Mission Possible:

Celebrating the innovative projects of Ontario's engineers

Innovation in Canada generates wealth and helps sustain our country's competitiveness in the global marketplace. It is also the gateway to a better future–one in which professional engineers are very much a part. Here's a look at several engineering innovations–from virtual reality mining tools to environmentally friendly green roofs–that are on the horizon.

By Karen Hawthorne

Going green

What's a good way to keep energy costs from quite literally going "through the roof?" A green roof may be the answer.

While they've been used in Europe for more than 20 years, green roof technology is still a relatively new concept in Canada. Some well-known examples include the Vancouver Public Library and a section of Toronto's city hall. On the forefront of the environmental movement, green roofs are an alternative to shingles or asphalt. They are composed of multiple layers, including a root and water barrier and a medium to grow plants and grasses. They can vary widely in flora and purpose.

Green roofs and rooftop gardens are aesthetically pleasing and contribute to the overall energy efficiency of a building by providing insulation, shade and evaporative transpiration of water, preventing excessive runoff. Green roofs can also help to reduce the "urban heat island" effect caused by heat-absorbing dark surfaces, such as rooftops and pavement that are concentrated in cities.

Although the technology is still expensive to install, its long-term savings and environmental considerations are gaining attention.

"This is a wonderful evolution of humans integrating nature into sustainable development," says Guy Larocque, P.Eng., manager, property management and engineering, Canadian Museum of Civilization Corporation. "It encourages respect for nature in an urban setting and it's very life-supporting."

Larocque was involved in the planning and implementation of the green roof–one of the largest in North America at 115,000 square feet–at the new Canadian War Museum in Ottawa, which opened this past May. Called a "stunning architectural feat," the building echoes the surrounding landscape, on one side following the lines of the Gatineau Hills, and on the other meeting the natural riverbank. Some of the grass seed planted on the roof are the same species that run along the river.

Aesthetics aside, it was the functionality of the roof and its ecosystem that sealed the deal for the new museum, says Laroque. "We looked at the structural load capacity, the cooling and heating capability, and we also found that the green roof can absorb 720,000 litres of storm water."

Traditional rooftops discharge 95 per cent of the stormwater volume accumulated, where green roofs discharge less than 20 per cent, because the water is efficiently used by the vegetation. Less discharge helps in overall stormwater management, reduc-

ing erosion to creek beds and helping roadway drainage systems work more efficiently.

Current data indicate that green roofs can exceed the life expectancy of conventional roofs by two to three times, especially in Canadian climates where infrastructure is subject to a wide range of temperatures. Conventional roofs lose the ability to contract and expand over time as elasticity of the material is reduced by solar radiation.

The City of Waterloo is another fan of green roofs. The city adopted an Environmental Strategic Plan in 2002 and carried out a feasibility study of green roofs on municipal buildings. When Waterloo's city centre building was in need of a roof replacement, the city's council approved the installation of a green roof. Construction began this past summer.

"Green roofs are good for the city, the environment and public health," says Karen Moyer, Waterloo's environmental coordinator. Rooftop gardens require more soil and maintenance, whereas many green roofs rely on about one inch of soil within the multi-layered growing system, and low-maintenance sedums, which are grasses that are drought-resistant and have thicker, hardy leaves, says Moyer. The roofs need only minor maintenance and the vegetation can go dormant according to its natural lifecycles.

"There are always going to be skeptics with new technology, but we're very pleased," says Tim Anderson, P.Eng., City of Waterloo director of public works/services. "We're looking at increasing the longevity of the roof, and mitigating the heat island core and air-quality issues. As for the aesthetic, it really does add another dimension to the building."

Natural Resources Canada's Office of Energy Efficiency (OEE) is giving a leg up to people interested in green roofing with its Commercial Building Incentive Program (CBIP) and the Industrial Building Incentive Program (IBIP). Up to $250,000 is available for implementing an energy efficiency retrofit, such as a green roof, that will result in energy savings.

