (SUPL)** | Australia | 1025 | $3.7 \times 10^{-4}$ | 300 (<30 with filtration) | - | Construction[16] |
| **Sanford Lab (SURF)** | United States | 1480 | $5.3 \times 10^{-5}$ | 300 | 242,190 $m^3$ | Operating[17] |
| **Yangyang Lab (Y2L)** | South Korea | ~700 | $3.8 \times 10^{-3}$ | 30-50 | 300 $m^2$ | Operating[18] |
| **Yemilab** | South Korea | 1,100 | $8 \times 10^{-4}$ | 30-2000 | 2,700 $m^2$<br>25,000 $m^3$ | Operating[19] |

## SNOLAB'S ROLE AS A HOST LABORATORY WITHIN THE INTERNATIONAL LANDSCAPE

SNOLAB has become a partner of choice for underground research, not only because of its attractive technical qualifications such as depth and cleanliness, but also because it is welcoming to potential users and provides users with substantial scientific expertise, and project management and technical support to experiments. In addition, Canada provides a geopolitically stable environment needed for long-term international science projects.

[10] Volumes and areas of laboratory space are provided where available.
[11] https://www.lngs.infn.it/en/lngs-overview and e-Print: 2212.07037 [hep-ex]
[12] https://www.ino.tifr.res.in/ino, Eur.Phys.J.Plus 127 (2012), 106, and estimate from K3MNeT muon flux model (Eur.Phys.J.C 80 (2020) 2, 99)
[13] https://www-sk.icrr.u-tokyo.ac.jp/en/ and e-Print: 2212.07037 [hep-ex]
[14] http://lsm.utef.cvut.cz/LSM.html
[15] PAUL Overview, Richard Newman, Paul Project Manager, Stellenbosch University, Jan. 18, 2024
[16] https://www.supl.org.au/, e-Print: 1805.06794 [nucl-ex] and accompanying full report, and Koo, J. 2016, Master's thesis (The University of Melbourne, School of Physics)
[17] https://sanfordlab.org/ and e-Print: 2212.07037 [hep-ex]
[18] https://cupweb.ibs.re.kr/en/facilities-and-equipment/underground-labs/y2l/, Front. Phys. 10 (2022), and JCAP 02 (2021), 013
[19] https://cupweb.ibs.re.kr/en/facilities-and-equipment/underground-labs/yemilab/ and Astroparticle Physics, Volume 114, 2020, Pages 60-67

Access to the underground research facilities described above varies broadly. It is determined by a myriad of factors such as: the national or international nature of the laboratory; access protocols; experiment peer-review processes and criteria; experiment requirements (such as depth, cleanliness and shielding for detectors); funding; and cost of operations. These elements influence decision-making on the ideal location of an underground experiment. Furthermore, geopolitical factors may play a role in determining how welcoming and accessible a facility may be to a team of scientists that represents many countries.

SNOLAB's capabilities have attracted major next generation experiments to SNOLAB's scientific program in recent years. This has positioned SNOLAB — the best shielded underground clean laboratory space with the lowest cosmic radiation in the world — as a global leader in deep underground science. This continues to be important as other high-profile physics research teams in areas such as the search for dark matter or the study of neutrino properties make decisions about where to locate their world-class experiments.

### *The Laboratory*

The SNOLAB campus includes laboratory space located both underground and at the surface. The campus includes 5,000 square metres of underground Class 2000 clean space for experiments of varying sizes and supporting infrastructure. In addition, the campus includes 3,100 square metres of recently renovated surface laboratory space that includes a warehouse, cleanroom labs, chemistry and radio-assay labs, a clean assembly hall, a machining and fabrication shop, dedicated user space, offices, boardrooms, and an auditorium.

SNOLAB features three large detector cavities, as well as safety systems, user support services, and supporting underground infrastructure for experiments including:

- HVAC cleanroom systems providing stable climate-controlled HEPA filtered air;
- electrical distribution infrastructure with automatic full backup generators;
- high-capacity ultra-pure water plant and distribution piping;
- domestic water distribution for flush toilets and showers;
- liquid nitrogen plant, scintillator plant, ultra-pure water plant, and TeA plant;
- compressed air distribution;
- transport logistics and materials handling;
- cleaning infrastructure;
- remote fire panels and building automation systems; and
- high-speed fibre-optics data link to surface.

SNOLAB's Operations group mange all process systems both underground and on the surface, including automation, instrumentation and logistics. Operations also provides skilled mechanical and electrical trades to construct and maintain infrastructure, maintains clean rooms at Class 2000 or better and manages all materials entering the lab.

