NRC · CNRC

From Discovery to Innovation...

RESEARCH EXCELLENCE

knowledge

At the Frontiers of Discovery

National Research Council Canada
Conseil national de recherches Canada

Canada

NRC VISION
Recognized globally for research and innovation, NRC is a leader in the development of an innovative, knowledge-based economy for Canada through science and technology.

This Vision is founded on five strategic pillars:

Outstanding People – Outstanding Employer
Recognition as a leading research organization distinguished by creativity and innovation

Excellence and Leadership in R&D
Integration of public and private strengths to create new opportunities and meet national challenges for Canada

Technology Clusters
Development of the innovative capacity and socio-economic potential of Canada's communities

Value for Canada
Commitment to the creation of new technology-based enterprises, technology transfer and knowledge dissemination to industry

Global Reach
Access to world-class science facilities, as well as global research and information networks. Stimulation of enhanced international opportunities for Canadian firms and technologies.

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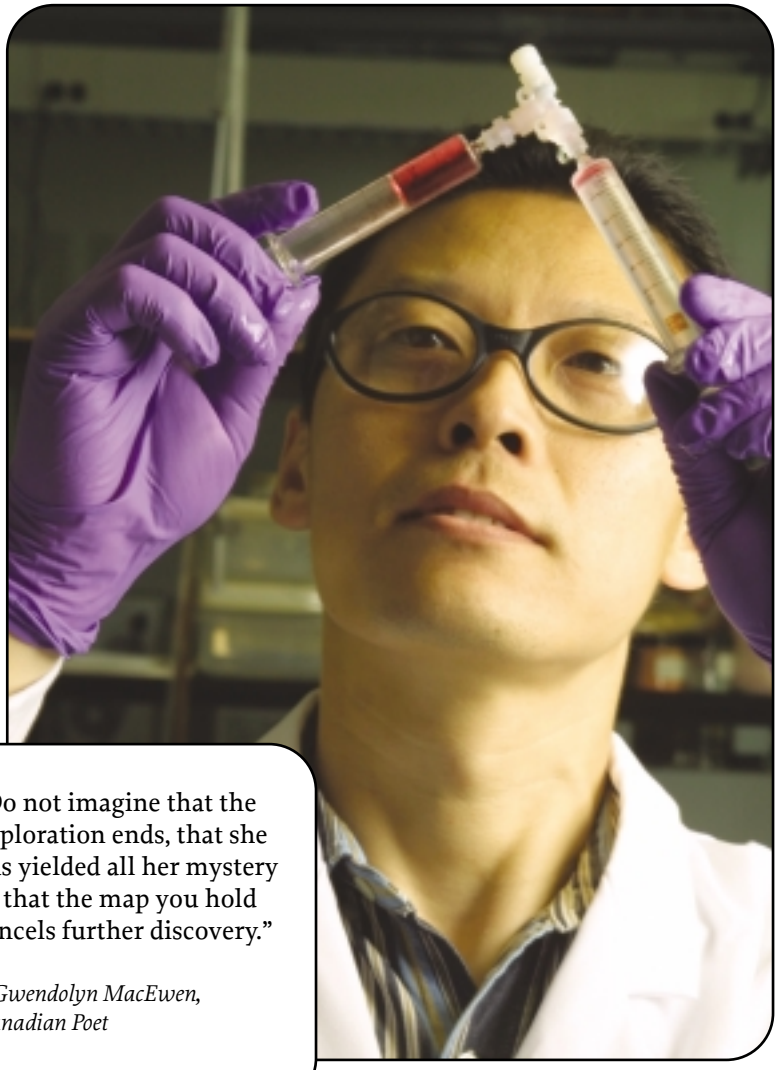
At the Frontiers of Discovery

***Cover photo**: Detail of a Molecular Beam Epitaxy system for gallium nitride epitaxy. Epitaxy involves the growth of one crystal on the surface of another. The epitaxial layer has the same crystalline orientation as the substrate on which it is grown. Epitaxy is a critical process in the creation of new semiconductor materials. Researchers at the NRC Institute for Microstructural Sciences are using the system to grow indium and aluminium gallium nitride on sapphire and silicon carbide substrates, creating new and novel semiconductor materials for use in the next generation of photonic and telecommunication devices.*

At the Frontiers of Discovery



"Do not imagine that the exploration ends, that she has yielded all her mystery or that the map you hold cancels further discovery."

– Gwendolyn MacEwen, Canadian Poet

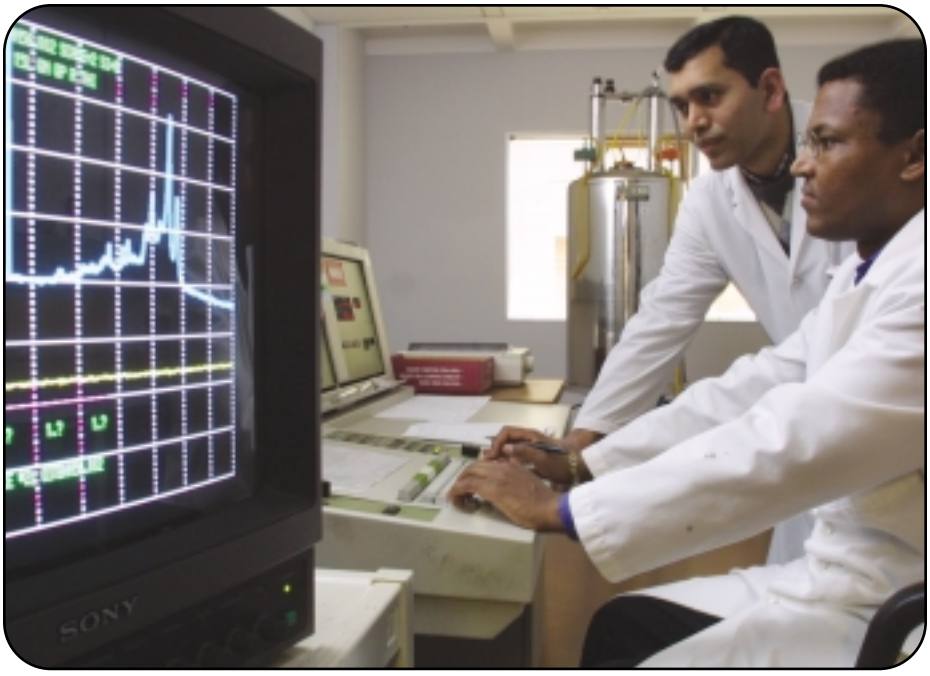
Science and Innovation Leadership

Today's research creates tomorrow's opportunities. Leading-edge research and development is at the very core of NRC's *Vision 2006* and NRC's contributions to Canada and all Canadians. Working in collaboration with industry, government and academic partners, NRC pursues strategically focused R&D to help build Canada's innovation and technology capacity and support Canadian industry.

Rapidly Moving from Discovery to Innovation

Truly ground-breaking scientific discoveries now draw from a wide range of scientific skills and expertise. Such conditions offer enormous benefits for flexible and highly networked organizations with a diversified pool of research expertise. NRC continues to develop its reputation as a world-leading research organization by cultivating multi-institute, multi-disciplinary teams in highly strategic research fields such

knowledge



Knowledge Creation

NRC creates knowledge for the benefit of Canada. In 2002–2003, NRC published 1,133 papers in leading peer-reviewed journals, including such prestigious publications as *Science* and *Nature*. It had 796 papers published in conference proceedings and produced 1,794 technical reports. NRC staff held editorships or sat on the editorial boards of some 161 S&T publications. NRC staff also sat on 505 national committees and 620 international committees, organized 185 conferences and workshops, and attended 732 international conferences. NRC staff also held 318 adjunct professorships with universities and colleges across Canada.

as nanotechnology, energy technologies and biotechnology.

For every "core" NRC institute in a particular research area, such as manufacturing, there are as many or more "partner" institutes and programs that play a valuable role in providing complementary expertise. For example, research into carbon nanotubes embraces applications both for the construction industry, to help provide structural support, and as a fuel storage device for fuel cells.

NRC's approach to R&D also includes extensive collaborations and partnerships. Such collaborations extend the reach of valuable resources and permit NRC to tap into other key sources of expertise needed to tackle research projects. Researchers are not only able to make initial scientific discoveries, but also help define the innovative new technologies, products and services that flow from them.

Responding to National Challenges

NRC actively seeks out solutions to national challenges in health, climate change, the environment, clean energy and other fields, helping lay the knowledge foundations for Canada's future growth. The focus is solving real problems – those with the potential for

"The Government of Canada's S&T efforts will identify emerging issues that matter to Canadians and refocus in response to changing needs in areas such as health and safety, public security, natural resources and the environment, and the growth of the knowledge economy."
– Science and Technology Advice: A Framework to Build On: A Report on Federal Science and Technology – 2002

saving lives, improving the environment and quality of life, or creating new technologies and industries where Canada can be a world leader. Recent examples include:

- NRC entered Phase 2 of its Genomics and Health Initiative, representing an investment of more than $75 million between 2002–2005, most invested in research programs involving partnerships between two or more NRC Institutes. Phase 2 entails eight major research programs involving different institutes and helps leverage valuable resources and expertise from across the organization.

- NRC is playing a significant role in the Government of Canada's response to Chemical, Radiological and Nuclear (CBRN) national security threats. The CBRN Research Technology Initiative announced 24 counter-terrorism research projects selected for its first round of funding. NRC is involved in four of the winning projects.

- Launched in 2000, the NRC Fuel Cell Program was created as a horizontal initiative to maximize the use of direct and indirect fuel cell expertise and resources that exist throughout the NRC network and research organizations across the country. This far-ranging initiative, based at NRC Institute for Fuel Cell Innovation (NRC-IFCI), now involves more than 50 NRC researchers, six NRC institutes and representatives from several universities. In its first round, 12 projects were funded that, in turn, have produced four technologies with patents pending.

