Basic Science and Technological Development: Very Beneficial Partners

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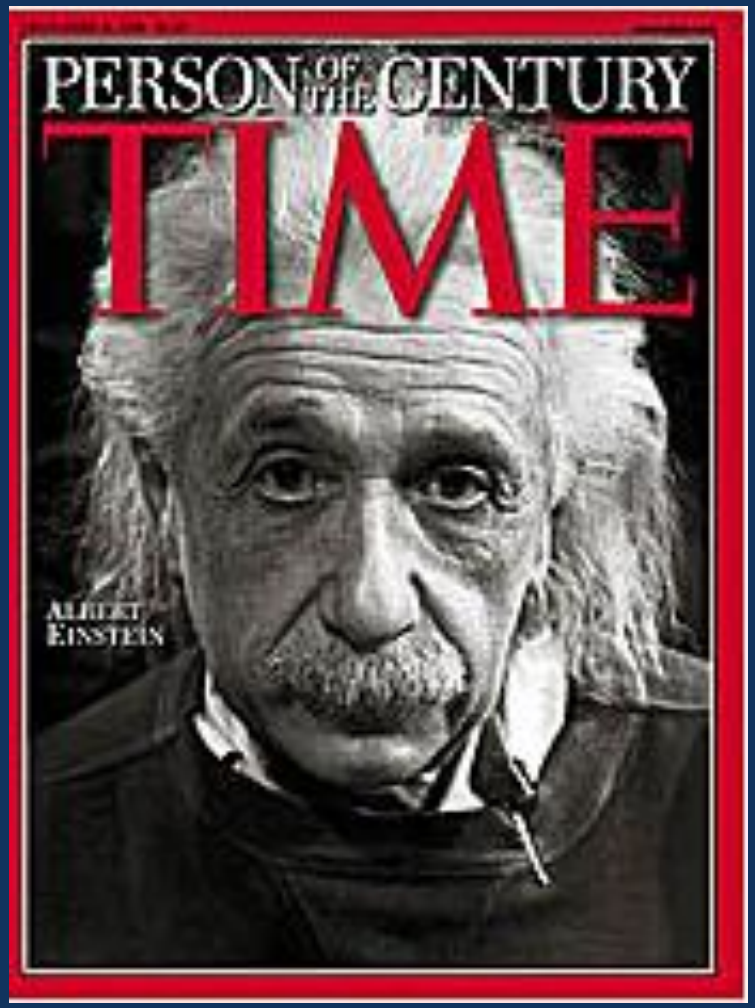


In 2000, TIME magazine chose Albert Einstein as the Person of the Twentieth Century.

- **Not because he invented the computer, the laser, the GPS or other parts of the technological revolution that characterized that century**
- **But his insights in fundamental science (Quantum Mechanics, Relativity) formed the basis for all these technologies.**

- **Understanding our physical world and the basic laws of physics enables our technology in the future.**

- **In return, new technology enables new breakthroughs in Science: A Very Beneficial Partnership**

- **Sometimes breakthroughs influence entire generations:**
  - **Science: Einstein (Quantum Mechanics, Relativity) influenced a century of technology**
  - **Technology:**
    - **Computers have revolutionalized our approach to experiments**
    - **The Laser revolutionized experimental atomic physics**

- **More commonly, developments in science and technology happen through basic and applied scientists working together and understanding the latest aspects of both areas.**

- **The cutting edge moves back and forth and "Necessity becomes the Mother of Invention" in both areas.**

- **Sometimes technology comes to a major obstacle that requires basic science for solution:**
  - **Moore's Law governs computer expansion for decades until one reaches the size of a silicon atom**
  - **The basic science of Quantum Computing becomes a necessity.**

- **Sometimes basic science requires new technology to proceed:**
  - **The Sudbury Neutrino Observatory**
  - **To detect neutrinos from the sun we had to push the boundaries of technology in:**
    - ✓ **Mining excavation and ground stabilization, water purification, electronics, radio-pure materials, computer simulation, data analysis .... often working with industrial partners**

Sudbury Neutrino Observatory (SNO)

Neutrinos are very difficult to detect so our detector had to be very big with low radioactivity deep underground.