The Low Background Counting Facility at SNOLAB provides material assay and screening and environment monitoring capabilities both. The facility instrumentation includes:

- five HPGe detectors and two sodium iodide detectors for gamma detection;
- an XIA alpha counter for the detection of alpha particles;
- a dual HPGe detector with coincident capabilities and a Passivated Implanted Planar (PIP) detector provides additional sensitivity to gamma and beta particles;
- three radon emanation chambers and two radon emanation boards;
- a thermal neutron detector;
- a fast neutron detector;
- a Bubble Technology neutron spectrometry system;
- XRF system for surface dust samples analysis;
- various sizes of sodium iodide detectors; and
- an inductively coupled plasma mass spectrometer (ICP-MS).

SNOLAB scientific support staff excel at utilizing this equipment, providing a wide range of physics support, chemical and radiological assay, chemical process development, surface laboratory operations, and a chemical safety program.

The underground laboratory has instrumentation to continuously monitor its radon levels. In addition, the laboratory employs instrumentation for seismic monitoring and a radio frequency spectrum analyzer to survey and catalog areas for electrical noise. The most recent addition to SNOLAB's environmental monitoring suite is an air monitoring station that is used as part of a collaborative effort with Health Canada to monitor compliance with nuclear non-proliferation treaties.

SNOLAB also owns and operates the Cryogenic Underground Test Facility (CUTE) designed to test components of other experiments in an extremely low temperature environment shielded from background radiation, and is designed to prevent micro-vibrations that could interfere with testing.

In addition to the infrastructure built at Vale's Creighton Mine, SNOLAB leverages a facility at Laurentian University for developing radioisotope calibration sources and measurements, sample-based analytical chemistry, and some electrical and detector component testing. SNOLAB also has office and meeting spaces at the university. SNOLAB is working with Cambrian College to co-develop some low background techniques and capabilities.

SNOLAB Research Scientists serve as collaborators in the research programs, providing local coordination and extensive experience within the underground environment, as well as leadership to the experiments as members of experimental collaborations. They are responsible for driving SNOLAB science programs and coordinating collaborators and students.

Large experiments at SNOLAB take many years to execute. They necessitate complex engineering design, construction, and stable operating conditions. Such projects are implemented through the SNOLAB lifecycle process and supported by the SNOLAB project management office (PMO). The PMO provides project management, project engineering, construction coordination, and cost controllers.

This office also interfaces to SNOLAB scientists, logistics support, Environment Health and Safety (EHS), and other corporate support.

SNOLAB's Corporate Services Division provides expert EHS, Information Technology, Human Resources, and Communications supports. The finance group provides budgeting and financial oversight supports.

SNOLAB demonstrates excellence in science, governance and management, design engineering, construction and installation, logistics, project management, technical support, and instrumentation. SNOLAB employees bring a wealth of knowledge and experience in the successful deployment of highly complex underground experiments.

## INTERNATIONAL COLLABORATION AND PARTNERSHIPS

Since its inception, SNOLAB has continued to increase its role within national and international research collaborations and helped stimulate research cooperation that leverages collective resources and expertise. Working closely and collaboratively with its stakeholders, SNOLAB has continued to invest significantly in the global promotion of its research capabilities and expertise, the establishment of international linkages through networking and conferences, and contributing to global physics strategic planning activities.

SNOLAB's collaborations with U.S. laboratories enable Canadian contributions to cutting-edge science and initiate important collaborations with facilities, such as:

- Pacific Northwest National Laboratory on low background radiation initiatives and ultrapure copper production;
- Fermilab in the areas of project management and experiment delivery;
- SLAC National Accelerator Laboratory on cryogenic technologies;
- Sanford Underground Research Facility (SURF) on operations and technical capabilities;
- Lawrence Berkeley National Laboratory towards the realization of the proposed nEXO experiment; and
- Oak Ridge National Laboratory on development for the proposed LEGEND-1000 experiment.

Outside of North America, SNOLAB has built strong connections to other deep underground laboratories and demonstrates leadership within this global community. Working closely with other underground facilities including Gran Sasso (Italy), Boulby (U.K.), Canfranc (Spain), Modane (France), Kamioka (Japan), Y2L and YEMI (South Korea), and SUPL (Australia), SNOLAB shares best practices in operations, management, and in the successful deployment of highly complex underground experiments.

For SNOLAB to not only continue being a partner of choice for underground research, but to also become the leading international lab for underground science, it must continue to exercise leadership with Canadian physics researchers and contribute to the global scientific landscape. SNOLAB must continue to adopt an innovative and agile approach to its research program to address the changing needs of scientists and respond to emerging international opportunities.

## SECTION B – STRATEGY AND IMPLEMENTATION

### SNOLAB VISION

**To be *the* leading international laboratory in deep underground science, hosting the world's most advanced experiments that provide insight into the nature of the universe.**

Cube Hall / **SNOLAB**

### SNOLAB MISSION

- **Enable world-class underground science** performed by national and international collaborative research teams, supporting projects from concept to completion;
- **Spearhead research and development** that maximizes the potential scientific and societal impact from underground projects;
- **Catalyze scientific collaboration** and knowledge exchange through workshops, local engagements, and professional outreach;
- **Promote innovation** through transfer of arising technologies; and
- **Inspire the next generation** of scientists, innovators, and leaders through strong public and educational outreach and formative training opportunities.