Leadership for Canada

As the Government of Canada's leading R&D organization, NRC provides advice and guidance on science and technology issues to government decision makers. Each year, NRC leads or plays a key role in new technology foresight and roadmapping studies, work which requires collaboration

and involvement from a variety of stakeholders and which helps define national science and technology priorities. NRC offers a key voice on these issues, helping balance perspectives from other players. As an added benefit, the depth of NRC's collaborations helps bring new partners to the table and helps stimulate wealth creation and the growth of community-based innovation.

NRC also plays an important role in helping manage and direct funding to large and complex science facilities that have already established an international reputation, such as TRIUMF, as well as others that are poised to have such a reputation, such as the Canadian Light Source (CLS). Researchers from a number of different NRC research institutes are involved in establishing the research priorities for the many beamline projects to be carried out at the CLS.

Photo courtesy of Canadian Light Source

Leadership Matters

- NRC organized a collaborative technology foresight study with other Government of Canada departments and Genome Canada concerning the post-genomics era in Canada. The purpose was to gather information on the status of Canadian genomics and proteomics R&D and its key players, to benchmark Canada against the global competition, and to develop a national action plan.
- NRC led the Federal S&T foresight exercise under the Federal Innovation Networks of Excellence – a $500,000 project involving some 250 S&T, government, business and university experts in five technical workshops centred on BioSytemics and GeoStrategies.
- NRC, with Industry Canada, played a key role in the development of the Canadian Marine and Ocean Industry Technology Roadmap and in the Canadian Fuel Cell Commercialization Roadmap. These Roadmaps outline key priorities and strategic directions for industries that can deliver significant economic value to Canada.

Building National R&D Capacity

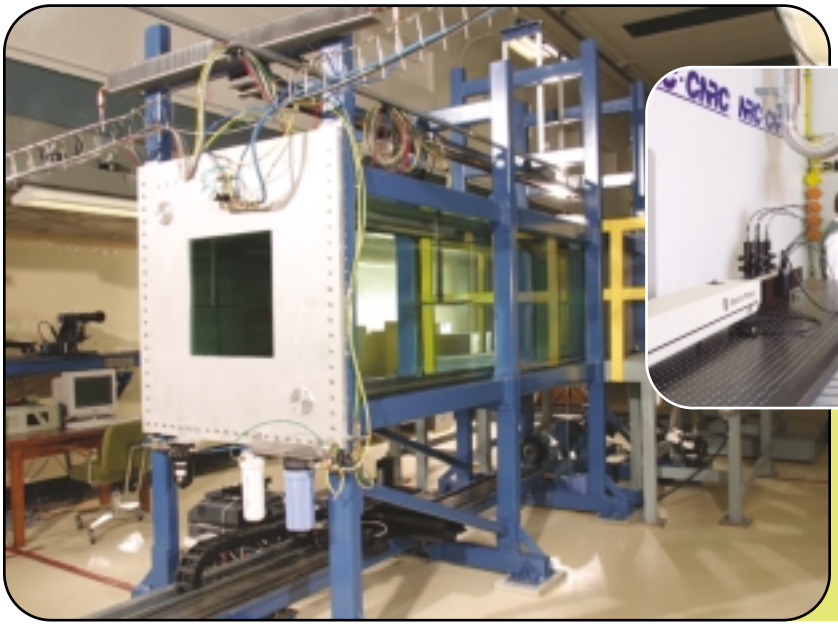
NRC makes strategic investments in R&D facilities, programs and networks in every part of Canada. It is the home of unique national science and engineering facilities, Canada's national science library, and Canada's source for science-based national measurements and standards. NRC's contributions to national infrastructure create new opportunities and leverage Canada's R&D investments.

The existence of such capacity, for example, plays a major role in driving community-level innovation and economic growth. Cutting-edge facilities, knowledgeable staff and vibrant knowledge networks help attract highly qualified people, generate key partnerships and produce significant technology transfer opportunities.

In 2002–2003, NRC continued to make major contributions to Canada's R&D infrastructure and capacity. Among the highlights:

NRC Gas Turbine Environmental Research Centre Earns International Standard of Quality

Construction began on the NRC Gas Turbine Environmental Research Centre (GTERC) in Ottawa, which will add critical experimental infrastructure to Canada's gas turbine engine industry. The facility earned the International ISO 9001:2000 Quality Standard registration. When completed, the facility will support industry in developing both aircraft and ground-based gas turbine engines in compliance with increasingly stringent environmental, safety requirements and operation demands.



Low Reynolds Number Pilot Facility

In 2002–2003, NRC-IAR designed and built a pilot-scale facility to study Low Reynolds number flows associated with very small flight vehicles, called Micro Aerial Vehicles. Conventional test facilities are unsuitable for these new and highly unique "tiny" vehicles. The facility, shaped like a long, covered aquarium, is filled with a mixture of water and glycerine with no free surface.

Everything Coming Up Nanotechnology

Design for the new National Institute of Nanotechnology (NINT) facility in Edmonton began in May 2002, with construction expected to start in August 2003 and occupancy in July 2005. When completed, the building will be one of the quietest, most technologically advanced nanotechnology research facilities in the world, enabling researchers to operate the next generation of electron and scanning tunnel microscopes at their extreme limits.

NRC Canadian Photonics Fabrication Centre

Ground breaking for the facility took place in the fall of 2002 and the entire outer shell of the building reached completion by the end of the 2002–2003 fiscal year. The NRC Canadian Photonics Fabrication Centre will develop and test prototypes of new photonics devices, train highly qualified personnel, and serve as a leading-edge R&D resource and network centre for industry and university researchers.

"Our business is education, education has an imbedded component that's called research ... I think it was quite visionary to have this facility established here, to combine expertise and excellence established in the two institutes [Carleton University and NRC-IMS]." – *Dr. Feridun Hamdullahpur, Vice-President, Research, Carleton University*

NRC – National Facilities and Critical R&D Infrastructure for Canada

- National astronomical observatories and data systems; access to international astronomical facilities
- National metrology facilities
- Canadian Bioinformatics Resource
- Canadian Centre for Housing Technology
- National aerospace facilities – wind tunnels, fixed and rotary wing research aircraft, structures and materials testing facilities, engine test cells
- Ocean and marine engineering test facilities
- NRC Canadian Hydraulics Centre
- NRC Centre for Surface Transportation Technology
- High-throughput screening, DNA sequencing, and microarray facilities
- Large-scale protein purification facility
- Marine Biosciences and Aquaculture Research Station
- Nuclear magnetic resonance imaging facilities
- Ultra-fast laser laboratory
- Canada Neutron Beam Laboratory
- NRC – Canada Institute for Scientific and Technical Information (NRC-CISTI)

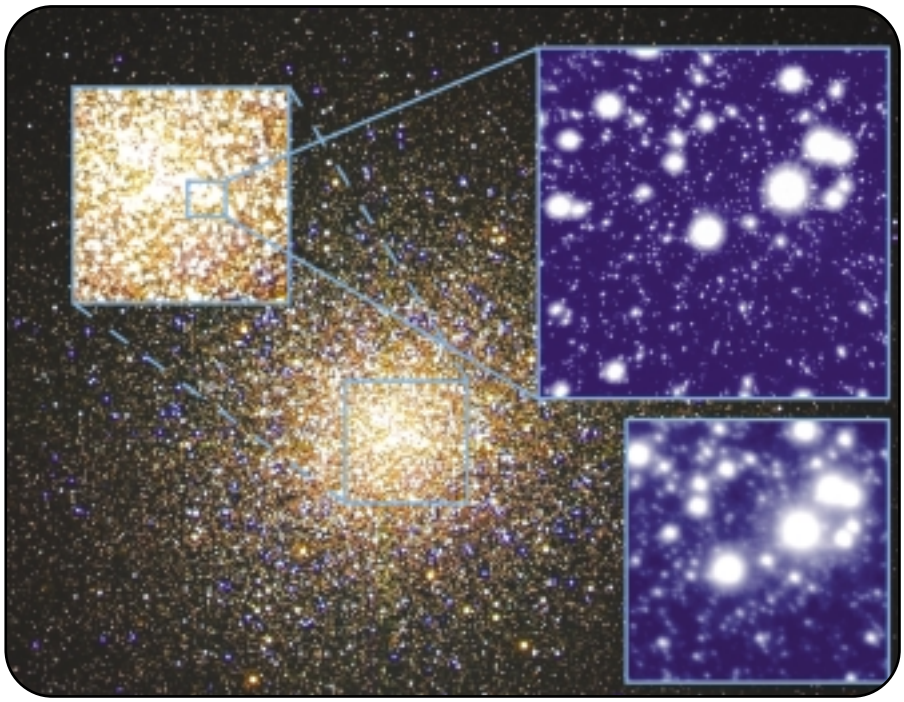
In all, some 400 S&T laboratories and facilities for Canadian R&D and innovation.

High-Performance Computing Platform
NRC is an important player in the rapidly developing field of grid computing. As part of a horizontal initiative in High-Performance Computing, several NRC institutes are working together to link computer resources across NRC. The result will be a multi-scale platform for computational modeling in a variety of domains.

Advances in Basic Sciences

Astronomy and Astrophysics – Our Gateway to the Stars
NRC conducts leading-edge research in astronomy and astrophysics, and provides the Canadian astronomy community with access to major astronomical facilities in Canada and internationally. NRC is also a world leader in the development of advanced instrumentation and works to transfer the knowledge and technologies it develops in astronomy and astrophysics to other disciplines.