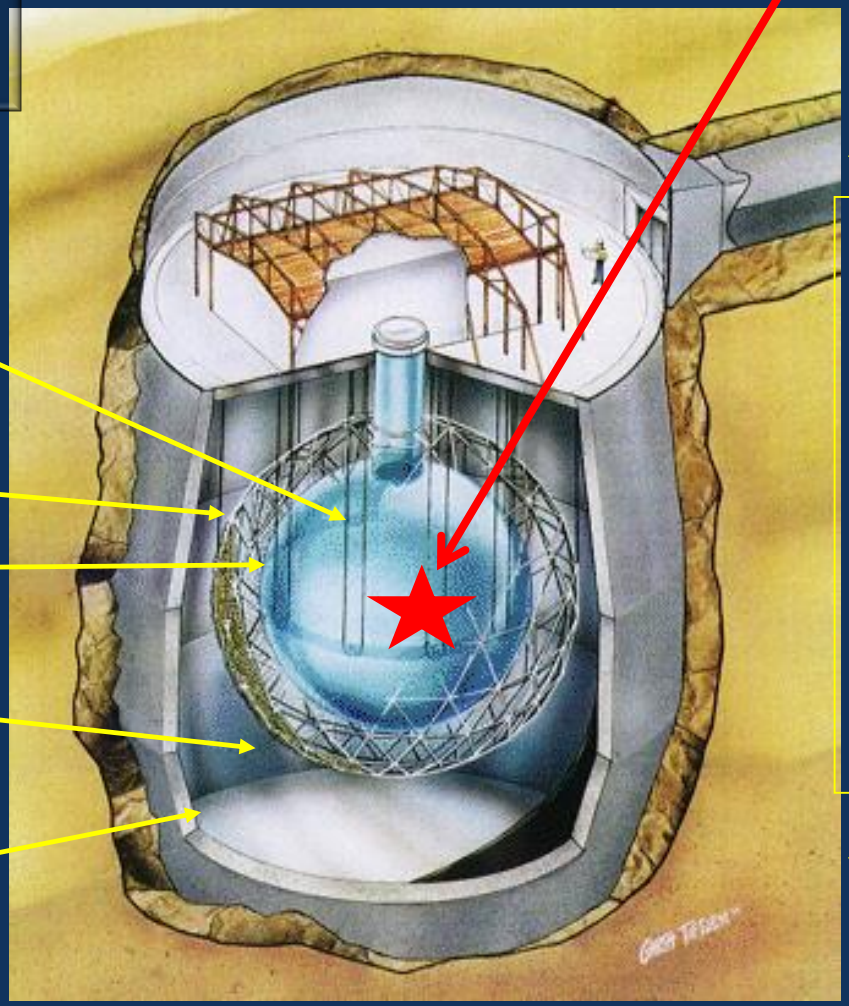
1000 tonnes of heavy water: D_2O
$ 300 million on Loan for $1.00

9500 light sensors

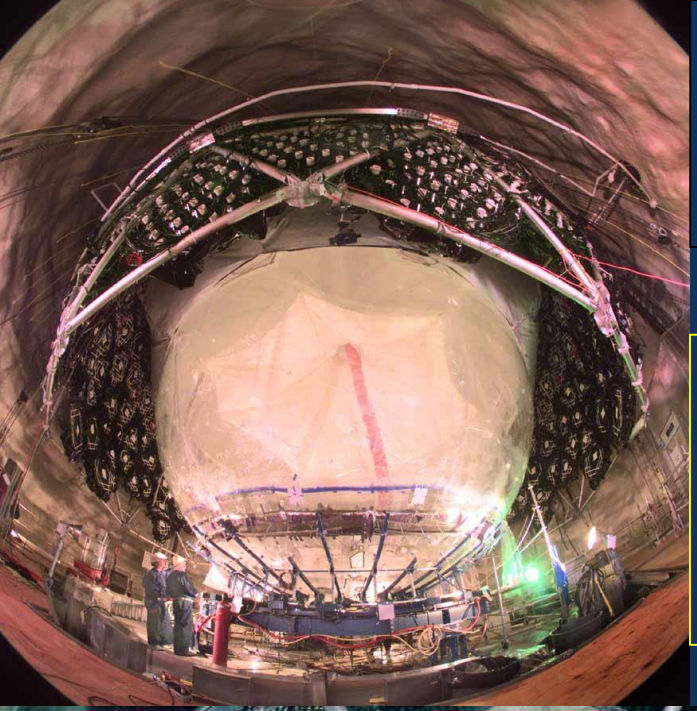
12 m Diameter Acrylic Container

Ultra-pure Water: H_2O.