## CORE VALUES

**Safety:** This is the foundation upon which we realize our mission: we are committed, both individually and as a team, to protecting the health and safety of our staff, users and collaborators, and visitors.

**Excellence:** We are committed to making full use of and continual improvement to our skills and knowledge. Our focus is on delivering high-quality inspiring science, through driving, supporting, and enabling excellence in research, operations, and community relations.

**Teamwork:** We are committed to the belief that each member brings unique experience and important expertise to the workplace, allowing project challenges to be resolved and creating a work environment that supports cooperation and collaboration in all aspects of work.

**Accountability:** We are committed to upholding an environment of trust, responsibility, and accountability to each other and to our external research communities, funding agencies, and public sponsors. We design our internal governance structures according to best practices and always respect these structures.

**Diversity:** We are committed to strengthening our team by embracing different perspectives. We strive to ensure our culture and work environment are fair and respectful and support the success of all. Creating a diverse and inclusive workplace will accelerate science, innovation, and discovery.

## STRATEGIC GOALS, OBJECTIVES AND MEASURES OF SUCCESS

Three core pillars underpin SNOLAB's Strategic Plan. For each, we have identified a goal along with a set of key objectives and expected measures of success.

### EXCELLENT SCIENCE

*Goal: Drive breakthrough discoveries at the frontiers of underground science.*

*Expected outcomes:*

- Cementing of Canada's leadership in deep underground science.
- A stronger, more competitive Canada in scientific discovery.
- More Canadian researchers positioned as global leaders.

**Objective 1: Increase the understanding of the particles and forces that shape the universe.**

**SNOLAB actions:**

- Maintain a strong focus on delivery of science from SNOLAB's world-class research efforts in neutrinos and dark matter detection by collaborating with the scientific community to both construct, upgrade, and operate state-of-the-art experiments.
- Site at least one large experiment with the potential to deliver world-leading science results in either the Cryopit or the Cube Hall.
- Enhance the supportive model of the project management office to better support experiments from concept to operations.

**Measures of success:**

- Delivery of published science results from SNOLAB's currently operational experimental program which includes SNO+, NEWS-G, SENSEI, DAMIC, PICO-40L, and HALO.
- Transition the experiments SuperCDMS, DEAP-3600, and PICO-500, which are currently under construction, to their operations phase.
- Achieve a balanced portfolio of experiments such that the laboratory always has some experiments in their operations phase, some experiments in their construction and commissioning phase, and some experiments in their design phase, and that negotiations are ongoing with experimental collaborations working towards an expression of interest to site experiments at SNOLAB.
- Integration of a next generation tonne-scale double beta decay and/or a third-generation dark matter experiment into the SNOLAB life-cycle process.

**Objective 2: Pursue new opportunities in emerging areas of underground science.**

**SNOLAB actions:**

- Engage the SNOLAB scientific community through the SNOLAB Experiment Forum and SNOLAB user meetings to understand the needs of the SNOLAB scientific community.
- Host biennial SNOLAB Future Projects Workshops to engage with the global underground physics community on potential future SNOLAB projects.
- Connect with researchers from Canada and strategic international partners to initiate a quantum technology strategy that includes the SNOLAB scientific program.
- Maintain a balanced portfolio of experiments.

**Measures of success:**

- Creation of an impactful research plan that positions SNOLAB to be fully utilized by 2029.
- Attract the best scientific opportunities in underground science and continuous demand for SNOLAB space and resources.
- Creation of a quantum technology program at SNOLAB that is integrated into the Canadian scientific landscape.
- Increased number of Canadian scientists who are leading research in emerging areas of underground science.