Goodbye gridlock

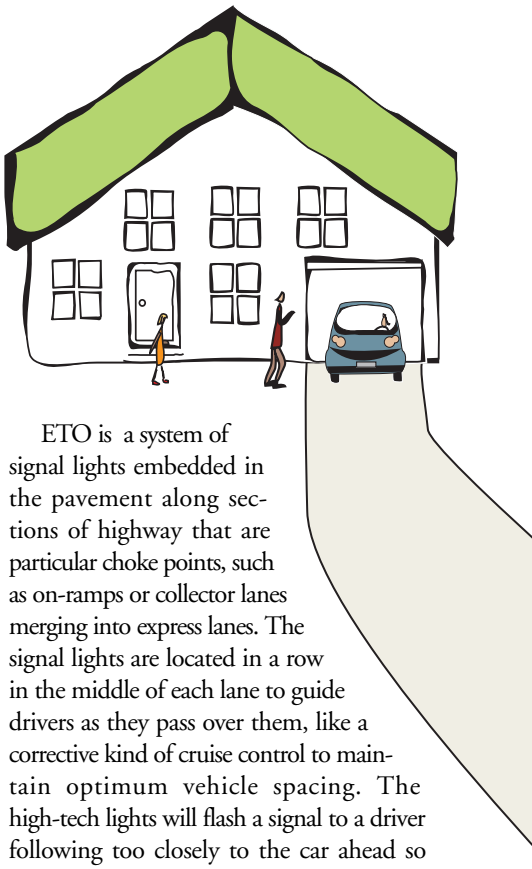
Imagine this: After a hectic day at the office, you pull out of your parking space, turn on some relaxing music and sail out onto the highway for a stress-free drive home. No traffic gridlock, no screeching brakes, and no raging drivers white-knuckling the steering wheel.

Not possible? Well, you've heard of smart drinks with brain-boosting enzymes and smart cars that navigate the most efficient route to your destination. Now there are "smart roads" up for consideration.

Steve Petrie, P.Eng., a retired software engineer in Oakville, Ontario, has developed a new intelligent transportation technology called Expressway Traffic Optimization (ETO), a system to increase traffic flow and put an end to gridlock on our highways.

"I wanted to solve a problem that is massive and societal," says Petrie. "We can either build more roads or wait for totally automated cars that you see in science fiction. But how are we going to get there? ETO is an intermediate measure and I'm very excited about it."

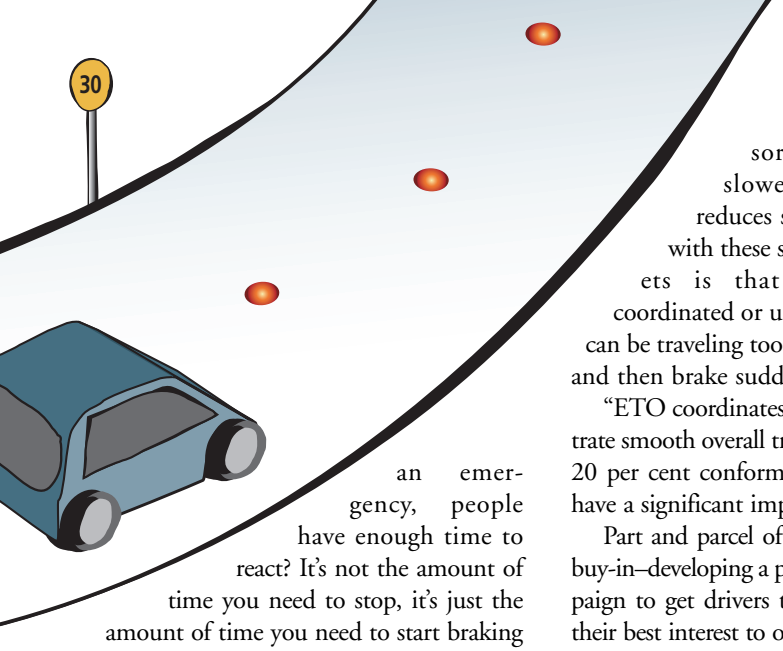
Gridlock is less the result of the number of cars as it is of traffic turbulence caused by poor driving: tailgating, severe braking and swerving, he says.



ETO is a system of signal lights embedded in the pavement along sections of highway that are particular choke points, such as on-ramps or collector lanes merging into express lanes. The signal lights are located in a row in the middle of each lane to guide drivers as they pass over them, like a corrective kind of cruise control to maintain optimum vehicle spacing. The high-tech lights will flash a signal to a driver following too closely to the car ahead so that drivers can leave the right amount of travel time between vehicles, or "headway" as it's known to traffic engineers. Headway is the time it takes to cover the distance from your front bumper to the next car's front bumper. The ideal headway time is 1.8 seconds, giving the driver enough time to react when necessary, says Petrie. "Late" signals will flash at slow drivers and "early" signals at speeders.

