



NRC-CNRC

Annual Report 2016-2017



National Research
Council Canada


Conseil national de
recherches Canada

Canada




“The NRC has made tremendous contributions to the development of science and innovation in Canada and, through these powerful instruments, it has helped shape our lives today and the world around us.”

– His Excellency the Right Honourable David Johnston, Governor General of Canada




“The NRC plays an instrumental role in delivering our Innovation and Skills Plan, resulting in the development of new solutions that will improve our quality of life, and more good-quality, resilient jobs for Canadians.”

– The Honourable Navdeep Bains, Minister of Innovation, Science and Economic Development



“NRC researchers provide our government with the scientific evidence we need to make decisions that will enhance our health, climate, environment and communities.”

– The Honourable Kirsty Duncan, Minister of Science



“The NRC’s national network of specialized facilities, scientists and innovation advisors is critical to helping small Canadian companies grow and succeed. Without the NRC’s support, these firms would be challenged to scale-up, export and compete on the global stage.”

– The Honourable Bardish Chagger, Minister of Small Business and Tourism

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Welcome to the National Research Council's Annual Report for 2016-2017—a year in which both the past and the future have figured prominently.

In the first instance, we celebrated the organization's centennial, looking back on a century of scientific and technical achievements, while simultaneously looking to the future with the launch of a wide-ranging exercise aimed at determining how the NRC can best support innovation in Canada in the years to come.

This internal consultation exercise, which we called the “NRC Dialogue”, was central to the mandate letter I received from the Minister of Innovation, Science and Economic Development and the Minister of Science upon my appointment as President of the NRC in August of 2016.

Based on the findings of our internal consultations, we have embarked on a renewal of the NRC as we forge ahead to solve complex problems in areas of critical importance to Canada. Over the coming years,

the renewed NRC will focus on: creating programs to deliver on government priorities including alignment with the federally-supported superclusters; research excellence in disruptive technologies; growing SMEs to scale and export; revitalizing the NRC research environment to include a more diverse workforce; and, enhancing environmental stewardship.

The strength of the NRC is founded on the passion, creativity, and dedication to excellence of its people. This excellence was demonstrated again

this year by the number of individuals from the NRC's ranks whose achievements have been recognized by the award of some of Canada's and the world's most prestigious honours for scientific and technical accomplishment.

Like everyone at the NRC, these award winners, whose achievements and contributions are detailed elsewhere in this annual report, are driven by a commitment to scientific discovery and technological development that will contribute to the betterment of Canada and all humankind.

This commitment has enabled a number of truly significant and exciting advancements in research and business innovations. These range from the development of a promising new anti-cancer drug and a potential treatment for Alzheimer's disease, and the discovery of a supermassive black hole to the

Making Canada a global innovation leader

delivery of a computer-controlled flight system for a full-size Aphid helicopter. The NRC has also redefined the kilogram by a fundamental, unchanging law of nature for more accurate measurement and helped to establish the Canadian Quantum Security Research Centre—to name just a few of the examples cited in this report.

Access to the NRC's expertise and equipment provides our collaborators with the opportunity to accelerate their commercial development timelines, while a focus on industrial applications provides the NRC with insights into commercial direction for research and technology development activities.

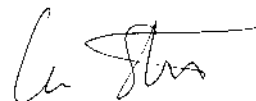
In addition, the NRC's highly regarded Industrial Research Assistance Program (IRAP) continues to play a key role in helping to accelerate the growth of innovative small and medium-sized enterprises (SMEs) in

Canada. Through the program, the NRC works with an average of close to 7,500 firms each year, and in 2016-2017, signed contribution agreements with more than 3,000 firms.

As Canada's contact point for EUREKA—a multinational network devoted to market-driven research and development—as well as an ever-growing number of bilateral and multilateral agreements with international research and technology organizations, the NRC is able to provide its industry clients and collaborators with access to opportunities to establish research and commercial relationships with partners in other countries, increasing their potential to grow and contribute to Canada's prosperity.

As demonstrated throughout this annual report, with a national footprint, a dedicated team of expert personnel and diverse

collaborative relationships in Canada and around the world, the NRC is able to bring together diverse expertise from a wide range of engineering and scientific fields to tackle national challenges related to business innovation, scientific inquiry and public policy. Through our process of renewal, we look forward to seizing new opportunities for the NRC to refine its role in connecting the various components of the Canadian innovation system and help propel Canada into a position of global leadership in innovation.



Iain Stewart
President

The NRC workforce: driven by knowledge, enriched by diversity

The NRC has approximately 3,700 scientists, engineers, technicians and other specialists.

155 of NRC employees serve as adjunct professors at leading universities across Canada.

The NRC's employee base includes 375 visiting workers and 244 students, helping to create new opportunities for collaboration with other organizations in Canada and elsewhere, and nurturing the next generation of NRC scientists.

NRC employees represent 77 different nationalities—reflecting the strength to be found in the diversity of Canada's population.



Achieving research excellence

The NRC's pool of highly skilled professionals, from scientists, researchers and technical experts to business support specialists and advisors, is key to the organization's ability to incorporate excellence in everything that we do.

As in past years, a number of members of the NRC's scientific community were recognized in 2016-2017—not only for their scientific expertise or technical achievements, but also for their dedication and creativity. NRC personnel honoured this past year included recipients of some of the most prestigious and respected national and international honours.

Dr. Sylvie Béland

Dr. Sylvie Béland, the NRC's first female director of aerospace research and development, was honoured with the Elsie MacGill Government Award from the Northern Lights Award Foundation. The award recognizes her illustrious career as an aerospace and space scientist, which includes holding a number of senior positions at the Canadian Space Agency. Now a co-champion on the NRC's National Women in Science and Technology Committee, Dr. Béland has earned an international reputation for her work, including for her part in developing new technologies for the Canadarm2 and the International Space Station.



Mr. Rajeev Chadha

In January 2017, Mr. Rajeev Chadha of NRC IRAP was awarded American Society for Quality (ASQ) Fellow status along with 17 other members of the worldwide organization dedicated to and passionate about quality. ASQ Fellows represent diverse industries on a global scale, with 2017 Fellows representing companies and organizations such as Abbott, GlaxoSmithKline and Xerox. Fellow membership status is awarded to individuals who are ASQ members in good standing and meet several criteria. The ASQ elevated Mr. Chadha's membership status to Fellow "for outstanding contributions to the professional quality movement in Canada and for meritorious achievements in the application of Lean Six Sigma, quality and continuous improvement technologies in the Canadian mining industry". Mr. Chadha's contributions to the industry range from developing K40 Analyzers for on-stream potash analysis to efficient operating systems for the large boring machines used in mining.