**Objective 3: Become an international hub fostering collaboration and connection.**

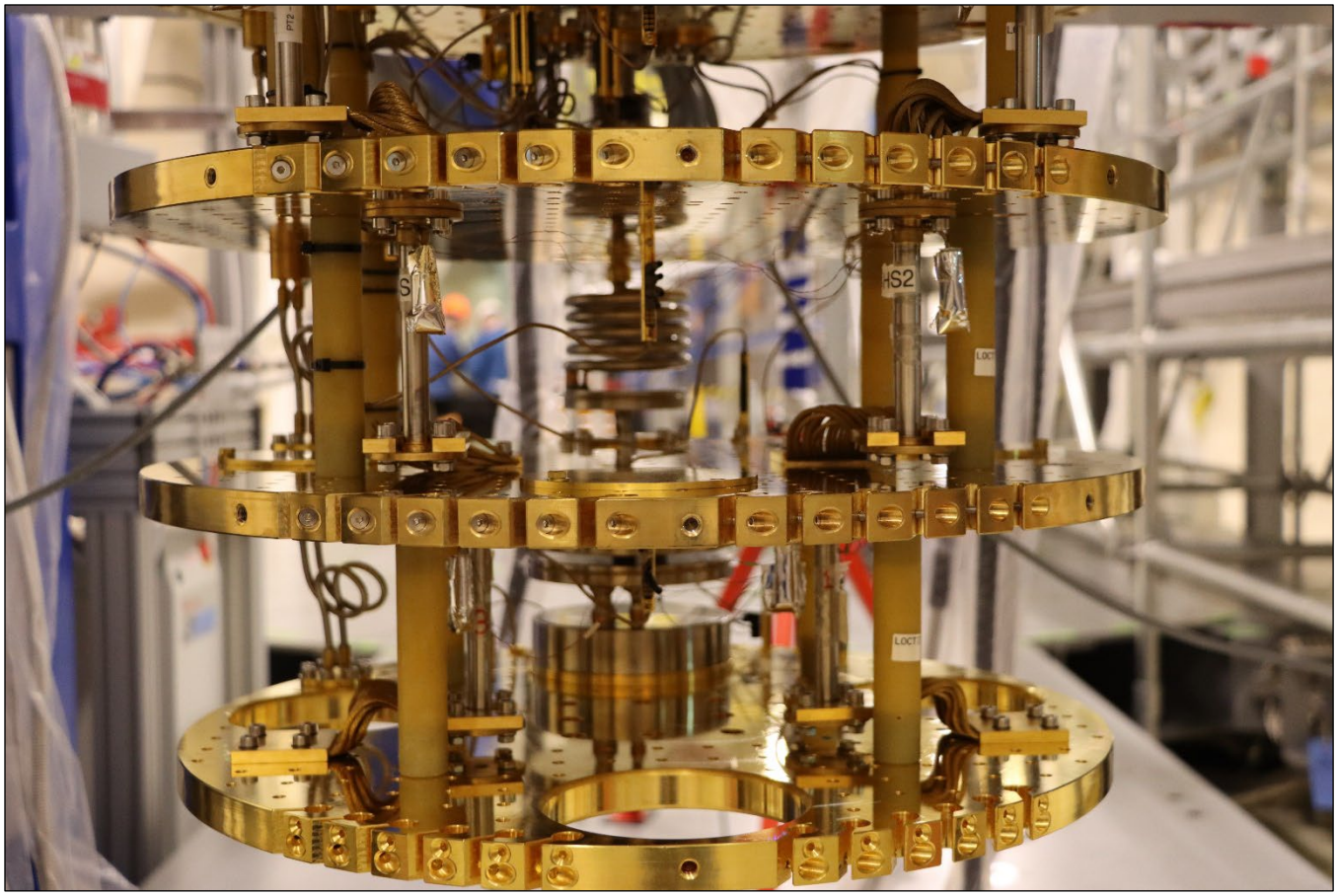
**SNOLAB Actions:**

- Create and sustain a Scientific Hub Program that increases the reputation of the lab, provides professional development opportunities for researchers, and enhances student education experience.
- Create an intellectually stimulating environment for the exchange of ideas.
- Attract more international community members to SNOLAB.
- Cultivate a new mechanism to allow research scientists to conduct direct research.
- Enhance visibility of scientists in the SNOLAB community as leaders in their fields of study who are critical to the success of our programs.

**Measures of success:**

- Enhanced reputation of SNOLAB and Sudbury resulting in senior personnel visiting the laboratory for extended stays.
- Enhanced recruitment and talent to scientific positions at SNOLAB and from SNOLAB to other opportunities.

- Through access to leaders in their fields and longer-term stays, accelerated progress of student users to their degrees.
- Attraction of theorists, computational physicists, and/or phenomenologists for extended visits to SNOLAB.
- Host at least one major international science conference at SNOLAB.
- SNOLAB research scientists become principal investigators, creating opportunities for them to provide leadership in all aspects of research projects and contribute to the diversification of SNOLAB funding sources.
- SNOLAB scientific staff recognized as leaders in their fields as measured by recognition with awards or fellowships.
- SNOLAB scientists recognized as leaders in their fields as measured by invitations to give plenary presentations at national and international venues.



SuperCDMS Dilution Fridge / **SNOLAB**

## CUTTING-EDGE INFRASTRUCTURE

*GOAL: Continuously improve our research infrastructure to remain state of the art.*

*Expected outcomes:*

- Attraction of the most advanced international experiments to Canada.
- Greater global impact and enhanced reputation of Canada's underground science infrastructure.

**Objective 1: Explore the full potential of cryogenic systems.**

**SNOLAB actions:**

- Increase capacity to produce liquid nitrogen.
- Research and development of techniques to produce detector quality liquid argon underground.
- Develop a program to fully utilize the Cryogenic Underground Test (CUTE) facility for experiment prototyping.