"The reason we use time instead of space is because we're working toward driver reaction time," Petrie explains. "If you and a hundred other drivers are all flying down the road in a convoy, what's the minimum time we need to give every driver so that in

The Canadian War Museum in Ottawa (left) opened this past May with an expansive green roof that features native grasses. At right, Tim Anderson, P.Eng., oversees the installation of the green roof at Waterloo's city centre building.



an emergency, people have enough time to react? It's not the amount of time you need to stop, it's just the amount of time you need to start braking because, if the whole convoy brakes at the same time, even though they're tightly packed, usually it works. Everyone slows down. It's only when someone didn't have enough time or wasn't paying attention [that there is a problem]."

The beauty of the system lies in its simplicity. It doesn't require any modifications to vehicles or cause driver distraction. Unlike passive speed limit signs posted on roadways and chevrons painted on pavement, these signal lights will be active, flagging the driver's attention. They will actively flash individual drivers who need to adjust their headway. Each signal device continuously reports traffic conditions to the central system, which will be programmed to ensure optimum speed and spacing everywhere at all times.

The aim is to empower drivers to improve the traffic flow and get to their destination more quickly and safely, without the stress, pollution and waste of fuel that comes with frequent braking and congestion.

"This is fairly well advanced in terms of intelligent transportation technology," says PEO Past President George Comrie, P.Eng., manager of transportation systems, Wardrop Engineering, Mississauga. Wardrop has joined with Petrie to form the ITS-ETO Consortium to pursue commercialization of ETO and start a pilot project with Ontario's transportation ministry, which could happen in the next few years.

"This is an area where a lot of money is going to be spent over the next 20 to 30 years. Canada is well positioned. We need the benefits of this technology," says Comrie.

Some experts say adaptive cruise control in vehicles is the answer, where the drivers set speed and headway and a sensor device detects a slower car ahead and reduces speed. The problem with these self-optimizing gadgets is that they're not all coordinated or uniform, and vehicles can be traveling too fast for traffic ahead and then brake suddenly, Petrie says.

"ETO coordinates its signals to orchestrate smooth overall traffic," he says. "Even 20 per cent conformity of drivers would have a significant impact on congestion."

Part and parcel of the system is public buy-in–developing a public awareness campaign to get drivers to believe that it's in their best interest to obey these signals.

"The key to the whole concept is drivers accepting that if you maintain the position, and drive at the posted speed, we can guarantee that you will get there faster," says Comrie.

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Steve Petrie, P.Eng.

Ground control

In the high-stakes mining industry, getting information, data, and experts to interpret information about ground conditions, location and quality of ore and mineral deposits is key to deciding where next to spend investment dollars. In Sudbury, Ontario, new virtual reality technology has been developed to improve access to this critical information.

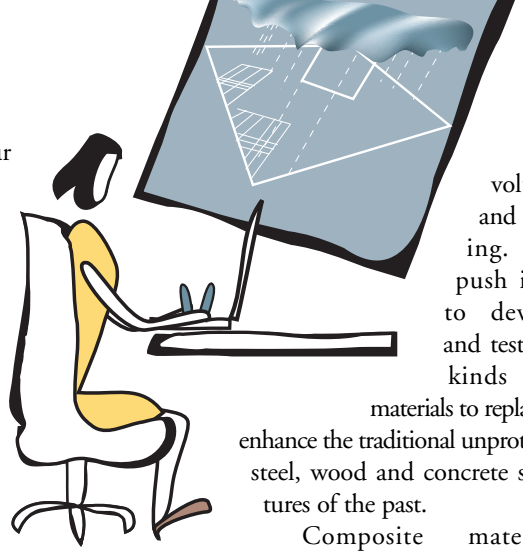
Peter Kaiser, P.Eng., and his team at the Mining Innovation, Rehabilitation and Applied Research Corporation (MIRARCO), a non-profit research centre at Laurentian University, established a collaborative virtual reality laboratory (VRL) that turns complex geotechnical datasets into a three-dimensional stereographic image on a spherical screen with a 22-foot radius. The VRL, which opened in 2001, speeds up the process for multidisciplinary teams to understand complex datasets and work together on strategic decision making.