Dr. Pavel Cheben

Dr. Pavel Cheben was honoured with a fellowship to the Optical Society of America (OSA), the leading professional association in optics and photonics, and home to accomplished science, engineering and business leaders from all over the globe. Dr. Cheben, Principal Research Officer at the NRC, is the only Canadian and one of a handful in the world to be both a Fellow of the OSA and a Fellow of the European Optical Society. He is best known for his foundational work in metamaterial integrated photonics, which allows the flow of light to be controlled and manipulated at a subwavelength scale in optoelectronic chips. Dr. Cheben was also one of the leading investigators for a Genomics Health Initiative project that resulted in a biological sensor which incorporates the NRC's patented photonic grating coupler technology. Since 2011, Dr. Cheben has been the most published scientist at the NRC.



Dr. Albert Stolow

Dr. Albert Stolow, Canada Research Chair in Molecular Photonics, Professor at the University of Ottawa and researcher at the NRC, was the recipient of the American Physical Society's 2017 Earle K. Plyler Prize for Molecular Spectroscopy and Dynamics, for developing methods in probing and controlling ultrafast dynamics in polyatomic molecules. Dr. Stolow established the Molecular Photonics Group at the NRC, currently dedicated to the study of quantum technologies and control, ultrafast molecular-electronic dynamics, strong field molecular physics, and coherent non-linear Raman microscopy—areas of study that could lead to breakthroughs in a broad range of applications, from diamond-based quantum photonics, to highly efficient solar cells, to laser-based manufacturing, to brain disease and cancer research. He is one of only four Canadian researchers to receive this prize since its inception in 1976.



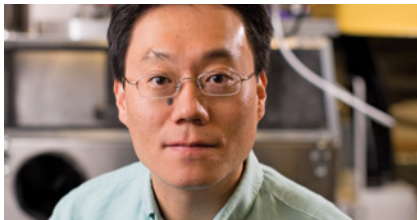
Dr. Keith Ingold

Dr. Keith Ingold, whose numerous honours include the 1988 Linus Pauling Award, was the 2016 recipient of the Royal Society of Chemistry's Sir Derek Barton Gold Medal, in recognition of his fundamental contributions to the understanding of free-radical chemistry. When Dr. Ingold began his research at the NRC in the 1950s, the chemistry of intermediaries, such as free radicals, was largely unknown. Dr. Ingold and his colleagues made outstanding contributions to international science by quantifying free-radical chemistry, enabling him to apply his findings in new ways that have had considerable impact on the petroleum and plastics industries. Developments in automotive oils, for example, can be attributed to his early research. Best known for his work on the application of the chemistry of free radicals in living organisms—specifically the human body—his investigations into the role of oxidation in the aging process have pioneered the understanding of the role of Vitamin E as an antioxidant in medicine and health.



Dr. John Hutchings

Dr. John Hutchings was recognized with the John H. Chapman Award of Excellence for his outstanding contributions to Canadian space astronomy. Described as an enormously productive scientist with several major scientific discoveries to his name—he is among the top 0.5 per cent of most-cited astrophysicists in the world—Dr. Hutchings has led Canada's participation in landmark missions such as the James Webb Space Telescope, the Far Ultraviolet Spectroscopic Explorer, the Hubble Space Telescope and the Ultraviolet Imaging Telescope on India's ASTROSAT, contributing to significant advances in space science and new technologies.



Dr. Keun Su Kim

In 2016, Dr. Kim was named Engineer of the Year by the Korean Federation of Science and Technology Societies. The award recognizes the outstanding contributions of overseas Korean scientists who have made important scientific achievements and fostered international collaboration. Dr. Kim, of the NRC's Nanocomposites group, demonstrated the world's first, large-scale production of boron nitride nanotubes—which are 100 times stronger than steel, but six times lighter and able to withstand temperatures of up to 2,000 degrees Celsius—offering the potential to revolutionize the production of everything from military armour to building materials.



Dr. David Villeneuve

Dr. David Villeneuve was presented with the 2016 Quantum Electronics Award from the Institute of Electrical and Electronic Engineers for his outstanding technical contributions to quantum electronics. Dr. Villeneuve is one of the NRC's pioneers of attosecond science in which pulses of light from a laser measured in quintillionths of a second are used to see and potentially control the movement of electrons within atoms and molecules. Dr. Villeneuve was also a key player in establishing the Joint NRC-University of Ottawa Attosecond Science Laboratory (JASlab), a unique facility that continues to attract top talent in ultrafast physics from around the world to Ottawa.



Strengthening the NRC's national network of R&D facilities





With some 90 facilities located at 22 sites across Canada, the NRC runs a national system dedicated to research and commercialization, spanning a wide range of industrial sectors and scientific fields. Beyond its mandated activities of operating and administering all astronomical observatories established or maintained by the Government of Canada, the NRC operates a host of specialized laboratories and testing facilities, including one of the largest ice tanks in the world, six wind tunnels, and a Photonics Fabrication Centre. Combined with its wide range of technical and scientific expertise, the NRC's facilities continue to offer clients and partners a unique network of collaboration platforms that brings together universities, industry and all levels of government. In 2016-2017, the NRC announced plans to enhance and expand its research capabilities at a number of its facilities across Canada.

Secured communications technologies

In November 2016, the government announced that a new Quantum Security Technology Access Centre (Q-STAC) would be established as a joint effort of the Communications Security Establishment (CSE), the NRC and other government departments, to be housed at the NRC campus in Ottawa. The emerging field of quantum communication promises un-hackable, secure communication that can be applied to protect digital infrastructure from malicious actors—adding a new level of protection from cyber attacks that can have significant impacts on public safety, national security and the economy. The Q-STAC works with academic institutions and industry to ensure leading experts can collaborate on research and technology projects and initiatives aimed at, among others, protecting existing government infrastructure, disseminating technology foresight, and prototyping quantum security sensing and communications technologies.



Safer air travel

Following the introduction of regulations requiring aircraft to be certified for operation in newly-identified icing conditions that pose a threat to flight safety, the NRC upgraded its Altitude Icing Wind Tunnel (AIWT)—one of the few wind tunnels in the world that can simulate and test aircraft surfaces, components and probes in icing conditions at altitude. Already able to simulate altitudes up to 40,000 feet and temperatures down to -40°C , the upgrades allow the production of high intensity levels of ice crystals within the wind tunnel, as well as supercooled large droplets in the

form of freezing drizzle and freezing rain. Providing for consistent and repeatable testing conditions—and more cost-effective than flight testing—the upgraded AIWT offers a competitive advantage to aircraft manufacturers racing to certify to the new regulations.

Advanced research computing

In December 2016, the NRC and Compute Canada announced a new, multi-year collaboration aimed at enhancing what is already one of the world's foremost astronomy research platforms. The collaboration will bring expanded “big science”

data management and processing capabilities to a much larger research community. The project's title—C3TP—references the “three Cs Transition Project”: the NRC's Canadian Astronomy Data Centre (CADC), Compute Canada and the Canadian Advanced Network for Astronomical Research (CANFAR) platform established on Compute Canada infrastructure.