**Measures of success:**

- Production of detector grade purity liquid nitrogen.
- Continuous availability of liquid nitrogen produced underground to SNOLAB experiments and infrastructure.
- Reduced underground shipments of liquid nitrogen dewars.
- Delivery of a conceptual design for an underground liquid argon plant that could be deployed when resources become available.
- CUTE facility fully allocated looking forward at least six months to one year with clear instructions for the preparation and submission of user proposals and documentation of the proposal adjudication process.

**Objective 2: Innovate new technologies and tools for ultra-low background environments.**

**SNOLAB actions:**

- Research and development of techniques to improve our capabilities to measure low level radioactive gasses in materials.
- Expand ICP-MS capabilities to more material types and institute a quality measurement program for our ultra-pure water.
- Explore the impact of coincident gamma ray measurements for improving the sensitivity of our high-purity germanium capability.
- Explore the development of new underground radiopure fabrication capabilities (such as electroforming, 3D printing, crystal fabrication, etc.).

**Measures of success:**

- Provide quantified noble gas transfer efficiencies.
- Lower the radon counting background by a factor of two through improvements to existing SNOLAB Lucas cells or replacement of Lucas cells with alternate technology.
- Provide ICP-MS measurements of solid materials that can be digested in nitric acid as requested by users.
- Provide continuous reliable records of ultra-pure water quality.
- Increase sensitivity to faint gamma ray emissions in materials by a factor of two or more.
- Produce a report on the scientific viability of new fabrication facilities and a conceptual design of such facilities to set the ground for the next strategic planning period.

**Objective 3: Continue upgrading SNOLAB's operational systems.**

**SNOLAB actions:**

- Create an investment strategy that will improve power delivery by minimizing power interruptions and improving power quality.
- Ensure the underground lab's chilling capacity meets the needs of the community in the near and long term.
- Update and upgrade the basic infrastructure of the underground lab to meet the needs of our staff and community.
- Continue to develop the resource planning processes to allow better predictability and transparency of the deployment of operations division resources.
- Development of an online system that is accessible to users and staff to track material location and movement.
- Improve laboratory wide communication with respect to SNOLAB research, project management, resources, and technical services through the development and creation of sitewide SharePoint site that includes links to resources and work requests and includes automated, digital workflows.
- Continue to develop best practices around information security by working toward both Ministry of Innovation, Science, and Economic Development Canada (ISED) baseline cybersecurity controls for small and medium organizations and ISO27001 standards.
- Ensure SNOLAB has appropriate security controls to protect business systems and research by continuous improvement of cybersecurity controls.
- Assess SNOLAB's existing security controls versus an industry recognized cybersecurity framework and execute projects to address deficiencies based on their priority.

**Measures of success:**

- Delivery of a project proposal with schedule, budget, equipment specifications, and requirements for the installation of a bridging power supply that can be mobilized as funding becomes available.
- Implementation of an analytics system that allows a detailed understanding of our chilling capacity and use.
- Delivery of conceptual design for the future replacement of our chilling system with evaporative cooling capacity.
- Updated underground shower facilities, with consideration to improve EDI aspects of the transition from the mine to the clean lab.
- Creation of an additional airlock system in the BAR/TAD area of the laboratory to improve the cleanliness and better utilize the space.
- Enhancement of the process plant exhaust system to improve laboratory cleanliness and versatility.
- Deployment of a functional system that tracks resource requests and is accessible by staff and users.
- Deployment of functional system that tracks material location and movement and is accessible to staff and users.
- Improved transparency of processes, improved access to policies and procedures, and improved communication of critical information as measured by the staff engagement survey and user satisfaction survey.
- Develop and implement a SNOLAB cybersecurity strategy that meets the Cybersecure Canada certification requirements.
- Improved scores on cybersecurity benchmark tests.

**Objective 4: Deepen SNOLAB's focus on safety and sustainability.**

**SNOLAB actions:**

- Expand our capabilities to conduct hazard-specific reviews in the engineering office to include fire risk assessment.
- Improve awareness of cryogenic hazards on site.
- Develop a program to account for research risks to projects at SNOLAB.
- Install electric vehicle (EV) charging stations, investigate solar panels, and continue to seek opportunities to reduce consumption of single-use plastic.

**Measures of success:**

- Key personnel in the engineering office trained in fire risk assessment.
- Development and deployment of sitewide cryogenic awareness training.
- Inclusion of research risk analysis into the project life cycle.