In February, the Ontario government gave the centre a $1.7-million boost to establish the Northern Advanced Visualization Network (NAVNet) over the next two years, a network of virtual reality facilities that will link the VRL at Laurentian with facilities in Timmins, Thunder Bay, Red Lake, a mobile lab ready for travel to remote mineral exploration sites, and mining trade shows and conferences in urban centres. With NAVNet in place, what engineers see at Red Lake is what they will see in Sudbury, so they can simultaneously work on

Steve Petrie, P.Eng., has invented an intelligent transportation system to put an end to expressway gridlock.

the same three-dimensional images and data across the Internet.

"It's about location, location, location for business, and Sudbury is the centre of mining for Falconbridge and Inco in the Sudbury basin. But it is not the centre of mining for everything else, [for example] the gold belt up in Timmins, Red Lake, etc., so there is a whole area that has no easy access," Kaiser explains. The goal is not only to build a communication network and bring development to northern Ontario, but also to promote this Canadian-made approach and Canadian engineers to



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Warren Holmes, P.Eng.

companies around the world for better, safer mining practices.

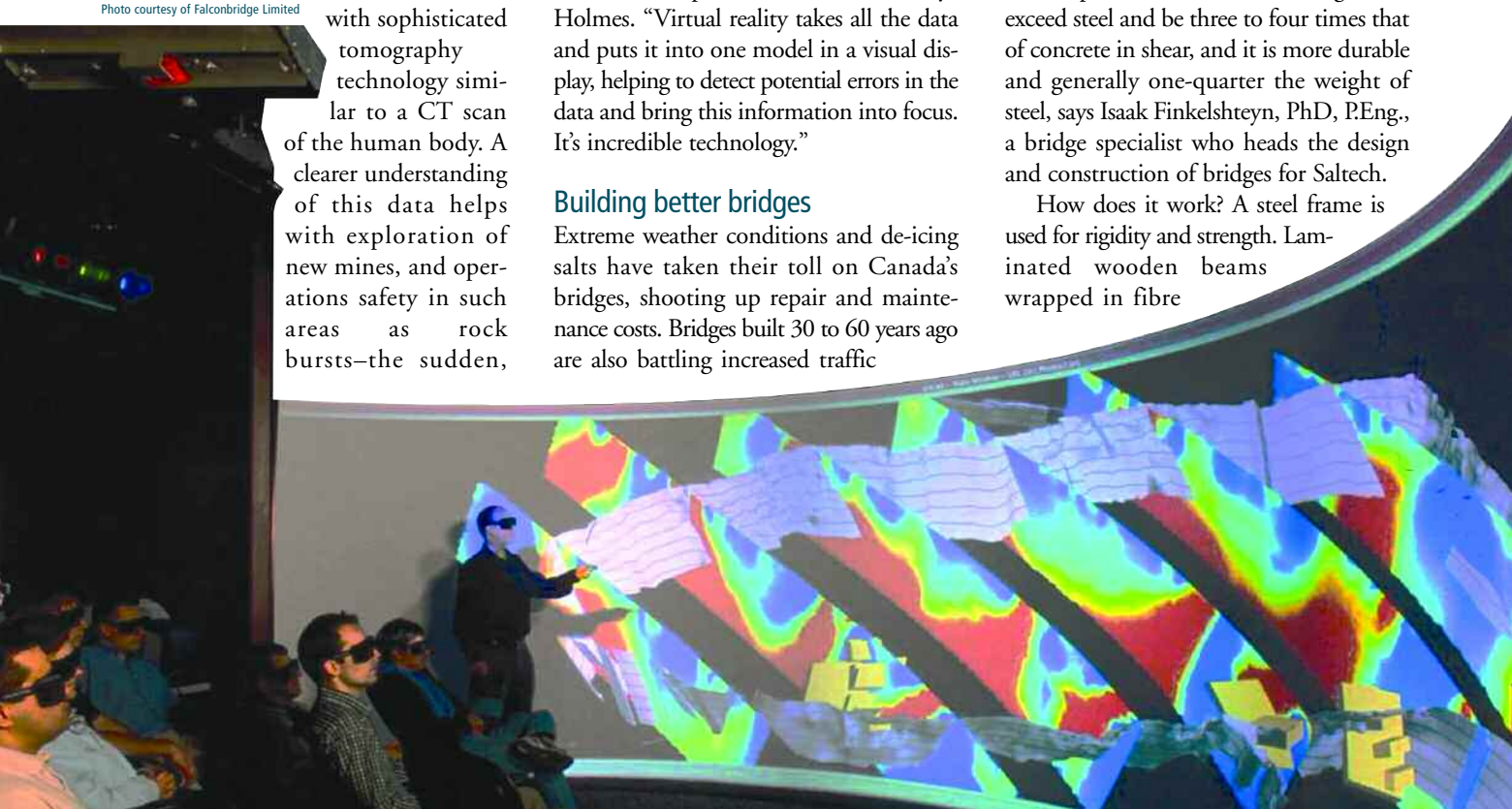
"Mines are underground and three-dimensional, with lots of tunnels and complex geology, so the ability to look at this three-dimensional data in true 3-D was very important," says Kaiser. MIRARCO's research infrastructure collects three-dimensional information from bore holes and earth sections with sophisticated tomography technology similar to a CT scan of the human body. A clearer understanding of this data helps with exploration of new mines, and operations safety in such areas as rock bursts–the sudden, explosion-like events that occur deep underground–and monitoring the performance of the mine's supporting structures.