Multiple Exposures Help Reveal New Moons
Scientists from the NRC Herzberg Institute of Astrophysics (NRC-HIA) in collaboration with the Harvard-Smithsonian Center for Astrophysics discovered three previously unknown moons of Neptune, yet another groundbreaking finding that will rewrite astronomy textbooks. The team achieved the success by taking multiple exposures of the sky around the planet Neptune. Using this

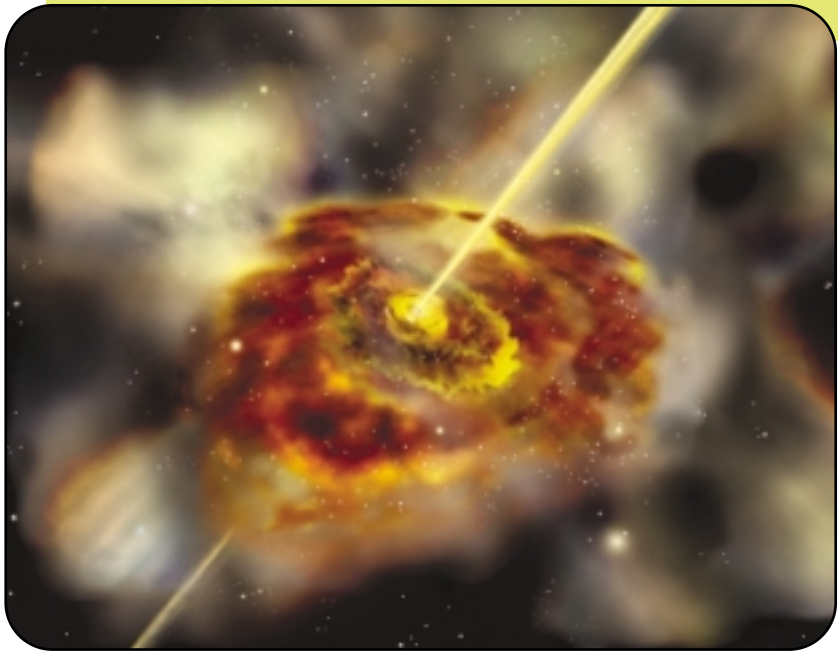


highly innovative technique, researchers were able to add many frames together to boost the signal. By tracking the planet's motion, astronomers detected stars in the final combined image as streaks of light, while the moons accompanying the planet appeared as points of light. These moons are the first ones discovered around Neptune since the Voyager II flyby in 1989, and the first discovered from a ground-based telescope since 1949.

Ground-Based Telescope Outperforming Hubble

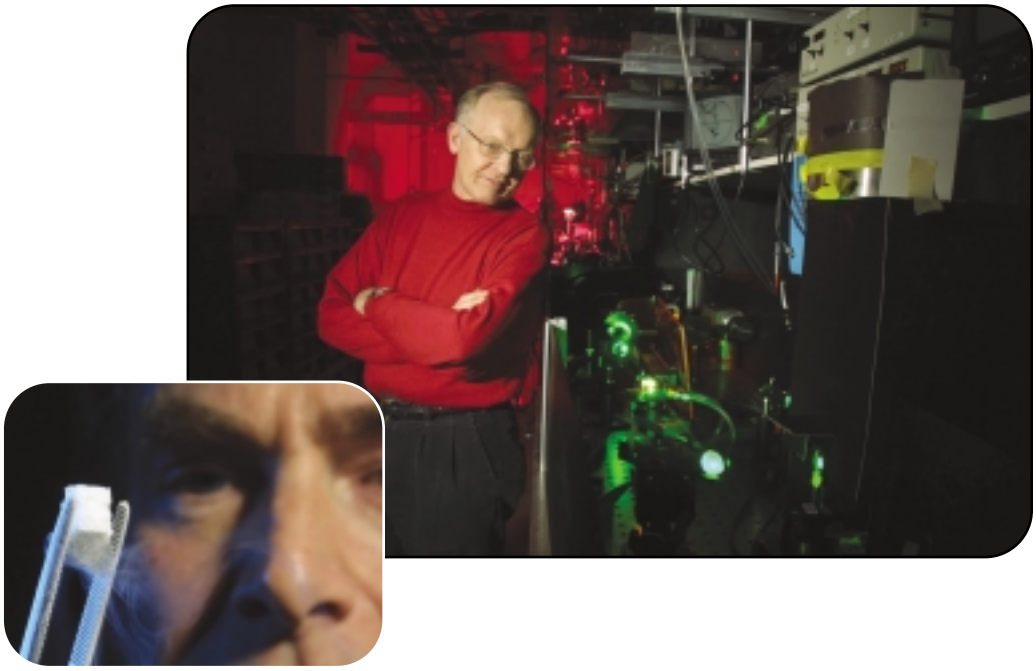
Researchers from NRC-HIA continued their successful track record of building innovative optical equipment capable of producing stunning results almost immediately upon installation. The team helped deploy the Altair adaptive optics system at the seven-nation Gemini Observatory North in Mauna Kea, Hawaii. One of the first images produced by the system revealed the core of the globular cluster M13, the Hercules Star Cluster, in unprecedented detail. The new instrument captures three times more detail in infrared light than the Hubble Space Telescope and will give astronomers a new capacity to see through the dust that blocks optical light and look into the heart of star formations. With this improved visibility, astronomers may soon be able to peek into stellar nurseries, or watch the birth of galaxies that formed 10 billion years ago.

NRC-HIA and UK astronomers studied infrared light from the most distant quasar known, SDSS J1148+5251, and found that it contains a black hole 3 billion times as massive as the Sun. The light was emitted 13 billion years ago, when the universe was only six percent of its current age. The finding provides important information about the early days of the universe.



Molecular Sciences – The Small Things Are Key

NRC conducts cutting-edge research in selected areas of molecular sciences that have the potential to stimulate entirely new or emerging sectors of the Canadian economy. Strategic fields for NRC include: nanoscience, chemical biology, laser science, molecular interfaces, organometallic chemistry, and their related technologies.



Gas Hydrates

New research findings by the NRC Steacie Institute for Molecular Sciences (NRC-SIMS) in the area of gas hydrates points to several applications for both the petroleum and fuel cell industries. A gas hydrate is a cage-like lattice of ice which traps molecules of methane inside. Gas hydrates are found in permafrost regions or beneath the ocean floor in deep-water locations. Hydrates also form in natural gas pipelines, blocking the flow of gas. NRC-SIMS researchers discovered that natural antifreeze proteins, designed to inhibit ice formation in plants and animals, also inhibit natural gas hydrate formation. This is a surprising result with implications both for understanding protein binding mechanisms and possible commercial applications in the gas and petroleum industry.

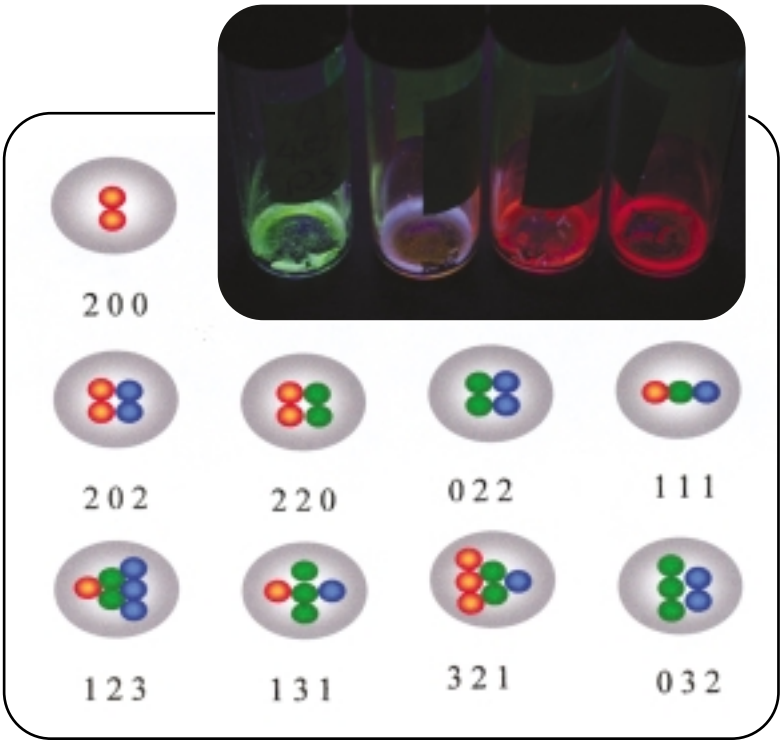
Major Breakthrough Casts Atoms in Starring Role

NRC-SIMS researchers achieved a major scientific breakthrough by tracking and recording the motion of hydrogen atoms in a hydrogen molecule. The research was based on NRC's expertise in femtosecond science (NRC has the world's fastest laser, pulsing at 1.8 femtoseconds). The NRC-SIMS team recorded the motion using a very unusual "flash," relying on electrons taken from the hydrogen molecules themselves. An intense laser beam pulls the electron free of the molecule and away from its parent ion, but when the electric force of the light wave reverses direction, the electron is forced back and collides with the molecule. The "collision" is what snaps the picture. Findings from this research suggest that electrons may be used for precision imaging, something that has never been accomplished.

The Science of Measurement
New knowledge in every field almost always depends on metrology – the science of measurement. Virtually every experiment requires precise knowledge of mass, length, voltage, chemical concentration or other quantities. Today, metrology faces new and exciting challenges from fields such as nanotechnology, where quantities and distances are exceedingly small. In these and other fields, the science of metrology continues to push boundaries.

Important Information Trapped in Light
Researchers from the NRC Institute for National Measurement Standards (NRC-INMS) are using the extreme size and unique physical properties of semiconductor nanocrystals to create a new form of document security technology. When these nanocrystals are exposed to UV light, they emit a wavelength that is determined by the size of the quantum dot particle. Changing the number of quantum dot particles alters the intensity of the luminescent emission. By creating an array of different-sized particles, researchers have demonstrated the possibility of encoding information within the florescent spectrum of wavelengths produced. Information is decoded using an exciting light and spectrometer. This work holds the promise of tiny, invisible information "info drops" suitable for encoding minuscule and irregular objects, passports and other security materials.