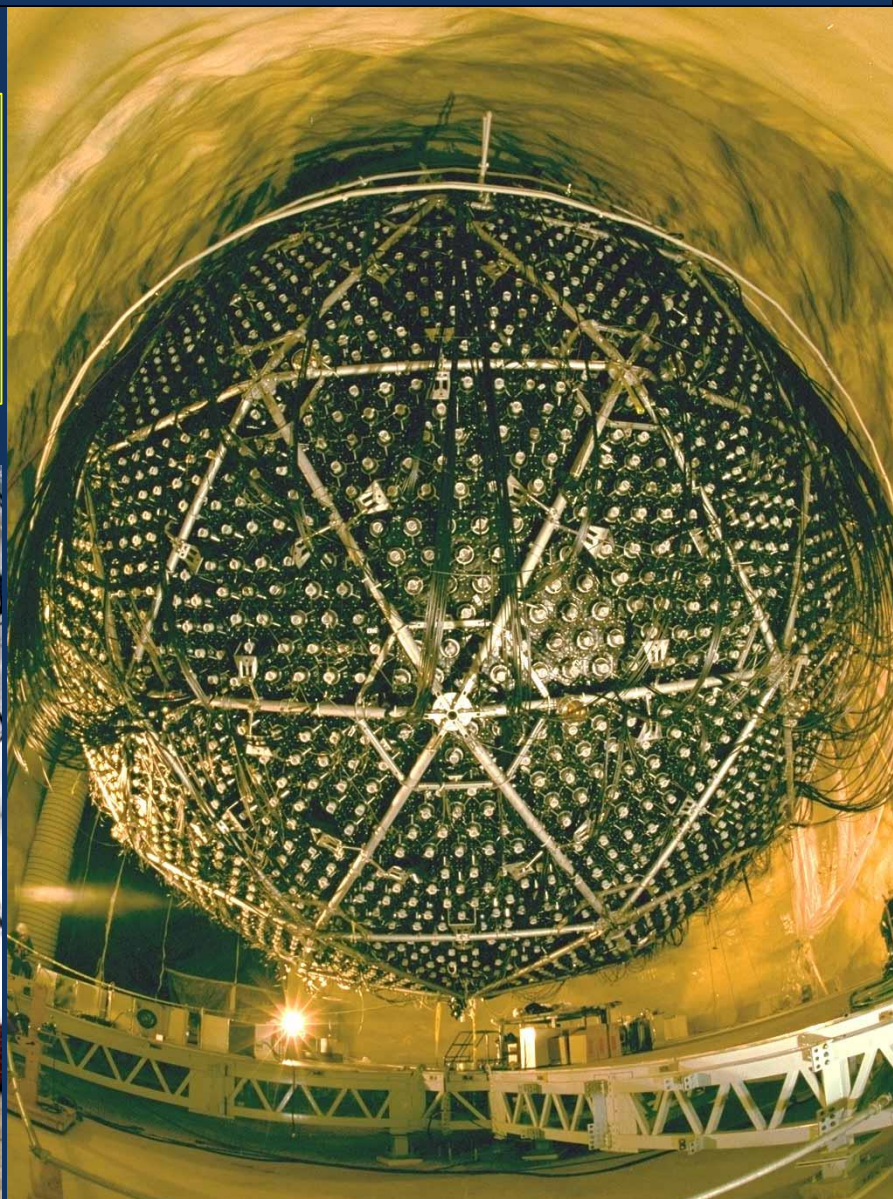
Urylon Liner and Radon Seal



SNO: One million pieces transported down in the 3 m x 3 m x 4 m mine cage and re-assembled under ultra-clean conditions. Every worker takes a shower and wears clean, lint-free clothing.