The VRL technology is being used in the Kirkland Lake area to develop the Abitibi geological belt. Nineteen mines have been modeled to enable interpretation of existing information for the purposes of either identifying new ore bodies or developing new means of mining to reduce production costs.

Warren Holmes, P.Eng., a former vice president at Falconbridge and now CEO of Nuinsco Resources in Toronto, has sent data to the MIRARCO laboratory to help his company with mining exploration here in Canada and in Turkey. "In this business, a key issue is the ability to interpret the info you have on a project to forecast the potential," Holmes says. However, even with sophisticated sampling technology and numerous sources of data, nothing is definitive and samples are often flawed, says Holmes. "Virtual reality takes all the data and puts it into one model in a visual display, helping to detect potential errors in the data and bring this information into focus. It's incredible technology."

The virtual reality laboratory (VRL) turns complex geotechnical datasets into a three-dimensional image for better mining practices.

Photo courtesy of Falconbridge Limited



Building better bridges

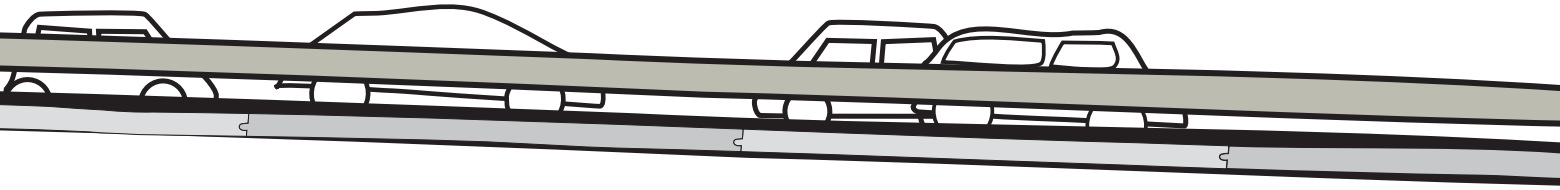
Extreme weather conditions and de-icing salts have taken their toll on Canada's bridges, shooting up repair and maintenance costs. Bridges built 30 to 60 years ago are also battling increased traffic volumes and loading. The push is on to develop and test new kinds of materials to replace or enhance the traditional unprotected steel, wood and concrete structures of the past.

Composite materials, formed by the combination of two or more distinct materials on a microscopic scale, have gained increasing popularity in the engineering field. Fibre reinforced polymer (FRP), a relatively new class of composite material manufactured from fibres and resins, has proven efficient and economical for the development and repair of new and deteriorating structures.

Saltech, a technology solutions firm in Milton, Ontario, is one company that has developed a composite structure for building bridges. The company has created a hybrid glass fibre reinforced polymer (GFRP) composite structure, using GFRP reinforced with steel and wooden material. GFRP is a form of a material first used in the aerospace, marine and chemical-processing industries for its strength, durability and minimal weight.

GFRP doesn't corrode or deteriorate, its compression and tensile strength can exceed steel and be three to four times that of concrete in shear, and it is more durable and generally one-quarter the weight of steel, says Isaak Finkelshteyn, PhD, P.Eng., a bridge specialist who heads the design and construction of bridges for Saltech.

How does it work? A steel frame is used for rigidity and strength. Laminated wooden beams wrapped in fibre



glass are placed within the steel frame and the entire structure is infused with thermosetting resin, creating a monolithic structure. Together, such a combination of materials reduces dead loads (bridge weight) by approximately 20 to 30 per cent.