Tree Retardant Insulation for High Voltage Underground Power Cables
Research by NRC-INMS is helping extend the life of crucial urban infrastructure, high voltage underground power cables. Water molecules and other contaminants can cause "water trees," electrically weak areas in polymeric insulation and, ultimately, high voltage underground cable failure. While cables using older technology can deteriorate in as little as 10 years, water tree retardant technology can provide a 40-year life span. During the accelerated aging test performed by an independent laboratory, cables made of NRC-developed polymer withstood electric fields 100 percent longer than cables made of other types of insulation.



Biotechnology

Core NRC Institutes

- NRC Institute for Marine Biosciences, Halifax
- NRC Biotechnology Research Institute, Montréal
- NRC Institute for Biological Sciences, Ottawa
- NRC Institute for Biodiagnostics, Winnipeg, Calgary, Halifax
- NRC Plant Biotechnology Institute, Saskatoon

Partner NRC Institutes and Programs

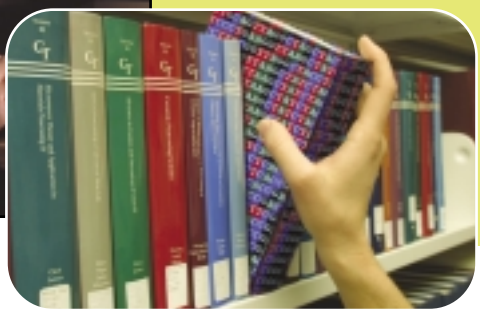
- NRC Steacie Institute for Molecular Sciences, Ottawa, Chalk River
- NRC Institute for Information Technology, Ottawa, Fredericton, Saint John, Moncton, Sydney
- NRC Institute for Microstructural Sciences, Ottawa
- NRC Institute for Chemical and Environmental Process Technology, Ottawa
- NRC Institute for National Measurement Standards, Ottawa
- National Institute for Nanotechnology, Edmonton
- NRC Industrial Research Assistance Program, across Canada
- NRC Canada Institute for Scientific and Technical Information, across Canada

Advances in Biotechnology

Biotechnology is a vital field of R&D for Canada. NRC has organized its biotechnology strengths into a strategic group including plant biotechnology, marine biosciences, biopharmaceuticals, biodiagnostics and biological sciences. NRC's capacities in other fields – such as IT, new materials, manufacturing technologies, nanotechnology, metrology and others – are coupled with dedicated biotechnology resources to address critical issues in health, the environment, agriculture and other fields of importance to Canadians. Working with public, private and academic organizations, NRC made significant biotechnology R&D breakthroughs in 2002–2003.

Engineering and Microbiology Make Effective Biobarrier

Researchers at the NRC Biotechnology Research Institute (NRC-BRI) combined unique expertise in bioengineering and microbiology to provide an effective solution to groundwater contamination caused by methyl tert-butyl ether (MTBE), a gasoline additive now banned in California. As part of a collaboration with the Institut français du pétrole, NRC-BRI researchers scaled up the production of a specialized biobarrier system to be deployed at contaminated sites. The barrier,



Making Knowledge More Accessible
High-throughput genomics and proteomics technologies have created a wealth of information about the biological function of genes and proteins; Medline contains more than 13 million publications in this domain. The Litminer project, led by the NRC Institute for Biological Sciences and the NRC Institute for Information Technology, is developing new tools that mine this information and connect it to specific gene and protein subsets.

packed with perlite, is augmented with pure cultures of *Mycobacterium austroafricanum*, a microorganism which accelerates the biodegradation process. NRC-BRI's expertise in biochemical engineering, meanwhile, contributed to the successful characterization and optimization of the biodegradation process, an important finding which will be used to improve the performance of the biobarrier.

Understanding and Fighting Infectious Diseases

Ongoing research into the structural genomics of bacterial proteins expanded into a major multi-institutional research project in the past year, attracting partners from Queen's University, McGill University and $3 million in funding from the Canadian Institutes of Health Research. Research focuses on identifying the structure of proteins that may contribute to the pathogenicity of *Escherichia coli*. So far, researchers from NRC-BRI have already identified 20 novel protein structures, good news for manufacturers looking to develop new drugs to prevent future deaths and illness from *E. coli*. The project is one of numerous NRC research efforts into infectious diseases.

New Uses for Old Drugs

The drug discovery process is a long and complicated affair, from initial discovery of promising drug targets, through numerous trials and eventual release to the market. To address this situation and to help speed up the drug discovery process, researchers from NRC-BRI have followed a new and novel approach focused on finding new applications for drugs already on the market. This work involves breaking down drug compounds into their

constituent parts and attempting to create new drugs from these materials. Researchers have now assembled a library of drugs for certain conditions. In the past year they have found new anti-glycation agents useful for treating conditions associated with Diabetes such as cataracts. Research has shown that certain inactive components within existing drugs used to treat Diabetes-related problems can be used as active components in new and novel formulations.

Improving Plant Architecture

As canola plants mature, the pod shatters and spills grain on to the ground, resulting in losses of the seed oil. Researchers from the NRC Plant Biotechnology Institute (NRC-PBI) have been successful in isolating and characterizing the *brevipedicellus* gene which plays an important role in determining the architecture of the flower, and ultimately how the seed pod is positioned. This discovery could lead to strategies to alter canola silique structure to minimize pod shattering. An understanding of this gene will also play a vital role in investigating how structure relates to crop productivity and plant ecology, and will lead to practical benefits in plant breeding, plant propagation, developmental biology, horticulture, and in the management of crop pests.

Healing Plants

Crops for enhanced human health represent an enormous market opportunity for Canada. However, success of this emerging area can be affected by a high degree of variability in active ingredients found in nutraceutical

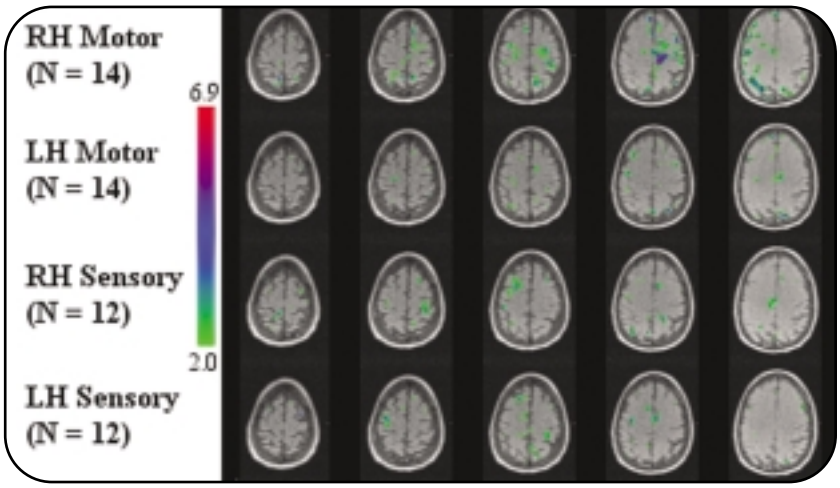
plants, unwanted substances also present in the plant, and agronomic traits. Effective breeding methods are key to addressing this problem. Researchers from NRC-PBI have developed effective and accelerated breeding protocols known as double haploidy effective for numerous herb, spice and nutraceutical species such as caraway, anise, dill, fennel and cow cockle. This will lead to the production of plant species with consistently high levels of active medicinal ingredients, removal of unwanted substances and superior agronomic traits.

Growing Our Export Markets

Since the late 1990s, Canada has become a leading exporter of chickpeas. Researchers from NRC-PBI have developed consistent and reliable transformation methods for chickpea, a pulse crop like peas and beans. The work offers the potential to add new improved characteristics to these crops such as decreased farm losses due to disease and weeds, and the ability to add value-added characteristics such as enhanced nutrition.

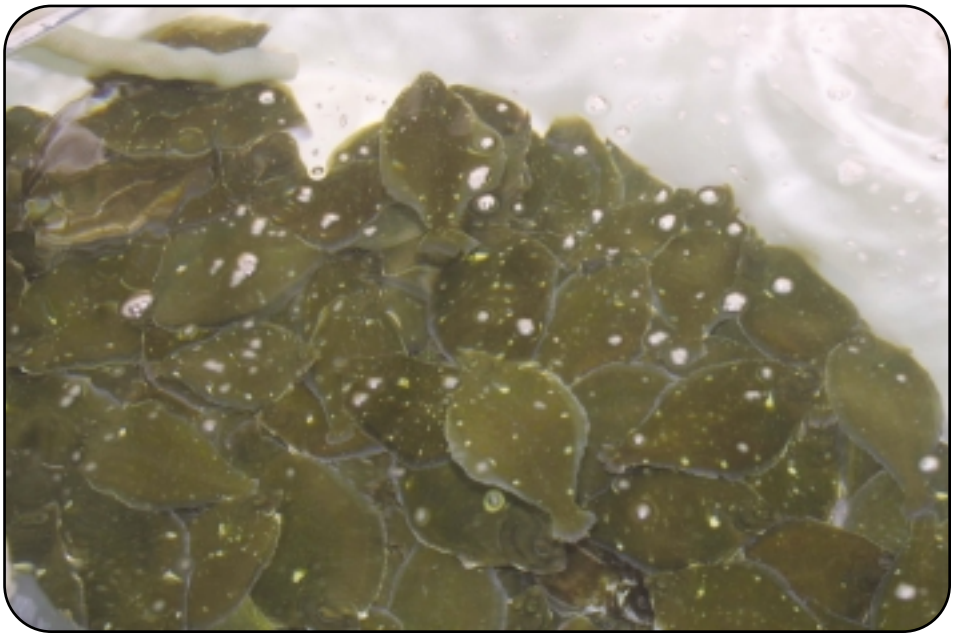
New Detector – More Safety

The NRC Institute for Biodiagnostics (NRC-IBD) has created a prototype ferromagnetic material detector for use in Magnetic Resonance Imaging (MRI) suites. Ferromagnetic material has iron content, and thus, is attracted by magnets. In high magnetic fields, this force of attraction can accelerate ferrous objects such as a wristwatch or metal instruments to the point where these "flying projectiles" can cause damage upon impact with the magnet or, worse yet, cause injury or death to people caught in the way. The detector operates in and utilizes the fringe field of a magnet to detect an object with iron content that passes through the device.



