LAB TO INDUSTRY: SCIENCE AT WORK FOR CANADA

BY SYLVAIN CHARBONNEAU

For many physicists, the lab is their universe; it's a place where ideas take form, are advanced, and where they study everything from massive galaxies and cosmic nurseries, to tiny particles and hot droplets of matter and laser-cooled atoms. While some physicists focus on fundamental science, others choose to conduct applied research for the development and commercialization of new products and technology. At the National Research Council of Canada (NRC), our cosmos is all-encompassing, merging all the goals of research, and working to advance society. But just as the great expanse of the cosmos appears empty without its stars, so too would our universe be dimmer without the researchers who work tirelessly behind the scenes to advance NRC's mission.

Over the past century, NRC has put Canada on the science map with paradigm-shifting discoveries. Looking through those years, so much of the research has led to an expansion of industry in Canada, and beyond.

When NRC was formed in 1916, Canada had just over four dozen pure science researchers. NRC staff comprised eight academics including one physicist, three industrial members and, interestingly, one banker. By 1925, NRC had grown significantly. After NRC's first full-time president, physicist H.M. Tory, was appointed in 1928, Physics and Engineering was split into two distinct departments. The organization's permanent research laboratories opened in 1932 on Sussex Drive in Ottawa and became world-renowned for an immense range of research projects.

While the Great Depression of the 1930s took its toll on research budgets, the outbreak of World War II brought a reversal of fortune. NRC was well-positioned to mobilize national science expertise for war research and grew its staff significantly under the leadership of President General McNaughton, who dramatically increased military-related R&D. Canada's participation in the war and NRC's work led to the establishment of new industries along with tens of thousands of technology jobs.

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SUMMARY

NRC's research has been contributing to the everyday lives of Canadians for 100 years, and the results have created new industries, new technologies and the jobs of the future.

By 1939 NRC had 300 paid staff, including 75 research professionals, in four laboratory divisions: Biology, Chemistry, Physics and Mechanical Engineering.

ON THE RADAR IN WWII

In 1940, when Britain realized it needed help with the war effort, it sent Henry Tizard on a secret mission to enlist the help of Canada and the U.S. in developing and harnessing the power of radar. At the time, Britain's radar discoveries, such as the cavity magnetron, were state secrets. The partnership with North America meant they had to share their secret technology and their operational experience. As a result, the Tizard Mission brought new technology to Canada: the cavity magnetron and the basic plans for a radar system for anti-aircraft 'gun laying'. This launched radar research at NRC (where no one knew about magnetrons).

The Radio Branch of NRC expanded rapidly, attaining a total staff complement of nearly 300 by war's end. This contributed to the growth of NRC's laboratories to nearly 3000 staff by 1945. In 1941, radar research for the Canadian services and the British government had matured and was ready for commercialization. To manufacture the radar and optical equipment technologies NRC had developed, Research Enterprises Ltd. was created. Approximately 8300 radar sets destined for the Canadian, U.S. and British Forces were built in support of the war effort.

NRC also made history at this point, since for the first time it galvanized a large pool of engineers and physicists to support radar communications. The organization's investment in the war effort led to an ongoing influx of major communications companies from around the world, and Ottawa today is recognized globally for its strength in information and communications technology development.

THE POST-WAR GOLDEN AGE

With NRC's capabilities and leadership status firmly established, resources began to flow inward. Political and university backing helped the organization develop nationally, train more researchers and expand into academia, government and industry with pure, applied and commercial research.

The 1950s and '60s saw progress into areas where none had gone before. For example, nuclear R&D performed in

With NRC's help, Canada installed the first operating radar system in North America – a coastal defence system near Halifax called the "Night Watchman." By 1945 NRC had developed about 30 different types of radar for various military purposes to help the Allies win the war. Source: http://www.nrc-cnrc.gc.ca/eng/about/centennial/achievements.html

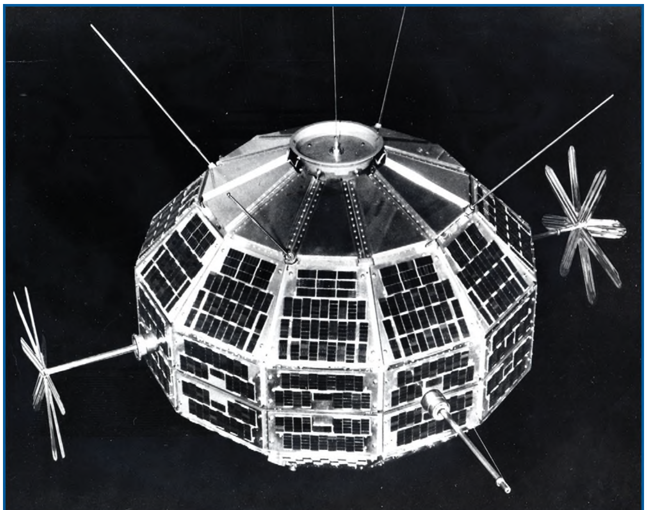
the early 1950s by NRC scientists in Chalk River enabled doctors in London and Saskatoon to create new treatments for cancer, using cobalt-60 gamma rays. NRC's development of the cobalt-60 isotope launched radiation therapy for cancer treatment and positioned Canada as a leader in the area of medical isotopes. Today, Canada produces about 75 percent of the world supply of cobalt-60.