The top surface is covered with asphalt, so it isn't subject to UV. The exposed and bottom sides are protected by a polyurethane coating. Accelerated tests simulating 75 years' exposure, showed 0.1 mm in degradation of the unpainted surface.

The company recently manufactured and installed two GFRP superstructures, both in Ontario. Two other larger bridges are in the works for Nova Scotia, one of which spans 90 metres. The technology allows for bridges up to 500 metres in length. These bridges are pre-fabricated in several sections, making them relatively quick to install so that they can be open to traffic in three to four days.

"Now that we've developed and tested [the material], including UV testing, the longevity of these structures looks like more than 150 years. Code requirements say 75 years, so this is twice that long without heavy maintenance," Finkelshteyn says of testing carried out at the Research Centre of the University of Western Ontario in London, Triodem Technical Services Ltd. in Mississauga, and Integrity Testing Laboratory Inc. in Markham. "This is very durable material."

Another hybrid GFRP bridge project in the works is a pedestrian bridge over Highway 10 in Caledon, which falls under the jurisdiction of the Ontario Ministry of Transportation's (MTO) Downsview office. Installation of the bridge is expected later this fall.

Alfred Ho, P.Eng., who heads structural engineering for MTO Downsview, says the ministry has an innovation initiative in place to support and monitor new technologies like the hybrid GFRP composite.

"We are interested in advanced composite materials, including glass fibres, and we're also looking at carbon fibres," says Ho. "I see huge potential in these materials because of their strength and durability." MTO has applied fibre reinforced polymer (FRP) wraps to several bridge columns over Highway 401, and another recently approved application is FRP reinforcement for bridge decks.

The need for safety and standards related to these new technologies is a top priority, says Ho. A new chapter under the *Canadian Highway Bridge Design Code* is in development for the design and application of advanced composite materials.

"Now we have a tool that we can use to evaluate these new technologies. When we see the benefits, we will exploit it," Ho explains.

Mark Green, P.Eng., a civil engineering professor at Queen's University, has studied FRP materials for 10 years, focusing on the behaviour of FRP-strengthened beams and columns when they are subject to the effects of freezing and thawing and low temperatures.

His research has shown that FRP rehabilitation is very effective and is undamaged to any significant degree by these exposures. Green has also investigated the effects of FRP wraps on corroding reinforced concrete columns. The wraps were found to reduce the rate of corrosion. His next major project is an investigation of the fire resistance of FRP-strengthened concrete beams and columns.

"One of the problems with repair and rehabilitation methods with traditional materials, especially steel, is that the repair material is subject to the same type of deterioration mechanism that caused the problem in the first place," he says. "One of the main advantages of FRPs is that they are resistant to corrosion."

In the near future, Green expects to see plenty of change in civil infrastructure. FRP prestressing applications, such as external FRP tendons and prestressed FRP sheets or plates for rehabilitation, will become more commonplace, because of the high strength of these materials. He also expects that sensors will be incorporated into FRP materials,

At left, part of a new hybrid bridge, made with a super-strong polymer material, is tested with weights for load capacity. At right, a new hybrid bridge nears completion.

so that engineers can remotely monitor the condition of the structures.

"As materials and technology advance, adaptive and potentially self-healing materials that can change their structural properties depending on their state of stress will also find their way into civil infrastructure. Such materials will give us the potential to control the behaviour of structures, like reducing vibrations on a lively pedestrian bridge, for example," says Green.

Thrills and chills

That gut-wrenching sensation as your rollercoaster car climbs to the top might be more intense the next time you visit Canada's Wonderland or Walt Disney World.