SEEP – A New Method for Functional Magnetic Resonance Imaging

New research will help extend the usage and benefits of leading medical imaging techniques such as Functional Magnetic Resonance Imaging (FMRI), an important tool for assessing brain and spinal cord function. Researchers with NRC-IBD are now able to produce FMRI images using inexpensive and low maintenance low magnetic field systems. Conventional FMRI methods measure changes in the relaxation times of protons in tissues which have been altered by the changes in the ratio of oxyhemoglobin to deoxyhemoglobin during brain activation. This method requires high-field MRI systems. In contrast, NRC's new technique, known as SEEP, makes



use of proton density changes, and so can use either low-field or very high-field MRI systems. Since both imaging methods produce slightly different information, images can be combined to produce even better diagnostic capabilities.

Improved Diagnosis for Fetal Alcohol Syndrome

Fetal Alcohol Syndrome (FAS) is a devastating and completely preventable condition that creates enormous social and economic costs. Yet, FAS is often hard to diagnose using current methods. As a result, early and effective treatment options are missed. To better address the needs of those with alcohol-related neurological disorders and FAS, collectively known as Fetal Alcohol Effects (FAE), researchers from NRC-IBD have been using MRI-based methods to improve the diagnosis of FAE. Using FMRI, researchers have examined brain function, including spatial working memory, attention and working memory in children and adults with known alcohol-related disorders. While the study is ongoing, initial findings demonstrate decreased activity in the dorsolateral prefrontal cortex, parietal region and caudate nucleus, among persons known to have FAE compared to those free of such disorders.

Cold-Hardy Fish a Valuable New Source of Antibiotics

Increasingly resistance-prone antibiotics could soon receive a boost from the cold-hardy winter flounder, found off the coast of Nova Scotia. A team from the NRC Institute for Marine Biosciences (NRC-IMB) have discovered a family of antimicrobial peptides contained in the winter flounder that have significant therapeutic potential. The peptides have demonstrated varying levels of activity against bacteria such as the infectious yeast *Candida*, *Staphylococcus aureus*, the scourge of many hospital wards, and *Pseudomonas aeruginosa*, a lethal threat

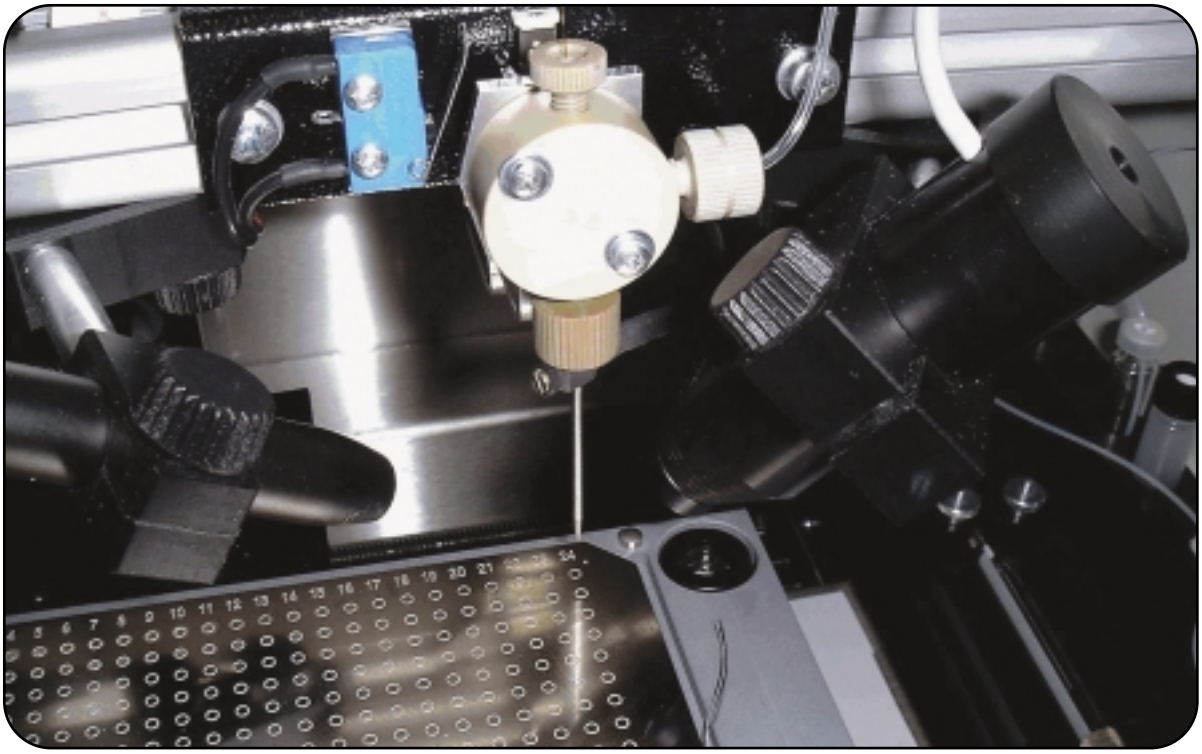
to patients with Cystic Fybrosis. Some flounder peptides are also effective against certain cancer cell lines. In 2002–2003, the team won a prestigious MedInnova Frontier Innovation Award for this research.

Shining a Light on Aquaculture Research

Researchers from NRC-IMB, in collaboration with Dalhousie University and Halifax-based Satlantic, successfully deployed an optical sensing system at a mussel aquaculture site in Ship Harbour, Nova Scotia. These buoy-mounted sensors allow remote monitoring of the feeding patterns of farmed mussels and algal bloom formation, including potentially harmful algae. The optical sensors measure light absorption at multiple wavelengths to detect plankton, and other dissolved and particulate materials in seawater, and can take measurements at the surface and under water at multiple depths, in any weather, during all daylight hours. The sensors will help farmers unravel the mystery of mussel feeding patterns and help determine the best size and location for a mussel farm.

Faster Drug Discovery

On a weekly basis, pharmaceutical companies can create as many as 10,000 new compounds in search of new drugs; each of these needs to be analyzed. Using current electrospray mass spectrometry techniques, analysis can take anywhere between 1 and 15 minutes per sample. Furthermore, some pharmaceutical



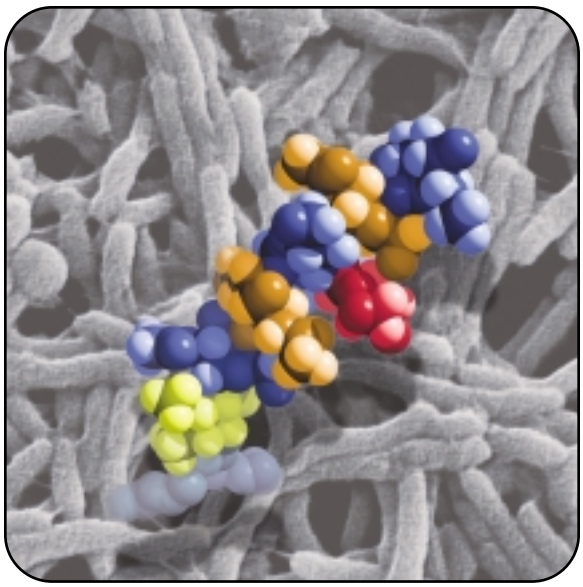
molecules are not amenable to electrospray analysis. Researchers at NRC-IMB have developed a new method for analyzing low proton affinity compounds using a reactive MALDI matrix. This concept extends MALDI to molecules that are normally hard to analyze by laser desorption/ionization or electrospray ionization. Together with a newly designed MALDI mass spectrometer, this technique can accelerate the rate of analysis to less than a second per sample.

Vaccine Targets for Major Food-Related Bacteria in Sight

New findings from NRC-IBS have identified promising new vaccine targets to protect against *Campylobacter jejuni*, a widespread and highly damaging bacterium. *C. jejuni* is the most common cause of foodborne illness in North America, affecting one in a hundred. Of those infected, approximately one in a thousand develop a form of paralysis known as Guillain-Barré syndrome. NRC-IBS researchers identified a new mechanism used by *C. jejuni* to add sugars to proteins, a process known as glycosylation. With the discovery of this ASN-linked glycosylation pathway, researchers have determined that the same group of sugars is added to all strains of *C. jejuni* and *C. coli* that have been examined. Research has also revealed that these sugars are added to not one but to over 30 proteins in *Campylobacter*, greatly increasing the number of potential vaccine targets. Collectively, these new findings point to valuable new targets for vaccine design and anti-infective agents.

New Hope for Damaged Brains

As part of ongoing research into treatment options for strokes and neurodegenerative diseases such as Alzheimer's, the NRC Institute for Biological Sciences (NRC-IBS) has developed new strategies for delivering therapeutics into the brain. NRC-IBS researchers have identified and characterized a new transporter, ABCG2, which is found in brain endothelial cells. The transporter is involved in the extrusion of drugs from the brain, preventing drug therapies from fully reaching their target. ABCG2 is part of a larger family of transmembrane proteins that are



responsible for the movement of a variety of compounds across biological membranes. Since the transporter represents a new channel across the blood-brain barrier, researchers are now investigating ways to use specific transport inhibitors to deliver therapeutics to the brain.