70,000 showers during the course of the SNO project



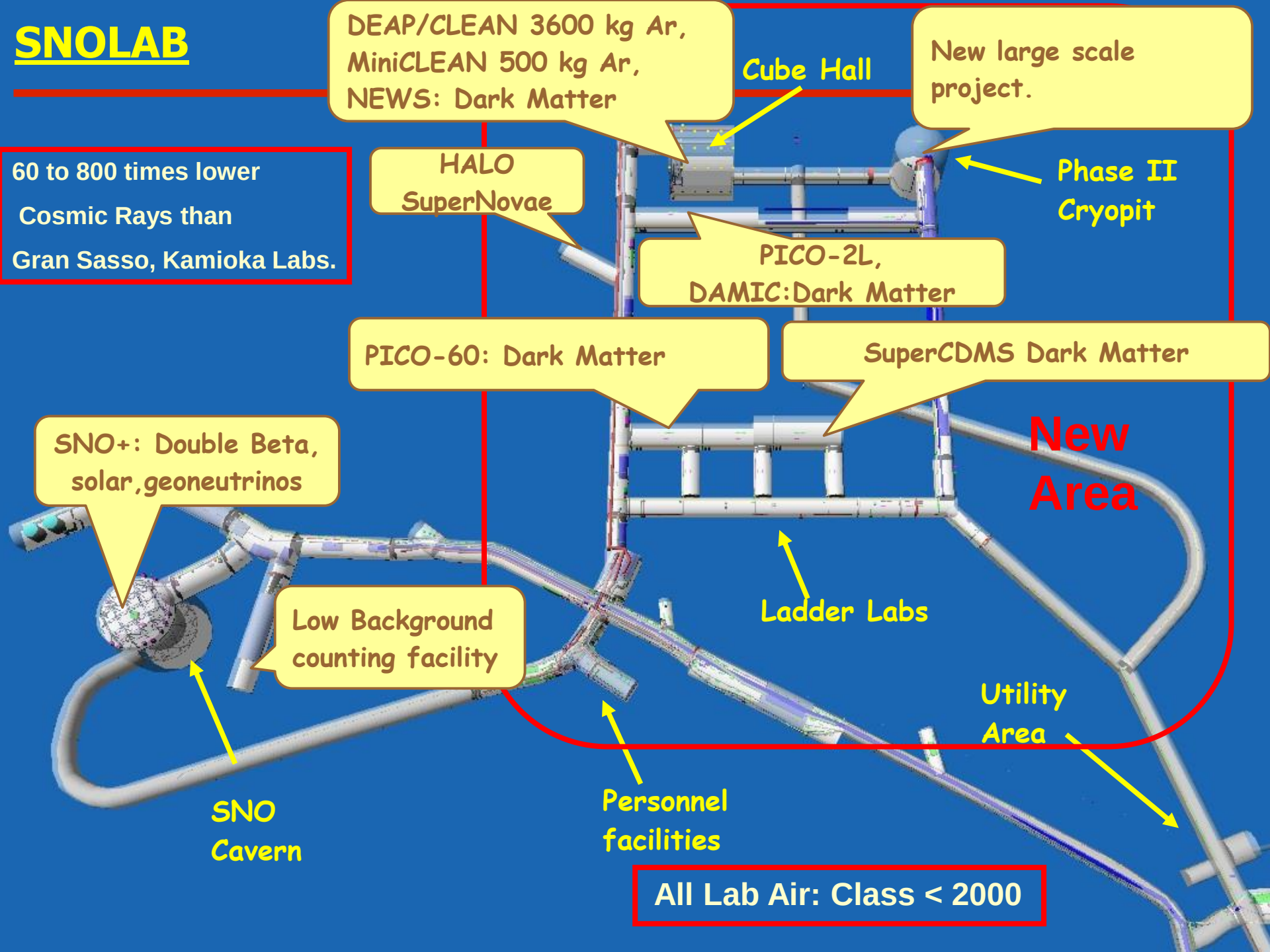
Water systems were developed to provide low radioactivity water and heavy water: 1 billion times better than tap water. Less than one radioactive decay per day per ton of water!!

Steven Hawking's Visit
Posed some special
Challenges – INCO
Designed a special
Rail car for him.