The advanced research computing needs of astronomers are evolving at the same time as Compute Canada's infrastructure is being redesigned to better serve Canadian researchers and collaborators in all academic and industrial sectors.



The project is the first of its kind to leverage the large-scale research infrastructure and funding from both the NRC and Compute Canada to advance common science goals. The CADC, also referred to as Canada's virtual observatory, is one of the first in the world to make the transition from data host to integrated systems.

Already, the massive calculations made possible by the existing CANFAR platform have helped guide the first close spacecraft encounter with Pluto and enabled the discovery of new dwarf planets and supermassive black holes. The new, enhanced system will take

the potential for such discoveries to a whole new level.

Smarter homes

In the summer of 2016, the NRC began upgrading the Canadian Centre for Housing Technology (CCHT) with construction of a semi-detached smart home to enable the evaluation of low-energy solutions and technologies for the multi-unit market. Scheduled for completion in summer 2017, the new building will support industry in assessing, testing and developing technologies in different areas, including exterior insulation systems, windows, renewable energy and

energy storage, electric vehicle charging, micro-grid applications, and smart-building control. This new capacity will bring the CCHT to the leading edge of building technology innovation by providing a semi-detached smart-home that is net-zero energy ready.

The upgraded facility will also enable the assessment of how renewable energy sources such as wind and solar can be integrated seamlessly into the existing electrical grid using intelligent load-management strategies.



Addressing national priorities by building innovation capacity through strategic partnerships

The NRC collaborates with thousands of private and public partners each year to deliver targeted research, technology development, and direct technology support to Canadian industry. Many of these strategic partnerships supporting business innovation also contribute to Canada's capacity to address national challenges, from food safety and cleaner technologies to transportation, health, and security, among others. In 2016-2017, the NRC continued to make significant progress toward the goals of existing research collaborations while exploring opportunities for new research initiatives and collaborations to address challenges faced by industry.

Food

Affordable genotyping

Under the Canadian Wheat Alliance with Agriculture and Agri-Food Canada, the University of Saskatchewan and the Province

of Saskatchewan, the NRC developed a genomics platform technology that can reduce the cost of genotyping a single DNA marker by approximately a factor of eight, increasing the cost efficiency and effectiveness of wheat breeding.

DNA markers identified by the NRC are now being used by breeders to help develop wheat varieties for insect and rust disease resistance, helping to protect Canada's multi-billion dollar wheat exports.

Safer, more sustainable aquaculture

KnipBio, a leading North American clean biotechnology firm, has been collaborating with the NRC to harness the potential of synthetic biology and metabolic engineering to pave the way for safer, more sustainable aquaculture. NRC experts in aquatic and crop biotechnologies helped to optimize KnipBio's microbial strain and fermentation process to improve the efficiency and cost competitiveness of its core



production process. The partnership resulted in the development of a protein source that combines the attributes of protein-packed fishmeal and carotenoids in one effective, affordable replacement called KnipBio Meal—a more sustainable fish food with the potential to improve the sustainability of the aquaculture industry by increasing diversity, reducing costs and improving product quality.

Improved food testing

In collaboration with Health Canada and the Canadian Food Inspection Agency, the NRC developed two patented microfluidic platform technologies for rapid isolation and identification of food pathogens, such as potentially deadly *E. coli* O157:H7.

Both platforms are being used in federal food testing laboratories with the goal of expanding their use beyond government labs to the commercial market in the coming years.

Clean technologies

Revolutionizing the management of carbon emissions

In November 2016, in collaboration with research partners at Pond Technologies and Votorantim Cimentos' St Marys Cement, the NRC brought the first algal biorefinery project in Canada online—showcasing a technology that could lead to a revolution in the management of industrial carbon emissions.

The process deployed by NRC experts and its partners is designed to rapidly recycle carbon dioxide (CO₂) and other airborne industrial emissions into biomass through the use of photosynthetic algae. The demonstration facility's environmental remediation and biomass production potential has drawn significant interest from the public, the international algae community, and industry. The pilot scale algal biorefinery uses CO₂ and other emissions captured from the cement manufacturing process as a food source to promote the rapid growth of algae in its 25,000 litre photobioreactor. The resulting algal biomass can be further converted into sustainable products, including renewable biofuels.

Transforming biomass into biogas

Using the NRC's biotechnology expertise and customizable anaerobic bioprocessing pilot plant facilities, NRC researchers developed a laboratory-scale version of a biomass to biogas system built by the Régie d'Assainissement des Eaux du Bassin de La Prairie (La Prairie Basin Water Sanitation Authority). The innovative system is designed to recycle more than 100,000 tonnes per year of wet, secondary sludge generated by the Régie's sewage treatment facility, transforming it into biogas that can be used to generate energy for heating and other purposes—the kind of technology that is turning the management of solid waste from a challenge to an opportunity in communities across Canada. By reproducing the Régie's innovative system and unique operating conditions at a laboratory scale, the NRC was able to validate the system's performance and suggest adjustments to optimize the Régie's biomass transformation process.

Transportation

Supporting new applications for UAVs

In collaboration with Defence Research and Development Canada (DRDC) and private-sector partner Meggitt Training Systems Canada, the NRC used its world-class aerospace lab and expertise in mathematical modelling to develop and test new sensors, electronics and computer programs that would enable future military Unmanned Aerial Vehicles (UAVs or “drones”) to perform above and beyond their original design specifications. NRC engineers outfitted a single-occupant Aphid helicopter with a series of sophisticated sensors to collect data on the aircraft's movement. A small, unmanned prototype helicopter was then used to test the instrumentation suite—including a GPS receiver, remote control, ground station, sensors, air data system, and autopilot system—before transferring guidance and navigation control back to the Aphid. After six years of design and development, the

research has delivered a computer-controlled flight system that allows the full-sized Aphid helicopter to safely take off on its own, perform manoeuvres via remote control and then return to an automated state for self-landing.

The Aphid helicopter has recently completed a series of flights in the Arctic to test the viability of using unmanned systems in the North. Longer term, DRDC will employ the new control technology in a variety of potential UAV applications, from search and rescue to military uses. The technology will also support the Canadian aerospace sector as it pursues new opportunities created by the growing demand for increasingly complex control systems, navigation equipment and communication technologies needed to enable new applications for UAVs.







Strong industry partnerships

Relying on strong partnerships to help develop and market specialty mix products within the powder metallurgy market (including an almost 25-year long relationship with the NRC) Quebec-based Rio Tinto Metal Powders (RTMP) technology solutions continue to make impressive gains in Canada and abroad. RTMP's flagship FLOMET™ mix technology—a combination of binder-treated powders that bond small additive particles to larger iron powder particles as a way to increase the productivity of compacting presses and part-to-part consistency—has been a particular success.