Advances in Engineering and Construction

NRC performs R&D in the area of engineering and construction, key sectors for Canada's economic growth and prosperity. In the aerospace sector, NRC provides key facilities for propulsion, flight, structural and aerodynamics testing and cultivates expertise in leading-edge manufacturing technologies, in-flight experimentation and other areas of importance to aerospace. In the ocean and marine technologies, NRC provides research strengths in offshore engineering and ship technologies. Finally, NRC boasts a unique capacity in construction research. In addition to fulfilling ongoing requirements for the maintenance and creation of new building and fire codes and standards, NRC research in construction continues to

Engineering and Construction

Core NRC Institutes and Technology Centres

- NRC Institute for Marine Dynamics, St. John's
- NRC Institute for Aerospace Research, Ottawa
  - *NRC-IAR Aerospace Manufacturing Technology Centre, Montréal*
- NRC Institute for Research in Construction, Ottawa
- NRC Canadian Hydraulics Centre, Ottawa
- NRC Centre for Surface Transportation Technology, Ottawa, Vancouver

Partner NRC Institutes and Programs

- NRC Industrial Materials Institute, Longueuil
  - *NRC Aluminium Technology Centre, Ville Saguenay*
- NRC Steacie Institute for Molecular Sciences, Ottawa, Chalk River
- NRC Institute for Chemical Process and Environmental Technology, Ottawa
- NRC Integrated Manufacturing Technologies Institute, London
- NRC Industrial Research Assistance Program, across Canada
- NRC Canada Institute for Scientific and Technical Information, across Canada

deliver meaningful breakthroughs in areas such as fire risk management, urban infrastructure and indoor environment.

NRC's Aerospace R&D – Flying High

The aerospace industry is a major industrial success story for Canada. The manufacturing component of the industry currently stands third in the world in terms of sales. Canada is a world market leader in regional and business aircraft, commercial helicopters, gas turbine engines, landing gear, flight simulators, and aircraft guidance and control systems. The NRC Institute for Aerospace Research (NRC-IAR) has served this vital industry sector for over 50 years with leading-edge research and development services.

Improved Coatings

NRC-IAR continued research on the development and applications of environmentally compliant coatings for aerospace applications. This work builds on new competencies in Unbalanced Magnetron Sputtering and focuses on the design, micro-structural characterization and qualification testing of coatings such as aluminium-molybdenum as a substitute for cadmium. Chromium nitrate and nano-structured coatings are also under investigation as substitutes for hard chrome.

NRC's Bell 205 airborne simulator zeroes in on targets simulating the motion of a ship at sea to collect data for development of Vertical Auto-Land Experimental Technologies (VALET). Once developed, VALET will allow the pilot to hand off control to an onboard, automated control system that will perform the transition from forward to vertical flight and conduct the entire landing phase. This is especially valuable in poor visual conditions and for shipboard helicopter operations.

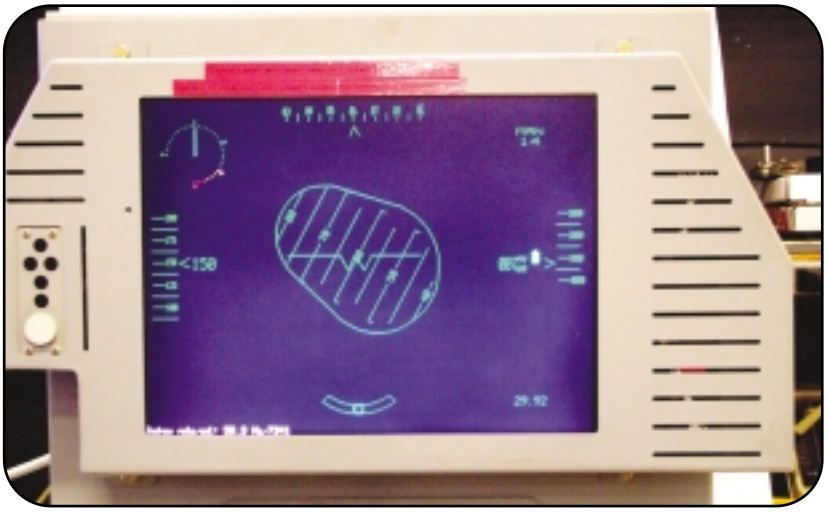
"NRC provides industry with strategic research infrastructure and is an effective partner in a broad range of research activities." – *Peter Boag, President and CEO, Aerospace Industries Association of Canada*

Safer Winter Flying

NRC-IAR recently completed a multi-year project that will help make winter flying safer. A final report has been distributed to the international aviation community. Researchers documented the effects of runway surface snow and ice contamination on aircraft take-off and landing distances.

"The Pear" Increases Air Safety

Statistics indicate that spatial disorientation accounts for more than 10 percent of all fatal air accidents. Joint research with Defence Research and Development Canada has led to several new display designs to help improve what's known as unusual attitude recovery. An NRC asymmetric attitude indicator dubbed "The Pear" shows early promise as asymmetric shapes are more easily interpreted when the aircraft is not in a normal attitude. If tests prove successful, the research could lead to an entirely new instrument panel view for pilots.



NRC's Construction R&D – Building Canada

The construction industry is one of Canada's largest, with over 850,000 people employed by some 215,000 firms, mainly small companies, and contributes more than $100 billion annually to the economy. Innovation in this sector poses special challenges. R&D and construction codes and standards are critical to this sector to lower transaction costs, facilitate technology diffusion and help reduce trade barriers to improve industry access to global markets.

Green: It's the New Blue

Urban areas such as Toronto suffer from a phenomenon known as the urban heat island effect. The result is a chain reaction of higher temperatures, increased energy consumption necessary for cooling, increased air pollution in the form of smog and sulphur dioxide, as well as more greenhouse gases. In 2002–2003, the NRC Institute for Research in Construction deployed Green Roof systems at two locations in Toronto as part of a multi-partner demonstration project. NRC-IRC is working with key technology, such as highly water-and-root-repellent membranes. NRC has instrumented the roofing systems and will monitor their performance over the next two years. Studies by Environment Canada show green roofs can help save energy, while reducing sulphur dioxide and greenhouse gas emissions.

NRC provided significant direction to the Canadian Marine and Ocean Industry Technology Roadmap, which completed its work in March 2003. NRC-IMD research strengths will continue to play a key role in growth opportunities for the cluster identified by the Roadmap. Significant potential exists in oil and gas services, ocean mapping and energy efficient transportation to name a few.

The Daylight Zone

Daylight, either too much or little, has a major impact on the indoor work environment. Good daylighting design can reduce lighting energy consumption by up to 50 percent, and increase occupant satisfaction with the indoor environment. NRC-IRC released several new software tools to help designers make improved daylighting decisions in planning or renovating office spaces. DAYSIM allows designers to account for the dynamic nature of daylight, occupant switching and blind use. SKYVISION calculates the optical and daylighting properties of skylights, quickly performing calculations for skylights of various shapes, sizes and glazing types.

NRC's Ocean Engineering R&D

NRC works with marine regulatory bodies, marine system designers, manufacturers and operators and the defence community to ensure that Canada's ocean engineering businesses and operations are safe, environmentally friendly and competitive. Research at the NRC Institute for Marine Dynamics (NRC-IMD) provides industry with a unique concentration of knowledge, facilities and technologies to solve engineering challenges related to Canada's ocean environments.

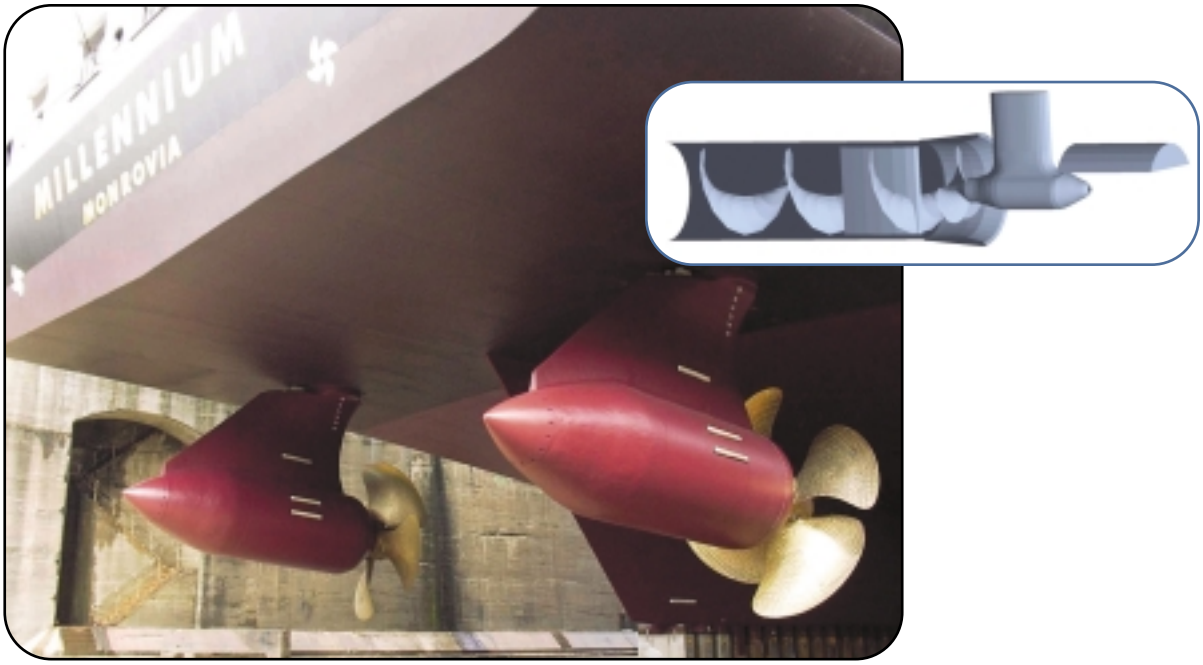


Photo courtesy of Rolls-Royce

Propellers that Move in Pods

NRC-IMD researchers are helping improve the design and performance of a new generation of ship propulsion systems, known as podded propellers, which are attached to the exterior of a ship's hull and are capable of turning to control ship direction. While these new propellers are widely used, their performance is poorly understood, particularly under unique hydrodynamic and ice loads. NRC-IMD has completed a complex experimental design for testing podded propellers, which will be used to study performance characteristics in a wide variety of conditions. The result will be much more predictable ship performance and, ultimately, better maneuvering of ships operating in various ocean and ice conditions.