The Sputnik 1 scare in 1957 provoked a significant spike in NRC funding for universities that by 1968 had amounted to nearly $30 million. With Sputnik, the first artificial Earth satellite, the Russians pre-empted the American effort, surprising the world with its success and triggered the international "Space Race."

In 1962, Canada's Alouette 1 – the first artificial satellite designed and built by a country other than the U.S. or Soviet Union – was launched. Built to study the ionosphere by bouncing radio signals back to earth, it featured a solution to a problem that, in 1951, had been solved by NRC researcher, engineer and inventor George Klein. The difficulty was that relaying the signals clearly from such a distance required a number of long, heavy antennas that would not only be cumbersome to transport but also use huge amounts of rocket fuel to launch into orbit. To address these challenges, Klein invented the lighter-weight Storable Tubular Extendible Member (STEM) antenna, which unrolls when the satellite arrives at its destination and remains stable during space operations. In September 1962, when Alouette took off, it was armed with STEM antennas —the first products of Spar Aerospace Ltd., the company now most famous for its Canadarm. The NRC antenna technology also became a standard on the American manned space missions Mercury, Apollo and Gemini.

BACK TO THE FUTURE

NRC has played a strong role in developing myriad inventions over the years, and will continue to do so. Much of the R&D progress and commercialization has been due to the support, expertise and funding provided by the Industrial Research



The Alouette 1 was Canada's first satellite launched in 1962. It carried 4 STEM antennas (2×11 m and 2×22.5 m). Source: https://www.emaze.com/@AQFWCOW/STEM-antenna

On December 1, 1989 the Bank of Canada issued its $50 banknote that featured NRC's thin films anti-counterfeiting technology, designed with security features to counter the colour photocopiers of that era. Source: http://www.nrc-cnrc.gc.ca/eng/about/centennial/achievements.html

Assistance Program (NRC-IRAP), established in 1962. Among the inventions kick-started with NRC-IRAP assistance were the BlackBerry, UV-degradable plastics, and the Weevac-6 baby evacuation stretcher.

In partnership with industry, NRC-IRAP continues to stimulate wealth by helping small and medium-sized enterprises (SMEs) exploit emerging technologies and reduce their risk during critical start-up years. Today, some 240 Industrial Technology Advisors (ITAs) with access to expert technical and business advice, financial assistance, business information and contacts in national and international networks, provide customized solutions to about 10,000 SMEs annually. Respected globally as one of the best programs of its kind, NRC-IRAP is a vital component of NRC's innovation strategy and a cornerstone of Canada's innovation system.

Optical thin films

A major discovery in the 1970s by NRC engineer Lloyd Pinkey led to a range of applications that are still used today for both research and industry. In response to a request from one of Canada's astronauts for "better vision in space," Pinkey applied the technology behind thin film target dots to develop a space vision system. Commercialized by Neptec, the system was first used on mission STS-74 to begin building the International Space Station.

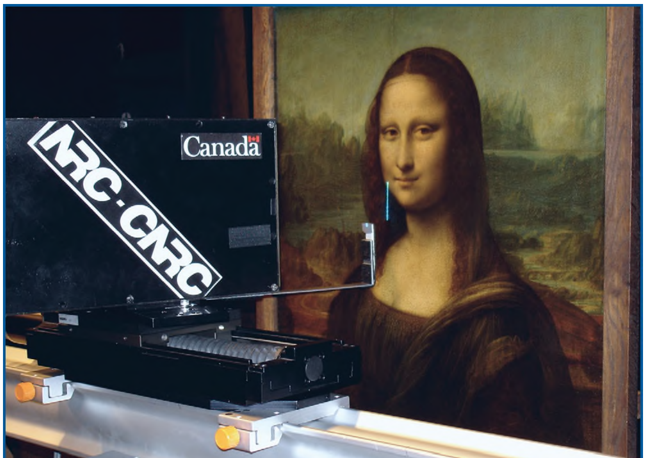
Growing the optical thin film industry in Canada was the lifelong work of NRC physicist George Dobrowolski, who adapted thin film products as a security technology to protect banknotes, passports and other important documents – and was awarded more than 30 patents. In 1968, the Bank of Canada (BOC) approached his group to develop a security solution for high-value banknotes. Dr. Dobrowolki and his colleagues quickly envisioned a way to embed an optical security device strip in the banknotes that made it almost impossible for counterfeiters to duplicate bills. This relationship between BOC and NRC continues today, with the familiar holograms and foils visible on every modern Canadian banknote, including the highly secure polymer banknotes in circulation today.