A collaborative effort from the very beginning, the NRC and RTMP have seen a steadily growing demand for

the FLOMET™ technology platform from countries around the globe. The technology has been especially popular in the automotive sector, where it is being used in the manufacture of a wide range of parts, from lighter and lower-cost camshaft pulleys to electric sunroof mechanisms. The use of RTMP's proprietary technology continues to expand, and now includes warm pressing mixes, green machining products, soft magnetic composites and environmental applications.

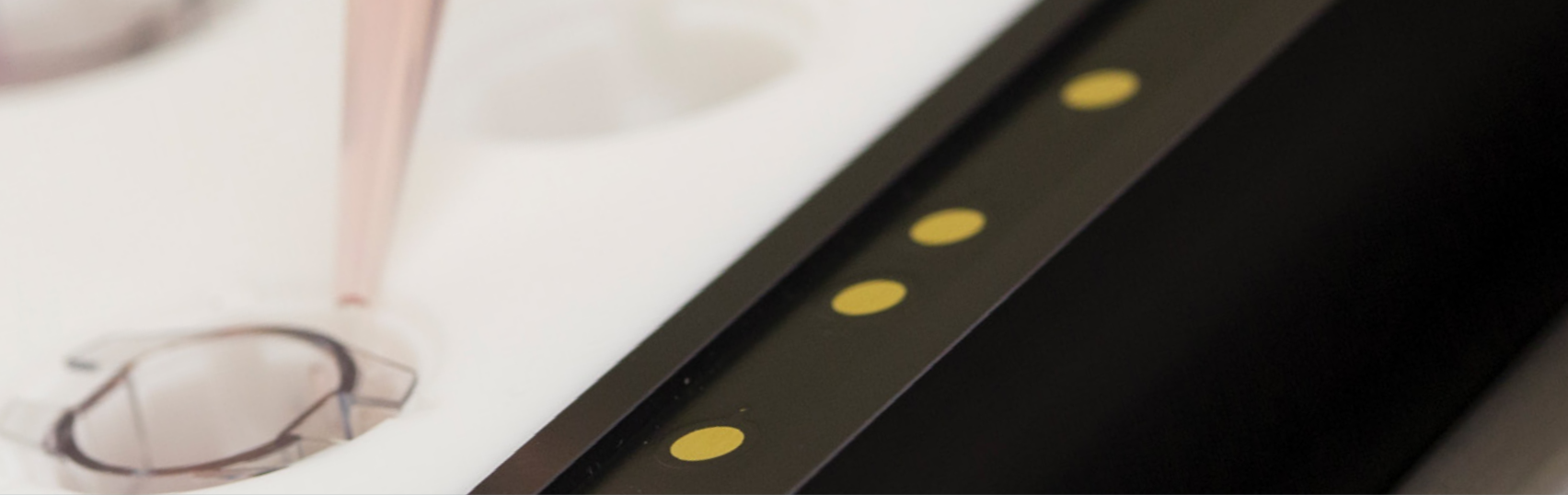
The ongoing collaboration with the NRC has also enabled RTMP to obtain several technology patents, and helped the company to establish itself as a key player in the manufacturing and development of essential end-user products for the automotive industry.

Health

Advancing cancer treatments

A recent collaboration between the NRC and Formation Biologics has led to the development of a drug that has proven successful in shrinking tumours in preclinical models and is now achieving positive results in Phase 1 clinical trials. The new treatment, AVID100, is an antibody-drug-conjugate (ADC)—a type of biotherapeutic that uses an antibody with a drug attached to it to target and destroy cancer cells with minimal impact on surrounding tissue.

By accessing the NRC's knowledge of the antibody's DNA sequence, Formation Biologics was able to win Investigational New Drug approval for AVID100, allowing trials in humans to begin.



Working with Formation Biologics enabled the NRC to further its expertise in ADC development, leading to a cutting-edge platform for ADC development and screening. The company is ready to pursue the development of other innovative treatments to benefit Canadians living with cancer, and plans to continue working with the NRC on a second molecule arising from NRC labs, AVID200, that has the potential to treat a number of diseases in addition to cancer.

Alzheimer treatments

In October 2016, Kalgene Pharmaceuticals and the NRC announced an agreement to further develop, scale up, and transfer the technology needed to manufacture a promising new treatment for Alzheimer's disease, extending a partnership launched

in 2015. The potential treatment is based on a custom-engineered biologic molecule developed at the NRC. The molecule is composed of a peptide believed to reduce amyloid beta deposits in the brain—deposits that have been strongly linked to Alzheimer's—coupled to an antibody designed to carry the peptide into the brain. Human trials of the treatment are expected to begin in 2018.

As the population ages and the incidence of Alzheimer's and other diseases of the central nervous system rises, the NRC's expertise in coupling drugs and other therapeutics with antibodies designed to ferry them across the barrier between the blood and the brain may help overcome some of the greatest medical challenges of our century.

Improved magnetic resonance imaging (MRI)

In collaboration with Sunnybrook Research Institute in Toronto, the NRC developed a new device capable of improving pancreatic magnetic resonance imaging (MRI). Tests on healthy subjects showed sharper images with clearer definition of the pancreas compared to techniques currently in common use. Pancreatic cancer is one of the most aggressive and difficult to diagnose forms of the disease, and early diagnosis is crucial if treatment is to be successful. If the results are validated in a larger group, this new Canadian technology could significantly impact diagnostic MRIs of the pancreas and other internal organs such as the liver, kidneys and prostate.