Innovative Underwater Vehicle Thruster

Offshore projects, ocean floor mapping and mine sweeping are creating increased demand for autonomous underwater vehicles (AUVs). But maneuverability of these vehicles has been a challenging and serious problem. Researchers at NRC-IMD have now created a unique technology to improve their performance. Known as the Damped Self-pitching WIG Effect Thruster Array, it generates substantially increased thrust in sudden acceleration situations and increased control over movement in any desired direction (i.e. pitch, yaw, vertical, lateral, etc.). The technology comprises a specialized thruster array which provides full control over the rotational motion of separate thrusters (increasing maneuverability),

and uses a new technique to produce higher thrust. Equipped with this new technology, AUVs will be far more effective, opening up possibilities for new applications.

NRC Technology Centres

Safer Highways – An End to Truck Roll-Over

New research being conducted by the NRC Centre for Surface Transportation Technology (NRC-CSTT) will improve the road safety of trucks carrying dangerous goods. As part of a project involving Transport Canada, NRC-CSTT will use its specialized outdoor tilt table and sophisticated expertise in transportation technology to test 47 varieties of tanker trucks. The project will help establish factors that contribute to the roll stability (or instability) of each vehicle. The project results will then be used to create a computer simulation for use as a design aid for future trailers and trucks.

Better Prediction Means Better Protection

The NRC Canadian Hydraulics Centre (NRC-CHC) continued to expand its environmental prediction and support systems simulation

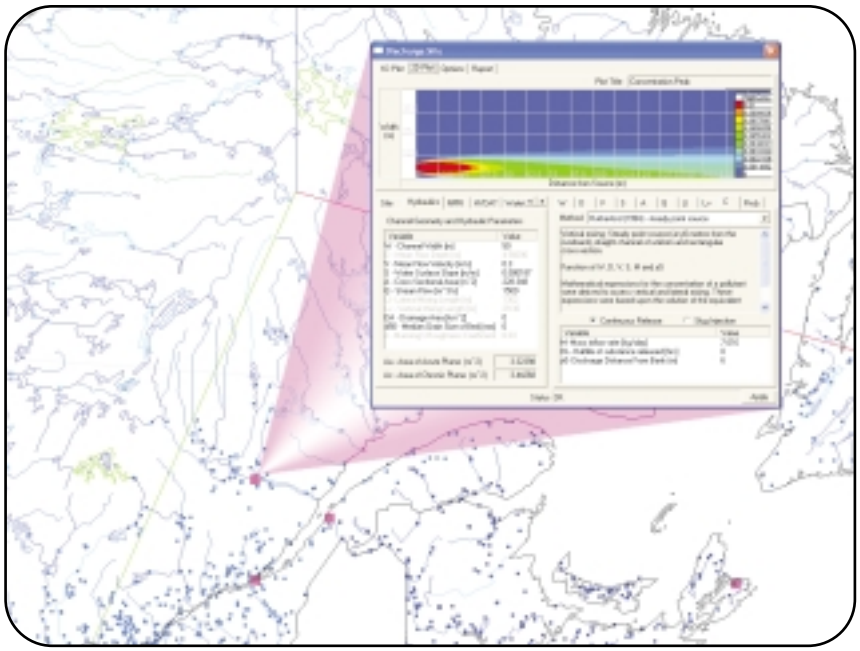
Information and Communications Technologies

Core NRC Institutes

- NRC Institute for Information Technology, Ottawa, Fredericton, Saint John, Moncton, Sydney
- NRC Institute for Microstructural Sciences, Ottawa

Partner Institutes and Programs

- NRC Institute for Marine Biosciences, Halifax
- NRC Institute for National Measurement Standards, Ottawa
- NRC Steacie Institute for Molecular Sciences, Ottawa, Chalk River
- NRC Institute for Chemical Process and Environmental Technology, Ottawa
- National Institute for Nanotechnology, Edmonton
- NRC Industrial Research Assistance Program, across Canada
- NRC Canada Institute for Scientific and Technical Information, across Canada



technology (EnSim™), used to study and develop emergency responses to problems related to flooding, water-borne pollution, sediment transport, water quality, dam breach, and oil spills. Over the past year, NRC-CHC created a new user interface for predicting the fate of pollutants dispersed into rivers and streams. The technology has already been deployed to help create a database of all industrial sites and sewage outfalls in Canada.

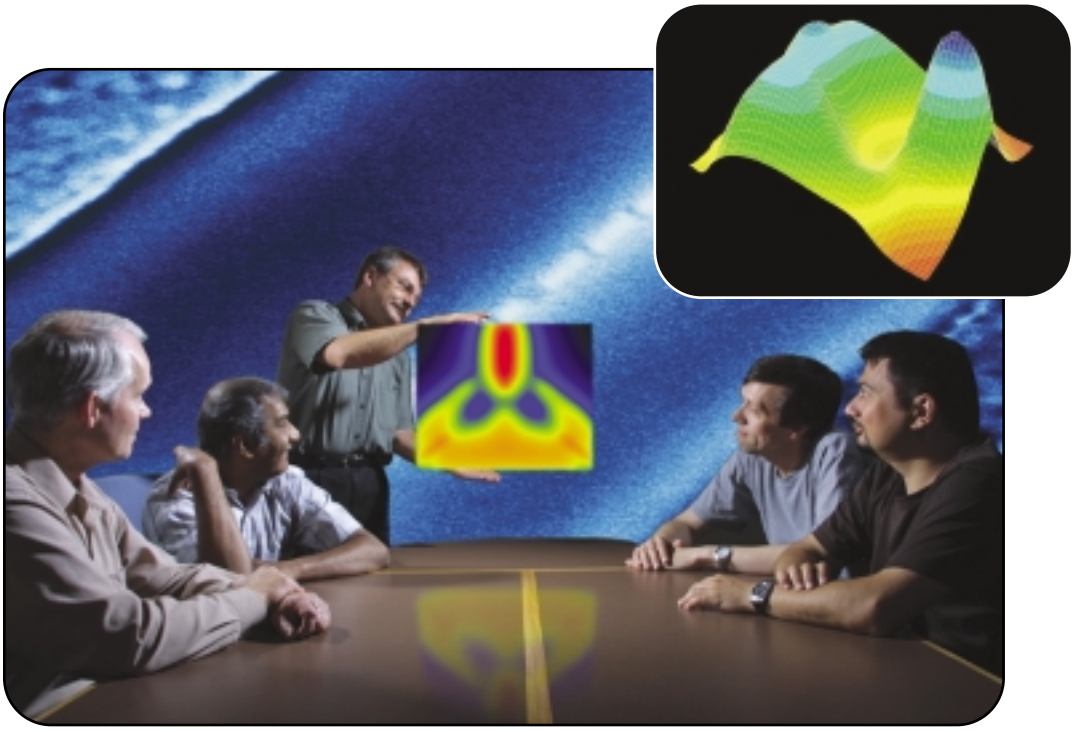
Advances in Information and Communications Technologies

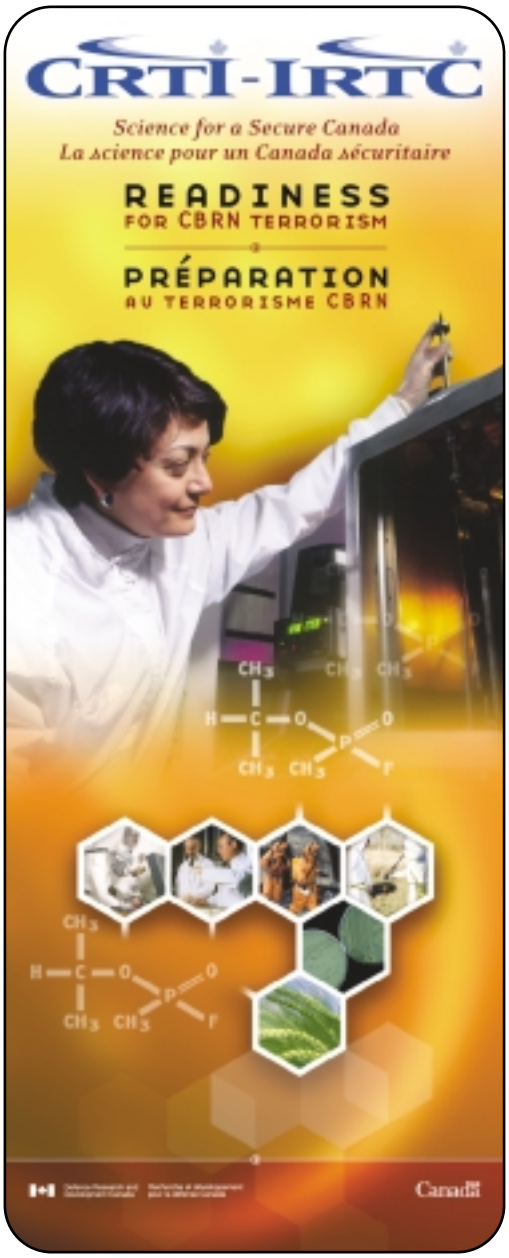
The Information and Communications Technologies (ICT) sector holds enormous significance for Canada's economy. ICT expenditures on R&D reached $5.2 billion in 2002, accounting for more than 45 percent of total private sector R&D in Canada. NRC's R&D continued to play a vital, cross-sector role in 2002–2003 with major advances in hardware, software, information processing, and fundamental enabling and next-generation technologies.

Spintronics – Paving the Way for a New Generation of Computing

New research by the NRC Institute of Microstructual Sciences (NRC-IMS) could revolutionize the way information is stored and transmitted, resulting in a new generation of electronics and telecommunications. In the past year, researchers achieved a world first, creating a prototype "spintronic" transistor. The breakthrough represents an enormous advance because current electronics, which depends on the charge of electrons, is approaching its technological limit.