Sudbury Neutrino Observatory (SNO)

- **By building the lowest radioactivity location in the world, we observed one neutrino an hour from the sun with no interference from radioactivity:**
  - **Proving that the physics calculations of how fusion reactions power the sun are very accurate – Of benefit for fusion power technology here on earth.**
  - **Proving that neutrinos change from one type to another and have a finite mass – Requiring changes to the fundamental laws of physics at the most basic level.**
  - **Proving that neutrinos are not the DARK MATTER that fills the spaces between the stars in our galaxy. DARK MATTER particles behave like no particle ever observed in the laboratory.**
  - **Leading to the establishment of SNOLAB, where we are creating some of the most sensitive experiments in the world to detect Dark Matter – and developing new technology to make it possible.**

SNOLAB


DEAP/CLEAN 3600 kg Ar,
MiniCLEAN 500 kg Ar,
NEWS: Dark Matter
Cube Hall
New large scale project.
60 to 800 times lower Cosmic Rays than Gran Sasso, Kamioka Labs.
HALO SuperNovae
Phase II Cryopit
PICO-2L, DAMIC:Dark Matter
PICO-60: Dark Matter
SuperCDMS Dark Matter
New Area
SNO+: Double Beta, solar,geoneutrinos
Low Background counting facility
Ladder Labs
Utility Area
SNO Cavern
Personnel facilities
All Lab Air: Class < 2000

IMPROVEMENTS IN TECHNOLOGY FROM THESE EXPERIMENTS

- **Neutrino and Dark Matter experiments, like all particle physics experiments are continually developing new technologies.**
  - **Light detection devices such as photomultipliers and now Silicon photomultipliers are essential parts of radiation detection for nuclear medicine.**
  - **Silicon photomultipliers, together with liquid Xenon and Argon gamma ray detectors can lead to significant improvements in Positron Emission Tomography (PET) scanners – better resolution, lowering of the required dosage.**

INVESTING IN CANADA'S FUTURE

Report of the Federal Panel on Fundamental Science

"Our government must ensure its support for fundamental research is coherent, effective and agile enough to keep pace with the dynamic nature of contemporary science."

— The Honourable Kirsty Duncan, Minister of Science

Panelists

C. David Naylor	Robert J. Birgeneau	Martha Crago
Mike Lazaridis	Claudia Malacrida	Arthur B. McDonald
Martha C. Piper	Rémi Quirion	Anne Wilson