Authentic, accurate and traceable time

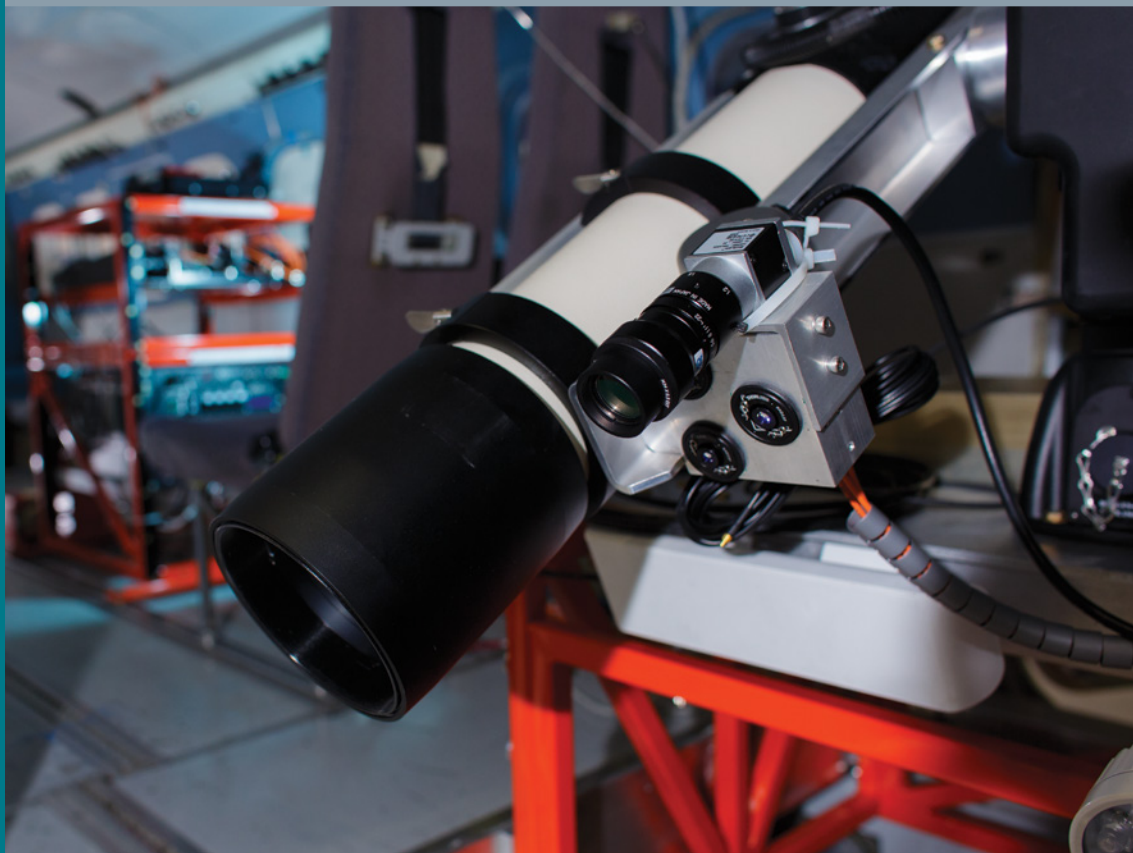
The demand for secure and accurate time has been growing in recent years in telecommunications, infrastructure, navigation and finance, with these sectors requiring traceable time with sub-microsecond precision. Currently available methods have technical or reliability limitations in achieving this goal, so the NRC has developed a remote time system with uncertainty reduced to the nanosecond level. Based on a high quality local oscillator and GPS for time transfer, the remote clock is continuously monitored and adjusted to Coordinated Universal Time (UTC) to ensure traceability, and minimize vulnerability to GPS signal jamming and spoofing.

Security

Infrastructure to de-risk next-generation quantum security technologies

Together with the Communications Security Establishment, Defence Research and Development Canada and Sherbrooke, Calgary, Toronto and Waterloo universities, the NRC was a key player in establishing the Quantum Security Technology Access Centre (Q-STAC) in 2016-2017.

The Q-STAC will support advanced research activity in the security sector, contributing to the growth of Canada's vibrant photonics industry through the transfer of NRC scientific expertise in chemical detection sensors, perimeter sensors, high-sensitivity imaging, quantum networks, quantum key distribution, and quantum-resistant algorithms. Drawing on expertise from across government, this joint initiative houses a quantum key distribution switch and standard network gear that will allow NRC researchers to perform work on quantum telecommunication technologies. This joint activity is aimed



at developing critical infrastructure to de-risk next-generation quantum security technologies and advise government and industrial partners on the future landscape of communications, sensing, and security.

Next-generation armour products

The NRC led the development of the Security Materials Technologies Roadmap (SMTRM) during 2016-2017—an initiative built on the previously developed armoured vehicle and personal protection roadmaps, and aimed at accelerating the development and adoption of

innovative armour products and systems in Canada. The SMTRM is now being used to guide the development of a Built-in-Canada Program pilot initiative that would better connect the needs of government departments with the innovation capabilities of Canadian industry, setting the stage for a new, demand-based procurement model.

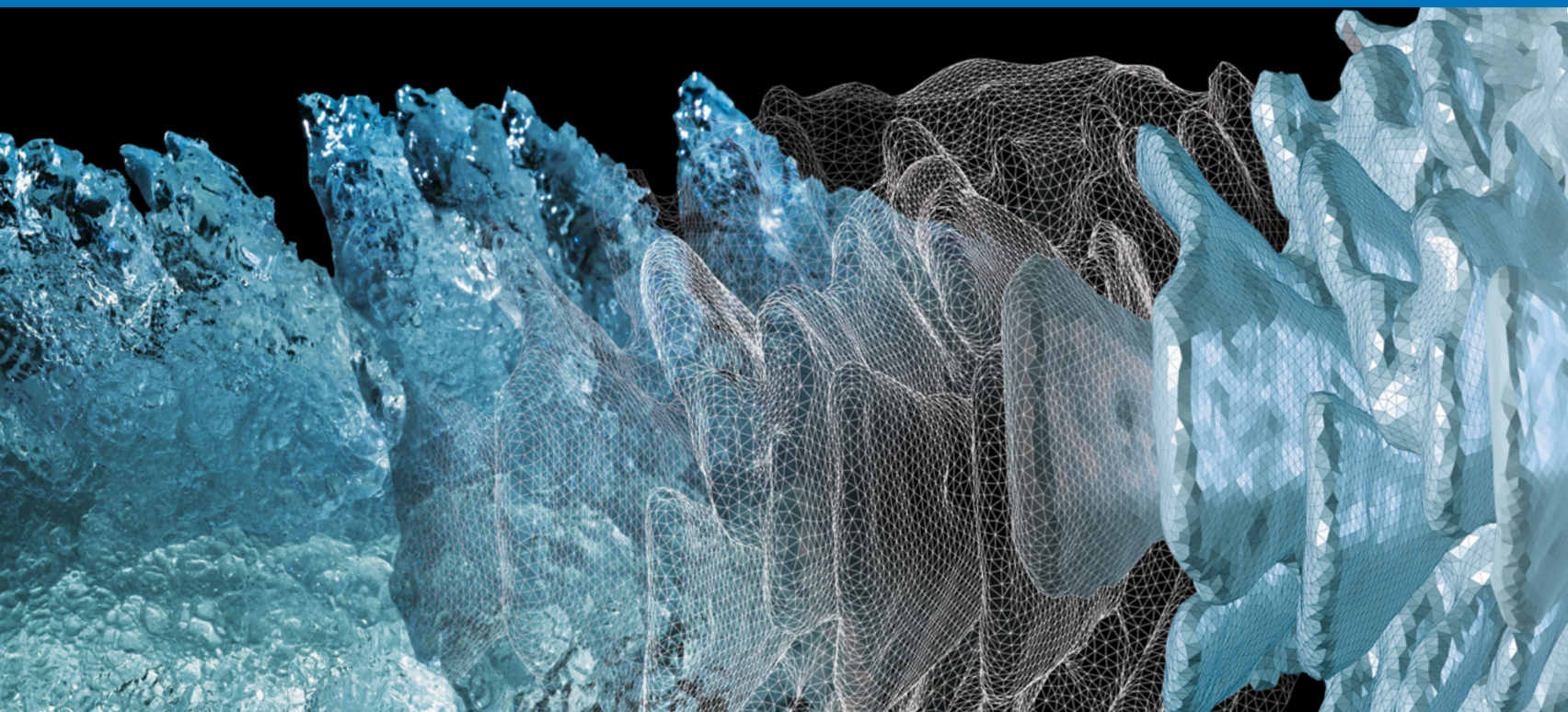
The roadmap is complemented by a new, virtual collaboration environment launched by the NRC, enabling stakeholders to cooperate in advancing technologies