Consequently, researchers worldwide are looking at ways to exploit the quantum property of an electron, namely its spin. The prototype device created at NRC shows how a single-spin-based transistor could work. The prototype is made from a quantum dot, which functions as an artificial atom. These dots exhibit quantum behaviour such as predictable and controllable energy levels. By connecting the dots to spin-polarized reservoirs through lateral tunneling barriers, scientists ensure that the electrons flowing in or out of the dot have their spins aligned in the same direction as the leads. The spin properties of the quantum dot can then be tuned externally to control the current through the quantum dot. This combination of control over single charges and single spins could also open the door to solid state forms of quantum computing, where the unit of quantum manipulation – called the qubit – would consist of specially prepared spin states.





Science for a Secure Canada

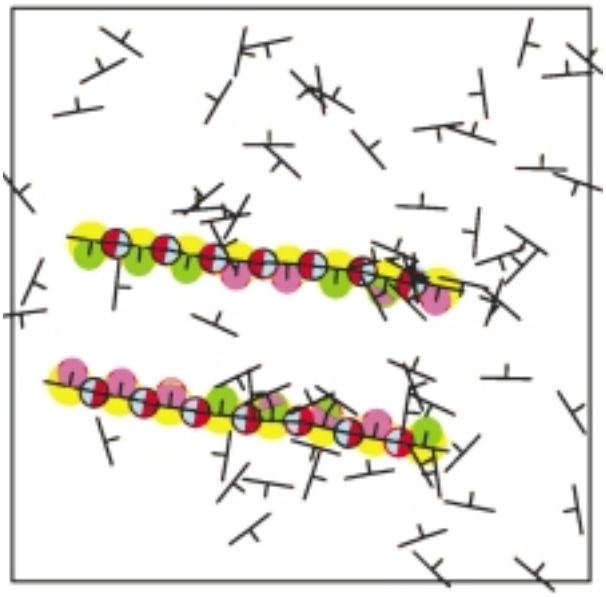
NRC-IMS began leading a new multi-partner project as part of a series of counter-terrorism research activities funded by the CBRN Research Technology Initiative. The NRC Institute for Chemical Process and Environmental Technologies (NRC-ICPET) is a key partner in the project. The main objective is to develop real-time portable devices capable of detecting chemical and biological agents by molecular imprinting techniques. Such devices will enhance the capabilities of first responders or military personnel to detect and/or rule-out the presence of harmful agents. The project will help Canada be prepared in the event of a terrorist attack and to meet its responsibilities to the international community for protection against such attacks.

Blink Detection

Traditional tools for entering information into computers, such as the mouse and keyboard, have not changed significantly in many years. Increasingly, research has focused on the creation of Perceptual User Interfaces (PUIs), which rely on users' motions, such as the movement of the face, to control programs. PUIs, which offer a hands-free interface, hold significant benefits for persons with disabilities. Researchers from the NRC Institute for Information Technology (NRC-IIT) have developed several breakthrough technologies that permit the development of more sophisticated PUI systems. One involves the ability to track motion within motion (face moving and eye(s) blinking). The use of blinking to communicate is well established. With the new blink detection software, users will eventually be able to extend the power of blinking to control computer programs. NRC-IIT recently licensed technology to the West Midlands Rehabilitation Centre in Britain.

Self-Replicating String of Computer Symbols

A new computer simulation tool created by researchers at NRC-IIT is shedding light on the self-replication process that underpins nature and the evolution of life forms. The simulation, known as JohnnyVon, uses T-shaped virtual objects that exist in a two-dimensional virtual soup. The objects are affected by several forces that govern interactions among the particles, allowing them to make and break bonds. The virtual objects assemble into patterns similar to the way codons make up strands of DNA or RNA. The tool offers the promise for inexpensive and flexible manufacturing processes, including the possibility of growing machines in vats of chemicals.



The Power of Language

Inuktitut is the major language of the circumpolar region stretching from Alaska to Greenland. It is also the main language for Nunavut. But computer-based tools taken for granted in most other languages, such as spell checkers, grammar checkers or search engines, are not available in Inuktitut. NRC-IIT researchers recently produced a tool in which each sentence of the Nunavut Hansard has been paired with its English translation. The accomplishment presents a rich source of information for educators and translators of Inuktitut versions of common government-oriented terms. The next step is to create an analyzer tool capable of splitting long and complex Inuktitut phrases, contained in a single string, into specific words.

qaisaaliniaqquunngikkaluaqpuq

Base/suffix	Meaning
qai	come
saali	early
niaq	future; today
quu	probably
nngik	general negation; "not"
kaluaq	really; actually
puq	he/she/it

qaisaaliniaqquunngikkaluaqpuq
(*verb*)

Advances in Manufacturing

Manufacturing remains one of Canada's major economic forces, touching virtually every sector of the economy. NRC's R&D programs

Manufacturing

Core NRC Institutes

- NRC Industrial Materials Institute, Longueuil
  - *NRC Aluminium Technology Centre, Ville Saguenay*
- NRC Institute for Chemical and Environmental Process Technology, Ottawa
- NRC Integrated Manufacturing Technologies Institute, London
- NRC Institute for Fuel Cell Innovation, Vancouver

Partner Institutes and Programs

- NRC Institute for Aerospace Research, Ottawa
  - *NRC-IAR Aerospace Manufacturing Technology Centre, Montréal*
- NRC Institute for Research in Construction, Ottawa
- NRC Steacie Institute for Molecular Sciences, Ottawa, Chalk River
- NRC Industrial Research Assistance Program, across Canada
- NRC Canada Institute for Scientific and Technical Information, across Canada

are targeted to help manufacturers increase their competitiveness and improve the commercial viability of their products and services. These programs also help manufacturers create and adapt to new technologies, materials and processes, and meet their environmental responsibilities.

In the past year, NRC has made significant advances applying manufacturing and materials expertise to the creation of new medical devices. Collective expertise has also contributed greatly to success in the area of fuel cells.

Assembly-Free Micro Fuel Cells

Researchers at the NRC Institute For Fuel Cell Innovation (NRC-IFCI) made a major breakthrough by inventing a low-cost method of fabricating micro fuel cells without assembly. Micro fuel cells are an environmentally friendly, refillable battery technology that can power laptops and cell phones. A major barrier to mass commercialization is the high manufacturing

A new electrochemical hydrogen compressor developed at NRC-IFCI delivers high-pressure hydrogen gas, has no moving parts to cause noise and wear-and-tear, and is highly compact.

cost related to manual assembly. NRC's patented process begins with a polymer substrate that doubles as a proton exchange membrane. Each component of the fuel cell is laid down successively using either ink-jet printing technology or micromachining methods. The process reduces the overall size of the fuel cell, eliminates problems with alignment and sealing found with traditional assembly methods and, most importantly, provides a much needed low-cost, automated manufacturing method.

Sensors Providing Critical Information
Researchers at NRC-IFCI recently completed the first prototype of a hydrogen sensor that can quickly and automatically locate hydrogen leaks in fuel cell stacks. The invention provides a method and apparatus to monitor the gas concentration distribution in situ, accurately pinpoint the leak location, and so enable easy fuel cell diagnosis and maintenance. Future work involves placing the sensors within the actual flow channels of fuel cells to provide real-time measurement of ultra-high concentrations of hydrogen within the fuel cell, information critical in helping optimize system performance.

Biomedical Implant/Titanium Foams
Researchers from the NRC Industrial Materials Institute (NRC-IMI) have developed a new manufacturing process to produce metallic foams. The foams' unique open-cell structure, with properties matching those of bones, makes them attractive for the

fabrication of biomedical implants. Their structure, corrosion resistance, biocompatibility and mechanical properties also make these materials attractive for tissue attachment. The targeted applications are porous implants and attachment systems for orthopaedic and dental applications.

Improved Galvanization Process
Galvanized steel is widely used in such industries as automobile manufacturing to protect metal against the harmful effects of corrosion. NRC-IMI researchers have developed new computer modeling techniques to help manufacturers maximize the impact of the galvanization process. This process involves placing steel parts or material into a bath of molten zinc. Research has shown that these baths do not provide a uniform environment which, in turn, affects the quality of the galvanized product. Cold or stagnant zones and zones with higher aluminium concentrations are two important variations. Modeling now permits manufacturers to predict the impact

of these variations which, ultimately, will allow them to change the design and usage of galvanization baths.

An Eye for Design

Researchers from NRC-IMTI are creating new and powerful applications for pen-based computing that will greatly increase the speed and efficiency of the automobile design process. In the past year, the team has created a prototype of a new intelligent sketching system that will transform freehand sketches done on a tablet PC into 3D mechanical design. The system first "recognizes" the freehand sketches to basic shapes commonly found in mechanical design, such as curves, lines, rectangles, and ellipses. The system then transforms the recognized sketch into a 3D object by using an innovative method that greatly simplifies the difficult problem of transforming 2D sketches to 3D models. Although the system initially addresses the needs of automotive design, the solutions are generic and could be easily adapted to address applications in other mechanical design domains.

Water to Drink

Desalination of seawater is used widely to meet demands for potable drinking water. Researchers at the NRC Institute for Chemical Process and Environmental Technology (NRC-ICPET) have developed new concepts that will greatly reduce energy consumption for spiral wound membrane systems used for desalination. Feed spacers currently used to separate the spiral membrane allow concentrate to collect on a membrane surface. The result is reduced flow pressure across the membrane and increased energy consumption to overcome this drop. Using computational fluid dynamics modeling, NRC-ICPET researchers have created virtual models of spacer geometries that will resolve such problems, ultimately improving the function of the membrane spacers by directing liquid flows more precisely and creating less accumulation of concentrate on the membrane surface. Prototype feed spacers based on this design will be produced next.