A detailed study of the federal academic funding system in Canada

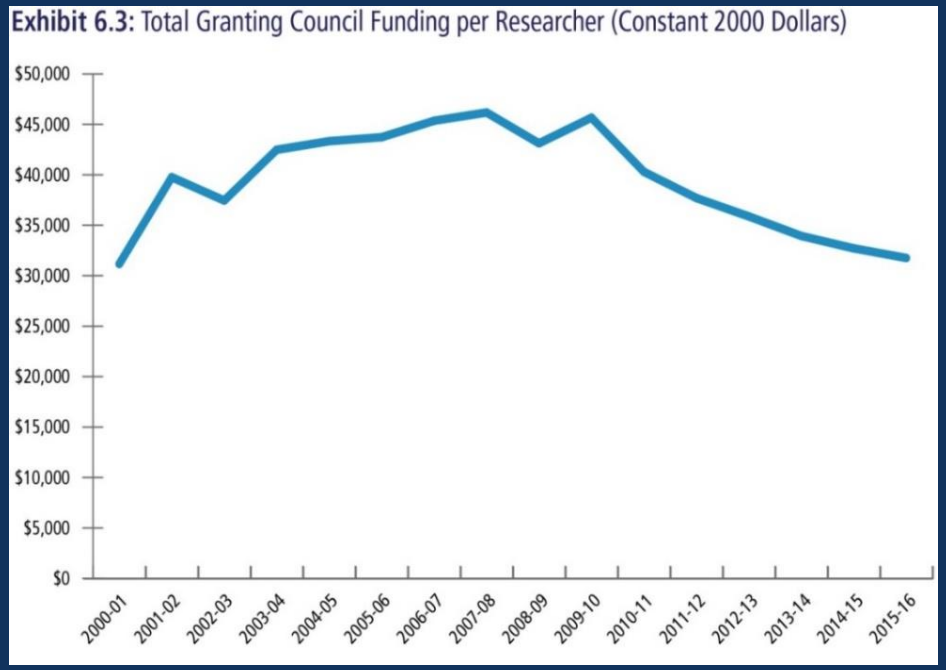
WWW.SCIENCEREVIEW.CA

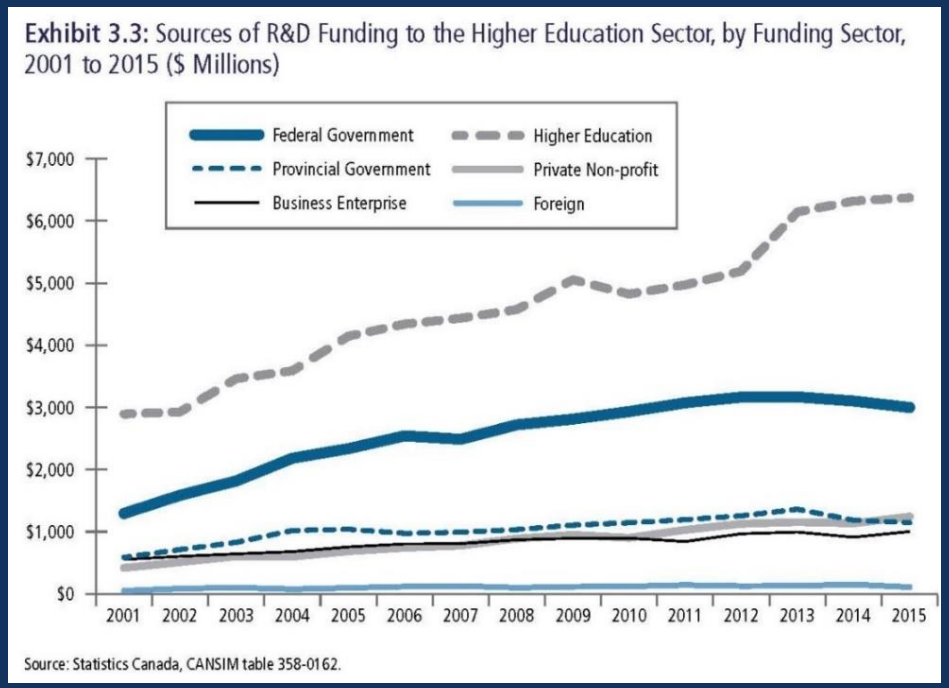
FINDINGS

Canadian accomplishments have long been a source of national pride, but:

- Research competitiveness has been eroded by lack of support for individual researchers

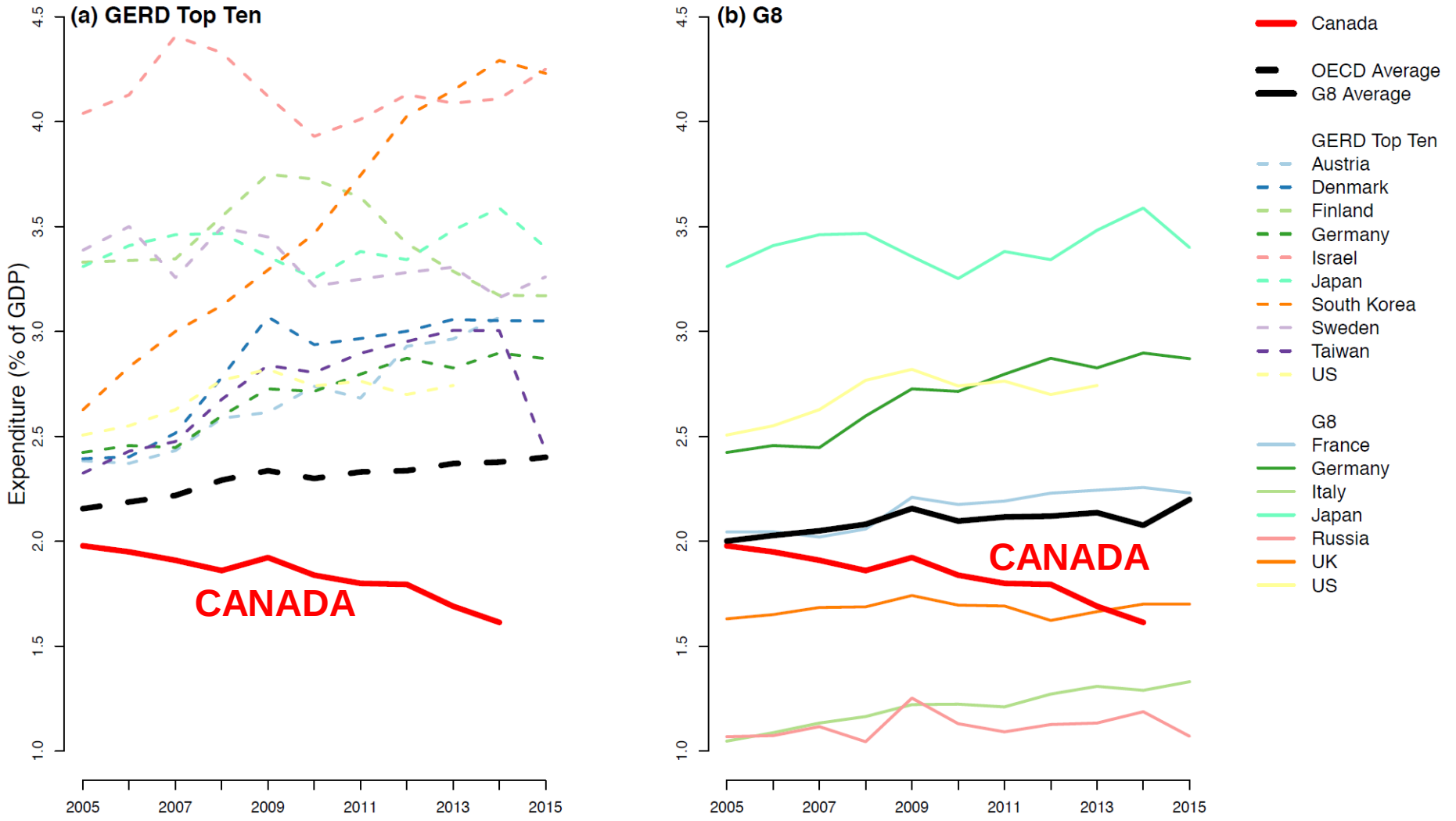
- For Higher Education Research and Development (HERD) there has been a decline in the proportion of federally derived funding. (Now ~23% of Total)