and developing next-generation products and systems to increase the competitiveness of Canadian industry and enhance protection for Canadian soldiers, first responders and security personnel. By identifying future market demands in Canada and internationally, and the technologies required to meet those demands, the SMTRM will help align, plan and coordinate technology development opportunities for Canadian industry and target R&D investments.



Corporal Marc-André Gaudreault,
Imaging Section, Valcartier Garrison

Breaking new barriers in the advancement of knowledge



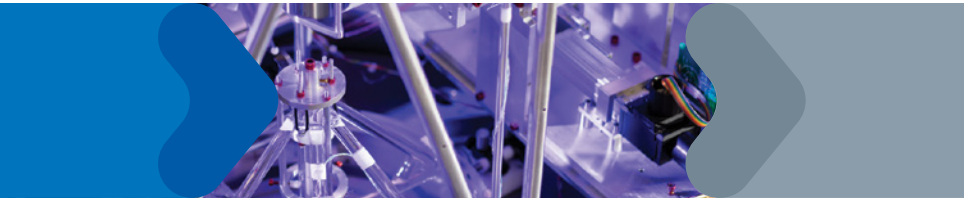
The NRC at the forefront of icing modelling and simulation technologies

In order to safeguard aircraft against the potentially dangerous threat of icing, it is critical to understand and predict how ice accumulates on aircraft structures in various conditions. A 3D morphogenetic icing prediction code, developed by Dr. Krzysztof Szilder and the Aviation Aerodynamics group at the NRC,

represents a significant improvement on traditional icing models used by top aerospace labs to calculate ice formation under different conditions.

The new model's accuracy puts it at the forefront of the ice prediction field and, with successful testing completed, it is ready for the next step—licensing to a Canadian company for commercial distribution. For the aerospace industry, the development of this highly-accurate

ice-predictive capability will support the certification of new aircraft designs to meet increasingly stringent regulations. In addition, the model can be used in other engineering and industrial applications to predict, for example, how ice may accumulate on wind turbines, transmission lines and bridge cables—as demonstrated as part of recent work performed for the new Champlain Bridge in Montreal.



NRC research to weigh heavily on the redefinition of the kilogram

Researchers with the NRC's Measurement Science and Standards have produced the most accurate measurement of the kilogram yet recorded—a result that will ensure recognition of the NRC's contribution to the redefinition of the international system of units planned for 2018/2019, and position Canada as a major contributor to international measurement standards.

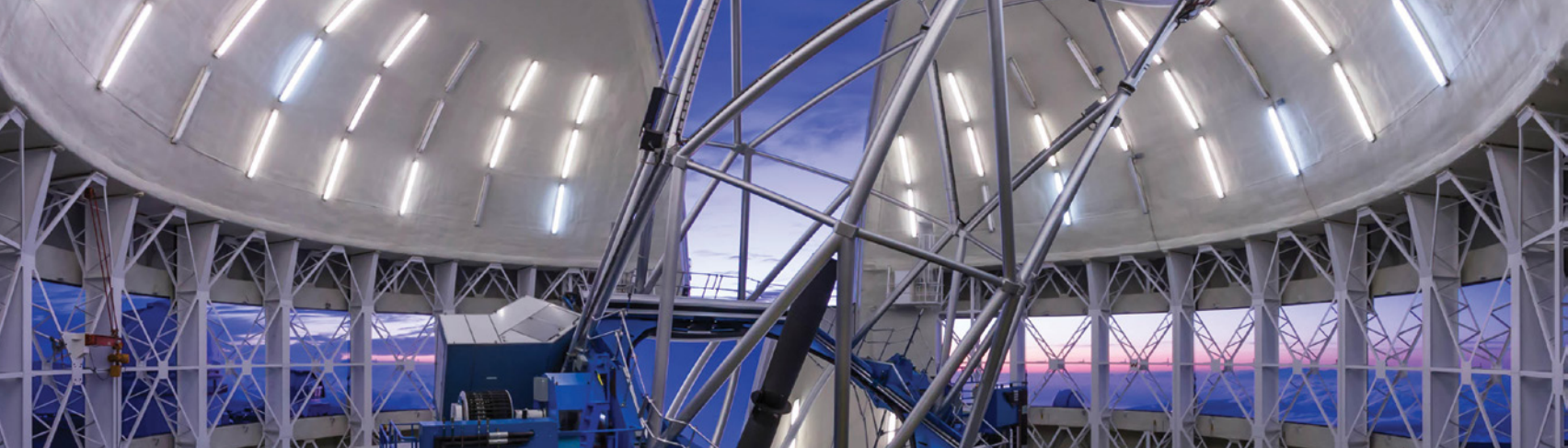
The kilogram is the one international measurement unit still defined by an actual artifact—a small metal cylinder locked in a secure vault in Paris—the value of which can be altered by something as simple as breathing on it. As with other units of measurement, the Comité International des Poids et Mesures wants the kilogram to be defined by a fundamental law of nature that does not change so anyone with the proper tools will be able to measure out a perfect kilogram whenever they need one.

Following the installation of a Watt (or Kibble) Balance in 2009, NRC researchers have worked tirelessly to improve the accuracy of the device, which measures weight using electromagnetic force with such precision that it can “see” earthquakes happening in the United States. While many labs around the world are working to redefine the kilogram, the NRC's recent results of 9.1 parts per billion represent the most reliable measurement of Planck's constant ever achieved—and make the NRC Watt Balance what is effectively the most accurate quantum scale in the world. In addition to being a crucial component in the redefinition of the kilogram, the work of NRC researchers in assigning a more precise value to Planck's constant will have far-reaching applications in the field of quantum mechanics and other disciplines.