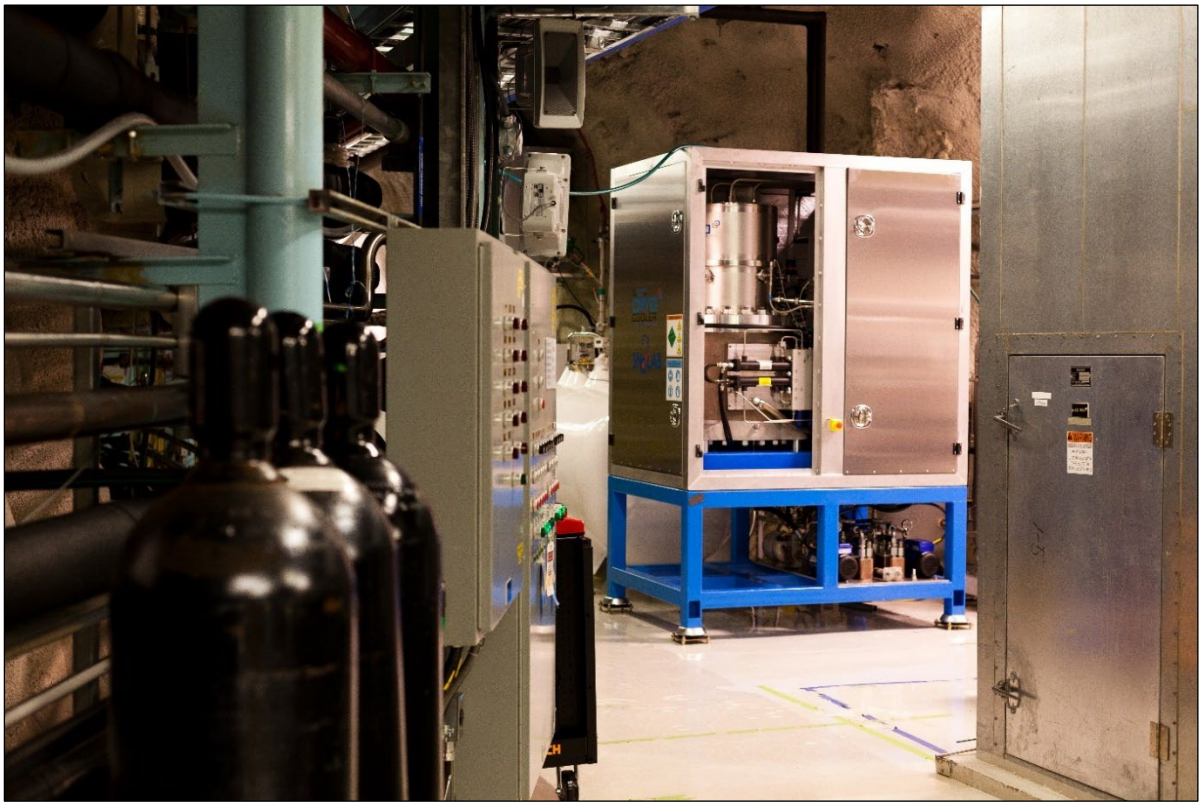
**Objective 5: Export SNOLAB underground infrastructure expertise around the world.**

**SNOLAB actions:**

- Work with major Canadian physics laboratories to formalize the organization of an annual project management conference.
- Interact with technical experts and personnel from other Canadian and international facilities through meetings, site visits, and exchanges of personnel.
- Participate in external reviews of experiments and projects that are not sited at SNOLAB.

**Measures of success:**

- SNOLAB participation in annual management conference with major Canadian physics laboratories.
- Increased number of requests for SNOLAB participation in meetings, visits, experiment and project reviews, and personnel exchanges.



Liquid Nitrogen Plant / **SNOLAB**

## SKILLED PEOPLE

*GOAL: Foster and develop diverse talent in an inclusive environment.*

*Expected outcomes:*

- Canadian leadership in advancing EDI in research facilities.
- A new generation of HQP prepared to discover and innovate in a global economy.
- Greater access to science, technology, engineering, and math (STEM) skills and opportunities in Northern Ontario.

**Objective 1: Embed equity, diversity, and inclusivity (EDI) into everything we do**

**SNOLAB actions:**

- Attract the best talent in underground science by implementing best practices for recruiting, hiring, and retaining a diverse workforce.
- Recruit a diverse set of board members who are representative of Canada's population.
- Create a standing EDI committee at SNOLAB to advise the Executive Director on policies, practices, and procedures.
- Require all experimental collaborations at SNOLAB to have an EDI plan and a code of conduct.
- Enhance the visibility of SNOLAB EDI expertise in the global community as leaders in the field, critical to the success of our programs.

**Measures of success:**

- SNOLAB will strive to meet the ISED 50-30 challenge to increase the representation and inclusion of diverse groups within the SNOLAB board of directors and senior management.
- An equitable workspace that is inclusive and diverse as measured by increasing scores the staff and user engagement surveys.
- SNOLAB staff and scientists recognized as experts in EDI as measured by and receiving invitations to give plenary presentations at national and international meetings, invitations to sit on external EDI committees, and published papers on EDI best practices.