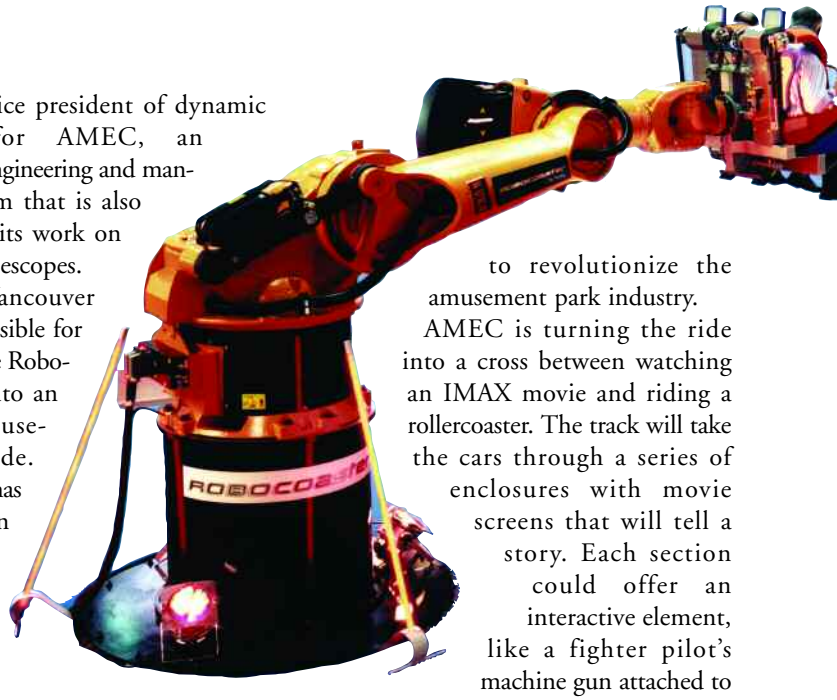
The next generation of amusement park rides was unveiled at conferences for the amusement park industry earlier this year. One ride that has people talking is the RoboCoaster G2, a new kind of rollercoaster where high-performance robots spin and loop riders in new directions.

Each RoboCoaster G2 car has a long robotic arm with seats at the top for passengers. The robot is programmed to shake, rattle and roll its passengers as its giant arm runs along a track. The ride uses reprogrammable robotic technology, so it has the potential to be modified throughout the day with different programming sequences to make it more exciting for thrill-seekers or tamer for kids and families.

"There is tremendous potential for this kind of ride because of its versatility. The goal is to link it with animation or a particular movie and make the experience interactive for riders," says David Halliday, P.Eng., vice president of dynamic structures for AMEC, an international engineering and manufacturing firm that is also renowned for its work on observatory telescopes.

AMEC's Vancouver plant is responsible for engineering the RoboCoaster G2 into an on-track amusement park ride. The company has rollercoasters in parks around the world, such as the Mad Cobra at Suzuka Circuitland in Japan, and Batman the Chiller at Six Flags Great Adventure Park in Jackson, New Jersey.

The robots for RoboCoaster G2 were first developed by KUKA Roboter in Germany for industrial manufacturing in the automotive industry, and were designed to perform a wide range of tasks: building cars, stacking pallets and pouring metal. KUKA developed RoboCoaster, the first generation, with six motors, two seats and a controller. The robot can be moved in six axes, which means that any kind of movement is possible: rapid ascents and drops, circles, rotation about an axis, spiral motions and loops, including a horizontal figure eight or a double-back somersault. KUKA brought the technology to AMEC two years ago to transform it into an on-track rollercoaster ride, ready to revolutionize the amusement park industry.



AMEC is turning the ride into a cross between watching an IMAX movie and riding a rollercoaster. The track will take the cars through a series of enclosures with movie screens that will tell a story. Each section could offer an interactive element, like a fighter pilot's machine gun attached to the car that the rider could shoot. There is an opportunity to partner the ride with a blockbuster movie and develop the robotic programming from there, says Halliday. "I could take people into the eye of storm or provide a visual of a plane flying with all the scenery and movement. It's all about making the motion connect with the visual," he says.

His team has also built a flight simulator to hone the engineers' programming expertise to perfect the synchronicity of the ride's movement with the visual storytelling displayed on the movie screens. Refining systems so they are economical for marketing the ride is also an issue, but the ride is ready for customization and taking on passengers when a buyer comes along.

Experts say AMEC is moving in the right direction. The trend in theme park amusements is to make them interactive, like the kid-film-inspired *Monsters Inc.* ride in the works at Walt Disney World, which allows riders to seek out the scary beasts using a flashlight, says industry consultant Frank Weigand, a former executive for Disney and Universal, who has taken notice of RoboCoaster G2.

He says the new rollercoaster is a good industry fit because of its versatility and its capability to link movies and motion. "It's reprogrammable, so you could make it spectacular enough for enthusiasts and then change it to a ride that the grandmother and her grandchildren could ride. That's a royal flush."

RoboCoaster G2 is a new kind of rollercoaster that uses robots along a track to whirl passengers in the air.