Solid State Optoelectronics Consortium (SSOC)

Dr. R. Normandin, a lead NRC researcher in optoelectronics, created the Solid State Optoelectronic Consortium (SSOC) in 1988. This five-year research initiative's underlying idea was to choose an area of evolving technology of economic significance, which could be developed to the benefit of Canada. With the participation of Bell Northern Research, Litton Canada and several SMEs, the consortium developed photonic technologies for wavelength division multiplexing (WDM) on a single semiconductor chip. This was the foundation of the optical communications revolution of the mid-1990s that led to unprecedented commercialization of a NRC discovery. By 2000, Canadian companies had captured 40 percent of the components market. Ottawa alone saw 70 start-ups generating more than $1 billion in sales and creating 7000 high-tech jobs. NRC spinoffs included: Iridian Spectral Technologies, BTI Photonics, Metrophotonics and Optenia – all exploiting innovative photonic technology solutions invented and developed by NRC researchers.

3D imaging

In the 1990s, Marc Rioux's fascination with imaging gave birth to the 3D imaging strength still housed at NRC. Characterizing the variations of the human body shape is fundamentally important in many applications ranging from animation to product design. Some of the better-known industrial uses



In 2004, NRC used its 3D imaging technology to perform scans of the Mona Lisa in the basement of the Louvre. This revealed the painting's state of preservation, and provided more information about da Vinci's *sfumato* technique used to create the corners of Mona Lisa's famous smile. Source: http://www.nrc-cnrc.gc.ca/eng/about/centennial/achievements.html

are special effects in films such as *The Matrix* and *The Lord of the Rings*.

Taking its 3D imaging technology into new realms in 2004, NRC used it to perform scans of the Mona Lisa in the basement of the Louvre. This revealed the painting's state of preservation and has shed light onto the *sfumato* technique da Vinci used to create the corners of Mona Lisa's famous smile. The same year, NRC researchers recreated the head of the Sulman mummy using a combination of scanning technologies to determine its shape, texture and colour prior to mummification. This proved that the mummy was a female – something earlier x-rays had been unable to do.

Canadian Photonic Fabrication Centre (CPFC)

In 1998, NRC President Arthur Carty sent me on a "mission" to develop a national photonic technology cluster strategy for integrating industry, government and university resources. It employed new partnership models to create technological and entrepreneurial advantages that would enable Canadian businesses to innovate and compete in the global marketplace. In 2001, the business plan for the NRC-Ontario cluster initiative – the Canadian Photonic Fabrication Centre – was approved for funding by the Treasury Board.

This pure-play photonic fabrication facility, established primarily to serve industry, was unique in North America. However, it also supports academic research and helps bridge the often financially risky gap between idea and commercialization that start-up companies have dubbed "the valley of death." Today, the CPFC provides a one-stop shop for world-class engineering and manufacturing services, commercial-grade prototyping and pilot-run production facilities for photonics-based components, from discrete components to highly sophisticated photonics integrated circuits used by the information and communication technology industry. These photonics circuits are the basis of today's high-end optical communication systems that fuel the Internet revolution.

Printable electronics (PE)

Printable electronics add intelligence to printed media that allow everyday objects to interact with customers in ways that were not even conceived five years ago. Using conventional, low-cost printing devices for processes such as screen printing, offset lithography or inkjet, PE adds electronic inks, the *optical* component of a film used in *Electronic* Paper Displays (EPD), to create active or passive applications for countless products. New goods include smart labels that reduce shipping costs, smart drug packaging that improves healthcare delivery, anti-counterfeiting measures that increase banknote security, and broadband printed antennas that harvest radio frequency energy.

The fusion of Information Communications Technologies (ICT) and printing is revolutionizing not only the manufacturing of high-volume, low-cost interactive consumer products and security documents, but also industries and markets worldwide.

Building on long-standing expertise in organic photonics and electronics in Canada (NRC, academia and industry), NRC launched a Printable Electronics Flagship Program in 2011 and tasked me with its strategic development. The business delivery model for addressing these needs was through a consortium involving the entire supply chain – from functional materials development to printable devices – in market segments that are important to growing our economy. Now fully established, the program has a multidisciplinary team addressing challenges related to next-generation printable functional materials, printable devices and imprinting.

During the past century, NRC has evolved greatly despite pressures from many directions. But it has always remained true to the values established when it was first created: Science at work for Canada. As NRC's work gained traction over the years, the research has paid off in supporting innovation for the country and led to start-ups that have created jobs, revenues and taxes reinvested in the economy.

Through reflecting on all this history, I am reminded of one of George Dobrowolski's famous sayings, which I feel captures the spirit of NRC: "Let us always remember that we are building on the efforts of other people and let's be humble about what we do." And by working together and sharing our results with the world, we continue to solve tomorrow's problems today.