**Objective 2: Increased professional development and training opportunities.**

**SNOLAB actions:**

- Expand and promote our Engineer-In-Training (EIT) program.
- Enhance staff knowledge and capabilities in cryogenics and low-background techniques.
- Expanded staff knowledge and capabilities in construction methods, technical procurement, contract administration, and scheduling.
- Develop engineering proficiency in performing finite element analysis in engineering design projects and thermal simulations for fire hazard analyses and cryogenic design.
- Develop project management training of key SNOLAB personnel to diversify the staff who are qualified to lead small projects.

**Measures of success:**

- Development of Professional Engineers of Ontario certified engineers and increased underground technical support to the SNOLAB scientific community.
- Expansion of SNOLAB operations support and project delivery capabilities to SNOLAB scientific community.
- SNOLAB ability to provide a broader range of in-house engineering services for our projects and reduction of need for outsourcing.
- Expanded capacity to support small projects. Assignment of SNOLAB personnel outside the Project Management Office as leads on small projects.

**Objective 3: Focus public engagement efforts on K-12 students.**

**SNOLAB actions:**

- Build a network to improve communication to educators by creating a channel for the communication of news, resources, and learning opportunities to K-12 educators.
- Creation of SNOLAB *Science & Engineering Experiments at Depth: LearnING at SNOLAB* (SEEDLING) program that allows K-12 students to propose small scale experiments that will be conducted underground in collaboration with SNOLAB researchers.

**Measures of success:**

- Stronger outreach to K-12 educators by engagement of at least 25 new educators to SNOLAB programming.
- Engage K-12 students in underground science by securing funding for the SEEDLING program which would allow for the participation of 500 students annually and for SNOLAB to conduct 10 experiments annually from the SEEDLING program.

# SECTION C – GOVERNANCE AND MANAGEMENT

## GOVERNANCE

The SNOLAB Institute (SNOLABI) is formally an unincorporated Senate-approved Institute of Queen's University. SNOLABI is operated through a trust agreement between five university partners: Carleton University, Laurentian University, Queen's University, University of Alberta, and the Université de Montréal.

The SNOLAB Institute Council is comprised of the Vice-Principals of Research (VPR) from each of the five university partners. The council is currently chaired by VPR at Queen's University. This council recommends the election, renewal, or revocation of members to the SNOLABI Board for approval by the Principle of Queen's University. The SNOLABI Board includes one director from each host institution and Vale. In addition, independent directors are appointed from academic, education, and industrial sectors.

The SNOLABI Board responsible for the stewardship of SNOLABI. This board provides direction in all affairs of the organization to ensure SNOLABI has the means, quality, depth, and continuity of management required to realize its major scientific and operational objectives. In addition, the SNOLABI Board oversees the conduct of the SNOLABI business, provides strategic direction, ensures that SNOLABI is managing risk, and that it will be financially sustainable.

## FUNDING

SNOLAB's operations are generously supported federally by Ministry for Innovation, Science, and Economic Development through the Canada Foundation for Innovation, and provincially by the Government of Ontario.

Project and infrastructure funding has been provided by the Province of Ontario through the Ministry of Research, Innovation and Science, the Ontario Innovation Trust (OIT), and the Northern Ontario Heritage Fund Corporation (NOHFC); and from the Government of Canada through the Canada Foundation for Innovation (CFI), the Natural Sciences and Engineering Research Council (NSERC), and the federal economic development agency for Northern Ontario (FedNor).

SNOLAB also benefits significantly from contributions from its visionary partners: Carleton University, Queen's University, Laurentian University, the University of Alberta, Université de Montréal, and Vale.

## ADVISORY COMMITTEES AND USER ENGAGEMENT

The Project Lifecycle process at SNOLAB ensures frequent interactions between the experimental teams and the SNOLAB facility staff. This ensures that the needs of individual projects are being

identified and incorporated into SNOLAB planning and execution, with regular updates to these requirements.

To remain fully apprised of the needs of its research community, the organization created the SNOLAB Experiment Forum. This group is composed of representatives from each active experiment and the facility more broadly and meets at least biannually. This forum provides an avenue for

- communication between SNOLAB experiments and the facility;
- disseminating information and requirements;
- discussing and coordinating funding opportunities;
- ensuring scientific priorities of the current experimental program are supported by facility infrastructure; and
- advising on the optimal allocation of SNOLAB resources.

To ensure scientific excellence, SNOLAB established an Experiment Advisory Committee composed of international experts that reports to the Executive Director on the science program that is undertaken at SNOLAB. The Committee performs two roles: providing advice during the initial assessment of experiments that are proposed for location at SNOLAB; and providing advice and oversight on the running program at SNOLAB.

In addition to the mechanisms described above, SNOLAB also engages the broader scientific community to determine future requirements of the community and ensure that SNOLAB is well positioned to support the next generation of experiments. Such engagement includes:

- contributing to community and funding agency strategic planning exercises to provide an overview of global research direction;
- engaging the community in quinquennial strategic planning exercises that define research priorities and deliverables to determine long-term research needs and requirements; and
- conducting biennial 'Future Projects Workshops' that facilitate the informal presentation of new projects to provide medium-term research needs and requirements for planning purposes.