Making our world smaller

In collaboration with researchers at the University of Alberta and international partners, the NRC published a report in *Nature Communications* in 2016-2017 detailing how switches for electricity based on the behaviour of a single atom could be created. These so-called atomic switches would be many times smaller than anything currently in use, allowing for the development of much smaller and more energy efficient computers and other devices.

Meanwhile, as reported in the journal *Nature Nanotechnology*, the NRC, the University of Alberta and the University of Calgary developed a first-of-its-kind miniature magnetic sensing device with extreme sensitivity. The device's small size and portability—the magnetic sensor is on a silicon chip smaller in diameter than a human hair—would allow for its use in a broad range of applications, such as probing and characterizing the magnetic properties of new materials being developed for applications in electronics and quantum computing. Among other uses, it could conceivably be a feature of future smartphones, enabling consumers to quickly and easily test food for bacterial contamination.



Advancing scientific knowledge

In March 2017, the NRC's National Science Library partnered with six other federal science-based departments and agencies to launch the Federal Science Library portal. This new self-serve portal enables researchers to search and have remote access to the vast collection of publications in science, technology, engineering and health and other related economic, policy and program information held in the seven federal libraries. Wherever possible, departmental publications, reports, data sets and other content are freely available for anyone to access or download. It also gives users the option to expand their search beyond the holdings of the seven libraries to include millions of publications from around the globe.

Massive black hole discovery

An international team of astronomers uncovered a supermassive black hole in unlikely isolation at the centre of galaxy NGC 1600. As part of the team, NRC astronomers working out of the Dominion Astrophysical Observatory contributed the critical observational data required to map and model the unexpectedly sparse environment around the black hole.

As well as being one of the largest ever measured, the newly discovered black hole is the first of its size to be found outside of a dense cluster of galaxies, putting in question astronomers' current understanding of how and where gigantic black holes form—and may suggest that more gigantic black holes are lurking in the universe, waiting to be discovered.

While the galaxy NGC 1600 has been subject to previous investigations, this recent breakthrough black hole discovery was made possible by the Gemini Multi-Object Spectrograph. This instrument, designed and built by the NRC in collaboration with the United Kingdom, resides atop Mauna Kea in Hawaii on the Gemini North 8-metre telescope. Gemini is one of the few telescopes in the world with the power to collect enough starlight and with the optical quality to make observations at the centre of an elliptical galaxy.



Supporting scale-up to success for high-performing SMEs



As one of the Government of Canada's longest-running innovation support programs for small and medium-sized enterprises, the NRC's Industrial Research Assistance Program (IRAP) works with approximately 7,500 firms every year—helping these businesses identify and pursue opportunities to accelerate their growth through the provision of advisory services and financial support. In 2016-2017, NRC IRAP signed Contribution Agreements with over 3,000 firms involving some 3,200 projects which, in turn, supported well over 12,000 jobs—including more than 1,300 jobs for young Canadians.

NRC IRAP is recognized around the world for the success of its innovation assistance program; providing the technology, tools and funding to accelerate expansion of high-growth firms, create new jobs in growing industries, and enable them to compete internationally and contribute to Canada's prosperity. During 2016-2017, NRC IRAP played a key role in the successful scale-up of a range of SMEs representing a variety of social and economic sectors. Here are a few examples.

Health

Monitoring hearts from afar

m-Health Solutions benefited from NRC IRAP support in several areas, including business analysis, technical advice, financial assistance, and regulatory guidance and support

during the certification process of an improved heart monitor kit called m-CARDS. This new wireless technology enables data needed for diagnosing heart conditions to be collected remotely. This capacity offers particular benefits to Canadians living in remote communities without

resident cardiologists, as well as people living in urban environments who may have difficulty getting to and from appointments in clinics or hospitals. The faster diagnoses provided by m-CARDS may also lead to healthcare cost savings by reducing the number of Canadians requiring hospitalization for heart disease and stroke.

Smart cities

Eye in the sky for a smoother commute

A series of innovations by Kitchener firm Miovision is helping to set the foundation for tomorrow's "smart cities." Listed as one of its "Technology Fast 50" by Deloitte—the consulting firm's annual ranking of the fastest growing tech firms in Canada—Miovision is reinventing the management of traffic data. The firm's innovative video streams and algorithms are already being used by city planners in more than 50 countries, enabling real-time traffic management decisions to optimize city-wide traffic flows by monitoring vehicle and pedestrian



volumes and controlling multiple traffic signals. Data collected and analyzed by the system also informs planning for more efficient roads decades into the future.

Founded by three University of Waterloo engineering students and based in Waterloo's Accelerator Centre, Miovision accessed support from NRC IRAP's Youth Employment Program to start developing its long list of hardware and software innovations. The firm has grown steadily, from six employees in 2005-2006 to 115 in 2017, and is expected to double its current workforce within the next three years.

Energy

Recharging battery research strategies

While new designs are improving the performance of the lithium-ion batteries that power more and more of our world, the cost and complexity of preparing the materials that go into the product is a major challenge for manufacturers. With support from

NRC IRAP, Vancouver-based Nano One has taken a giant step toward overcoming that challenge, developing a process that eliminates a number of time-consuming, expensive steps needed to create the lithium cathodes that are a key element of these batteries. While some processes involve as many as 100 steps and production cycles of up to seven days, Nano One's technology has 75 per cent fewer steps, a production cycle that can be completed in one day and uses less expensive, lower-grade raw materials.

NRC IRAP was instrumental in helping the company refine this technology for immediate commercial application, enabling it to pursue the tremendous opportunities that exist—Lux Research has predicted that the market for these batteries will grow to \$50 billion by 2020 from the current \$35 billion, as the demand for batteries for small, portable devices grows to include larger formats, such as power supplies for vehicles and storage of electricity generated by solar and wind generators.

Environment and Clean Technology

NRC IRAP network helps bring environmentally-friendly culvert on stream

Lethbridge, Alberta-based Enviro Span designed a new, modular culvert system to reduce the environmental impact of stream crossings. Unlike the conventional steel tube, the Enviro Span culvert is a semi-circular design, allowing it to be placed in a stream with minimal disturbance to the stream bed or sensitive habitat. Made from a lightweight but strong and durable thermoplastic material, the culvert is also easy and inexpensive to install. With NRC IRAP assistance and a partnership project with Lethbridge College and the City of Lethbridge to showcase the technology's environmental and cost-saving features, Enviro Span increased sales and signed on a new distributor. The company's culverts have been installed in locations across the United States, as well as Ontario, Quebec, Alberta and British Columbia.

Government partnerships increase international access for SMEs

NRC IRAP continues to invest in international networks and partnerships to open doors for Canadian SMEs. Over the past year, NRC IRAP has extended its reach by partnering with 13 other government departments to deliver different departments' innovation programs to SMEs in a coordinated way. In particular, NRC IRAP is working with the Trade Commissioner Service of Global Affairs Canada to co-deliver the CanExport program. This program is designed to support SMEs in managing export development costs such as business travel to target markets; participation at trade fairs and trade missions; market research; and, adaptation of marketing tools for new markets. Applications have been approved for exports to over 70 markets.