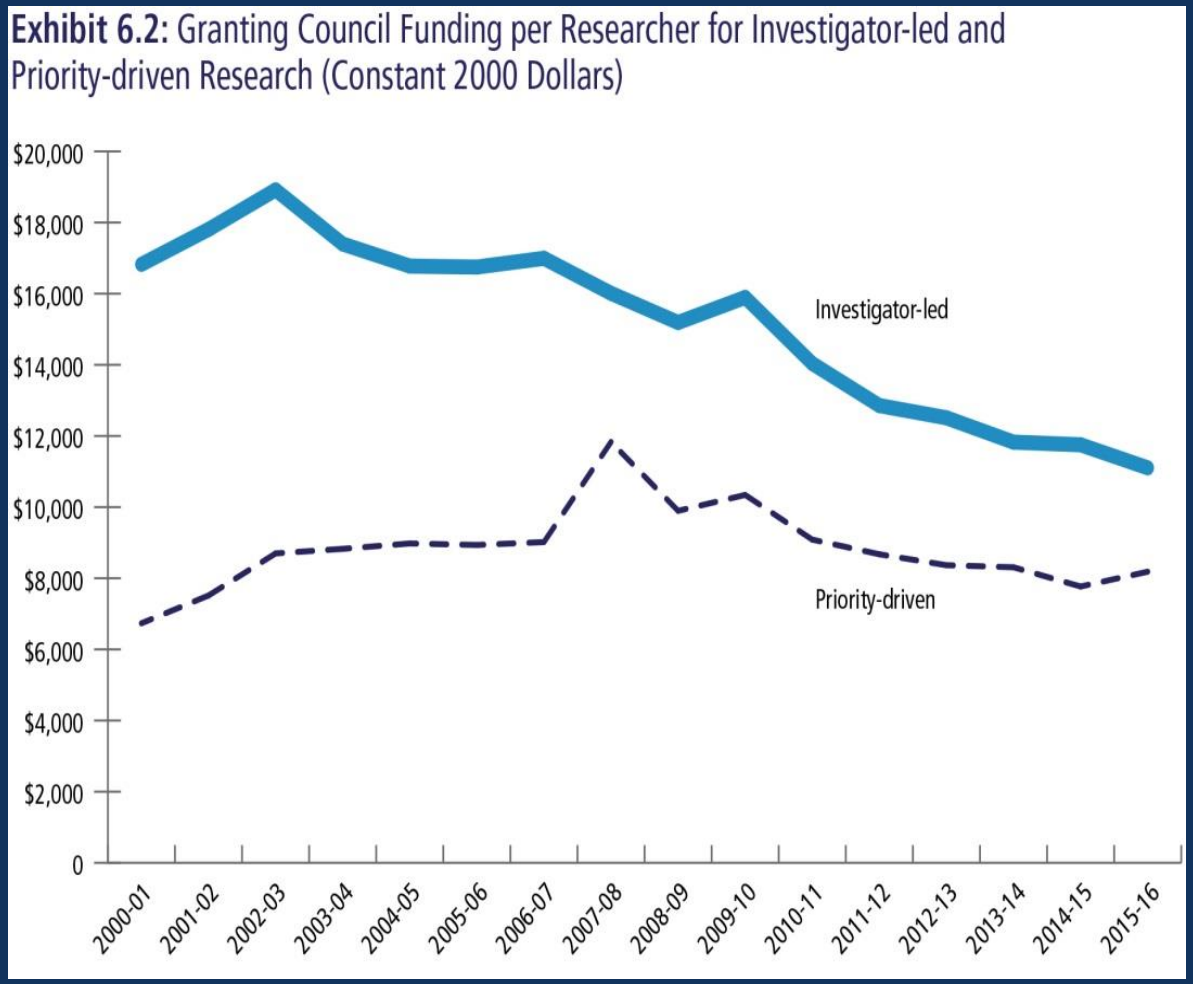
Key facts:

- **Canada Dropped out of top 30 nations for “research intensity”.**
- **GERD (GROSS EXPENDITURES ON RESEARCH AND DEVELOPMENT) is declining**



DIRECT PROJECT FUNDING - PRESSURES

New Funding initiatives in the past 10 years mainly ignored investigator-led research and were primarily directed to top-down, prioritized initiatives for commercialization. We are losing our Fundamental Science base in Canada. This imbalance will greatly affect our ability for Innovation.



The value of Fundamental Science Research to CANADA

- Provides the Evidence for Evidence Based Decision Making across a wide range of Decisions: from social science to health and natural science.
- Provides the next generation of Highly Qualified Personnel who have learned how to solve fundamental problems. This is essential for a world-leading country in innovation and social justice.
- For our Innovative businesses, provides Technology Leaders who can scan the Canadian and international landscape at the point of transition from fundamental to applied technology.
- Attracts high quality personnel and businesses to Canada: students, immigrants and businesses.

Over SNO 200 students and Post Docs are now contributing broadly to society 10 years after the experiment was completed:

University Professors: 26 %,

5 Canadian Universities + Berkeley, Oxford, Heidelberg, MIT, Queen Mary, Lancaster…

Industry: 24%, including

Owners, CEO: Membratec, Zuxell, Tree MD, Clickmox, ITG Financial
Technical Leads: Boeing, Inphi, SUSS Microtec, NEC, Anaconda, AltaSens, Encoded Genomics, Carl Zeiss, Honeywell, Jannatec, Pelmorex, Sequitor Labs, Data Motion, Agilent, NanoString Tech, IBM, Bubble Tech, Phillips

Major Research Laboratories: 26%, including

Medicine, Physics, Geophysics, Nuclear Chemistry, Genomics, Canadian Nuclear Labs (Chalk River), TRIUMF, SNOLAB, 4 US National Labs.

Government: 15%, including

CMHC, National Defense, Natural Resources, UK Business, IT Security

Finance: 7% including

JP Morgan, Travellers Ins, Wells Fargo, BMO, Rock Creek, Squarepoint

The Report's Recommendations dealt with:

- **Governance, Oversight and Advice**
  - **Chief Science Advisor**
  - **Improvements to Peer Review processes (Equity, Diversity)**
  - **Four Agency Coordinating Board (SSHRC, CIHR, NSERC, CFI)**
  - **National Advisory Committee on Research and Innovation**
  - **Stabilization of funding for CFI (Infrastructure)**
- **Support for Diversity, Early Career Researchers**
- **Multi-Disciplinary Research, Internationalization, Rapid Response**
- **Restoration of funding levels for Granting Councils to 2006 levels. 35% increase over 3 years for investigator-led research**

- **Balance between Support for Basic Science and Technological Development is important for future success in both**

- **We have wondeful opportunities for advances each of these areas in Canada with a balanced future program**