## MANAGEMENT STRUCTURE

In 2023 SNOLAB underwent a corporate restructuring allowing it to focus on becoming a more productive and responsive workplace, to better support SNOLAB's user groups, and to ensure SNOLAB continues to evolve into a hub of scientific endeavour with a global reach. These changes included implementing:

- a streamlined management team, allowing SNOLAB to invest fully in its core business of supporting science;
- simplified reporting structures within groups;
- the reduction of siloing within groups to strengthen communication between them; and

- a more agile management team built on the confidence SNOLAB has in capable and dedicated staff at all levels.

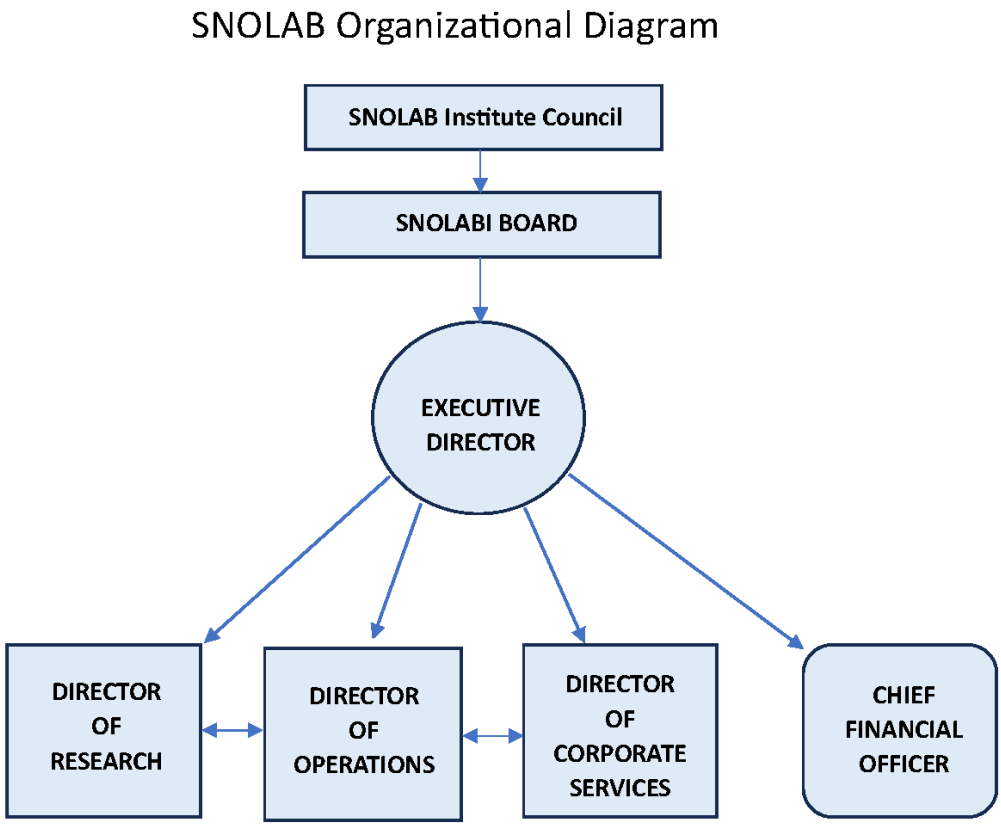
The management organization of SNOLAB is optimally designed to enable its three strategic goals, delivered through the specific objectives outlined in this Implementation Plan.

SNOLAB is managed by an Executive Directors Office (EDO), led by an Executive Director, and comprised of directors of Research, Operations, and Corporate Services, and a Chief Financial Officer (CFO). The organization has a divisional structure as follows:

- Research Division
- Operations Division
- Corporate Services Division
- Finance Group

The priorities, plans, and resource requirements are defined for each division or group by maintaining an annual divisional delivery plan. These plans also detail the specific time-bound actions to achieve the Implementation Plan objectives.

*Table 2. SNOLAB Organizational Chart.*



## APPENDIX A: SNOLAB BOARD OF DIRECTORS

**Robert Svoboda**, *Chair*
University of California, Davis

**Tom Corr,**
AI Partnerships Corporation

**Robert Dunlop**,
retired from Industry Canada

**Aksel Hallin**,
University of Alberta

**Marianne Mader**,
Canadian Association
of Science Centres

**Luc Stafford**,
Université de Montréal

**Ellie Brümmer**,
Vale Base Metals

**Sandra Crocker**,
Carleton University

**Tammy Eger**,
Laurentian University

**Peter Krieger**,
University of Toronto

**Kimberly Palladino**,
University of Oxford

**Nancy Ross**,
Queen's University

**Kim Sturgess**,
WaterSMART Solutions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