Canadian companies, such as 4Deep inwater imaging, are already benefiting from the program. The Nova Scotia company has used its patented holographic technology to create powerful yet simple microscopes that enhance undersea research and discovery. With CanExport's support, 4Deep is marketing and promoting its submersible microscope system in India to monitor water quality in lakes, rivers and oceans.

Intelligent packaging

Canadian company has global success with help from NRC IRAP and EUREKA

Jones Packaging, of London, Ontario, is set to transform how both prescription pharmaceuticals and over-the-counter medications are purchased, through the introduction of interactive “smart labels” and “intelligent packaging”. The new packaging, aimed at enhancing both product integrity and consumer safety, is the result of a successful research and development collaboration with Thin Film Electronics ASA of Norway and Sweden—a collaboration made possible by support from NRC IRAP, Sweden's national innovation agency (Vinnova), and Canada's membership in EUREKA.

Facilitating “EUREKA!” moments through international partnerships

Canada's associate membership in EUREKA—an intergovernmental and transnational network for market-driven industrial research and development—continues to open doors for Canadian innovators.



With its decentralized and flexible approach, EUREKA provides Canadian innovators with the support and contacts required to develop new products, services or processes through transnational collaborations with entities in dozens of countries in Europe and beyond. EUREKA is also giving Canadian industry a competitive advantage by facilitating access to key global value chains and foreign markets, as well as the potential to access greater capital.

EUREKA at a glance

EUREKA is the largest innovation facilitation network of its kind, providing a mechanism for international, market-oriented cooperation among 40-plus economies across Europe, and in Israel, South Korea, South Africa and Canada.

The NRC houses and manages Canada's EUREKA National Office and provides companies with a first contact point for Canadian innovators seeking access to EUREKA's global network. Using the EUREKA network, the NRC connects Canadian organizations with potential partners and opportunities and, through IRAP, offers funding support to eligible Canadian SMEs participating in EUREKA projects.

In less than four years since becoming an associate member, Canada has received approval for more than 50 EUREKA network projects valued at \$77 million.

In 2016-2017 alone, NRC IRAP supported 39 SMEs in initiating 16 bilateral EUREKA projects worth a total of \$11.7 million, and in labelling 11 multi-lateral EUREKA cluster projects valued at \$158.6 million.

In March 2016, Canada joined the EUREKA "Eurostars" program. During the September 2016 Eurostars call for projects, Canada's engagement was strong with participation in 12 project submissions. Ultimately, six of these projects (valued at \$12 million) were approved and received funding from all international partners—a 50 per cent success rate compared to the average 30 per cent success rate for Eurostars submissions.

Collaborative projects underway involve 76 Canadian SMEs, three large firms and five universities. To date, EUREKA has enabled Canadians to partner with organizations in Belgium, Finland, France, Germany, Israel, The Netherlands, South Korea, Spain, Sweden, Switzerland, Turkey and the United Kingdom, among others.





The NRC Dialogue



As part of his mandate, the NRC's President, Iain Stewart, was asked to take stock of the current state of the NRC in several key areas and propose a way forward to support the government's Innovation and Skills Plan.

Discussions, consultations, and an extensive exchange of views and ideas were essential to the success of this internal assessment that engaged employees throughout the NRC in an organization-wide process called the NRC Dialogue. In all, 3,180 employees, 15 external experts, town-hall discussions in 10 provinces, and 350 consultation sessions at 18 NRC sites across the country contributed to the process—and the renewal of the NRC is now taking shape.

As its primary objective, the NRC Dialogue was to determine how the NRC could support the Government of Canada's Innovation and Skills Plan, and to present options for how we could enhance the NRC's capacity to advance scientific

knowledge, support government priorities, and spur business innovation in Canada.

Tiger Teams comprising a cross-section of employees were created to support the roll-out of the NRC Dialogue. Each Tiger Team

was to consult widely across the organization; make a critical examination of specific areas of the NRC; and, propose a desired future state for the NRC. Throughout the process, the Tiger Teams were supported with guidance and advice from expert external advisors who also performed a challenge function as the teams carried out their work.

This year was quite unique as we embarked on a journey to renew the NRC, while we continued to forge ahead to solve complex problems in areas of critical importance to Canada. Over the coming years, the renewed NRC will focus on: creating programs to deliver on government priorities including alignment with the federally-supported superclusters; research excellence in disruptive technologies;

**18**sites visited to
consult employees**350**consultation
sessions held**3,180**attended consultations
and town halls**3,096**feedback forms received
and surveys completed

growing SMEs to scale and export; revitalizing the NRC research environment to include a more diverse workforce; and, enhancing environmental stewardship.

The ideas and actions brought forward in the NRC Dialogue were developed by staff, challenged by external advisors, discussed with our Ministers and will now be implemented through a four-year action plan.

Taken together, these changes will result in an organization that emphasizes collaboration and is better aligned with federal priorities, and that is more balanced across its three core areas of delivery: support to business innovation; support for federal mandates; and, advancing science and innovation through exploratory research.

“The NRC Dialogue has been an opportunity for the NRC to take stock of what is working well and to identify where we can make improvements to better support Canadian research excellence and innovation to achieve the goals of the federal Innovation and Skills Plan.”

— Iain Stewart, President

External expert advisors

Anne Peyroche

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Centre national de
la recherche scientifique

Raymond Leduc

President,
Nova Bus and Prevost
(Volvo Group)

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Canada Revenue Agency

Peter Nicholson

Former CEO,
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Elizabeth Cannon

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University of Calgary

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Group Member, Canadian Institutes
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Martha Crago

Vice-President,
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McGill University

Richard Dicerni

Former Deputy Minister,
Industry Canada;
Deputy Minister,
Executive Council of Alberta

Bob Walker

Former CEO,
Atomic Energy of Canada Limited



The NRC Leadership

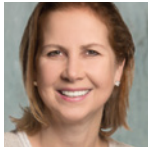
Council Members (2016-2017)



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Chair of the Board,
Open Text Corporation,
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Senior Executive Committee (2016-2017)



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François Cordeau
Vice-President (Acting),
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Ian Potter
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Maria Aubrey
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Isabelle Gingras
Vice-President,
Human Resources



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Policy



Dick Bourgeois-Doyle
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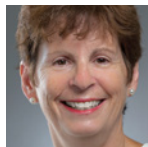
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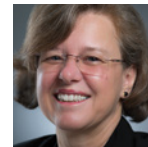
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Vice-President,
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Dale MacMillan
Vice-President,
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Geneviève Tanguay
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