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FACTORY FORWARD: HOW ADVANCED MANUFACTURING IS RETOOLING ONTARIO'S INDUSTRIAL HEARTLAND

The Innovation Economy Council is a coalition of tech-sector leaders dedicated to shaping Canada's industrial innovation policy. Led by MaRS, Ontario Centres of Excellence, Communitech, DMZ, Invest Ottawa, CCRM, Spark Centre, CENGN and NGen, the IEC works with active members of Canada's innovation ecosystem to identify areas for in-depth analysis and offer timely insights to increase Canadian productivity and growth.

Author: Barrie McKenna

Data and Analytics: Nigel Biggar

Editor: Guy Nicholson

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Factories aren't dead, they're just adding value

The past couple of decades have not been kind to Ontario in its role as Canada's manufacturing heartland. As recently as 2005, one million people worked in the province's factories. But the last recession wiped out nearly a quarter of those jobs, and most have not come back. Before the pandemic, the manufacturing sector employed 761,000 people.

A spate of high-profile factory closures, including General Motors' Oshawa vehicle assembly plant, Hershey in Smith Falls and Kraft Heinz in Leamington, has reinforced the perception that Ontario is no longer a place where things are made. But manufacturing is not dead in Ontario. Nor it is headed for extinction. The thousands of lost jobs don't tell the whole story — not even half of it.

The business of making things is in the midst of fundamental transformation. It's rapidly moving up the evolutionary scale. Manufacturers aren't just automating by outfitting their factories with robots, sensors and 3D printers; they're also packing more technology, software and services into their physical products than ever before. And they're harnessing data to do it all better and more efficiently.

Advanced manufacturing in 2020 is about what knowledge gets built into final products. It's less tied to what companies make than how they do it.

NGen, the federal government's Ontario-based advanced manufacturing supercluster, recently surveyed its roughly 2,500 members, asking them whether they identified themselves as manufacturers, technology providers or service companies. The majority said all three.

"That is reflective of the state of advanced manufacturing," explains Jayson Myers, NGen's chief executive. "You have to think of yourself as a technology company."

Increasingly, manufactured goods are platforms that deliver other technologies and services. This shift is changing the notion of what's low-tech and what's advanced. For decades, the production of commodity products, such as textiles and metals, has been moving to parts of the world where labour is much cheaper. That narrative is being upended by Ontario startups, such as Toronto-based Myant Inc., which is creating wearable interactive electronic devices by weaving sensors and actuators into fabric. Or Smarter Alloys of Waterloo, which uses shape-memory nickel-titanium alloys to make such items as sophisticated orthodontic wires and metal belt – driven turbines to turn waste hot water into power.

"We've entered a new era in manufacturing," argues Linda Hasenfratz, president and chief executive of auto-parts maker Linamar Corp., based in Guelph. "It feels like manufacturing is turning into a technology business, more than anything else."

Research by the Innovation Economy Council shows that a clutch of advanced manufacturing industries create an outsized share of factory jobs across Ontario and the rest of Canada. Advanced manufacturing accounted for half of the more than 45,000 factory jobs created in Ontario since 2010, according to data compiled by the IEC. Over the past decade, employment has grown 98 percent in agricultural chemicals, 45 percent in aerospace, 42 percent in industrial machinery, 22 percent in auto parts, 17 percent in electronic components, 17 percent in medical equipment and 14 percent in motor vehicles. That compares to average job growth of 7 percent across all manufacturing industries.

The marriage of high-tech and conventional manufacturing is also spawning new and unusual partnerships. For example, Linamar, which specializes in powertrain components for the automotive sector, recently teamed up with Toronto startup Synaptive Medical Inc. to build robotic surgical microscopes and lightweight mobile MRI machines. It's a case study in convergence.

The expanding definition of advanced manufacturing is particularly evident in the automotive sector, which is the backbone of Ontario manufacturing. Even after the closure of GM's Oshawa facility, the province is home to seven automotive plants. These plants directly employ more than 32,000 people, plus tens of thousands more in their vast network of suppliers. Motor-vehicle parts manufacturing alone employed more than 66,400 Ontarians in 2019.

But Henry Ford likely wouldn't know what to make of today's cars. The newest vehicles have millions of lines of computer code and dozens of electric control units running everything from brakes to headlights. Electronics and software make up a third of a car's value. Within a decade, that share is expected to reach 50 percent.

The pace is accelerating as the industry pivots to making electric, autonomous, shared and connected vehicles, says Warren Ali, senior vice president of the Automotive Parts Manufacturers' Association. The big automakers, he says, are treating their products like "cellphones on wheels" — platforms that deliver much more than a mode of transportation. Carmakers now think of themselves as technology companies first. Canadian motor vehicle and parts manufacturing R&D was roughly $211 million in 2017, a number that will almost certainly grow.

"They are selling consumers kilometres, services and electrons," Ali says. "The value is in the information that those parts create."

That means that software companies and service providers are now an integral part of the vehicle manufacturing supply chain. Canada, and Ontario in particular, has a vibrant technology sector with expertise in areas such as

artificial intelligence, cybersecurity and power storage, which are increasingly at the heart of making modern vehicles. Toronto alone has 14,000 tech companies and more than 65 incubators. It also has the world's highest concentration of AI startups. Toronto led North America in tech job creation with more than 123,000 tech jobs added between 2013 and 2018.

One key challenge for Canada's advanced manufacturing sector, though, is that there are few homegrown companies at the top of the supply chain. Canada does not have corporate giants on the scale of Apple, Google or Tesla to drive innovation. One consequence is that promising startups often falter or get acquired before they can grow large enough to become financially viable.

Another economic current sweeping through the manufacturing sector is the push to shrink global supply chains and bring them closer to home. The trend was already underway before the novel coronavirus pandemic hit, driven by the U.S.-China trade war and rising protectionism elsewhere. COVID-19 has made the case for going local even more compelling. Canadians now recognize the importance of maintaining the capacity to make things domestically. That includes ventilators, protective masks and medicines, but also key products essential to the smooth functioning of the wider economy — everything from auto parts to computer software to advanced medical therapies.

So, no, manufacturing is not dead. Much of it is thriving, particularly the pockets focused on high-value-added products, specialization and technology. These are the gaps some companies are trying to fill.

Ontario has advantages in advanced manufacturing

Ontario is still a manufacturing powerhouse. More than one in 10 of the province's jobs are in manufacturing.

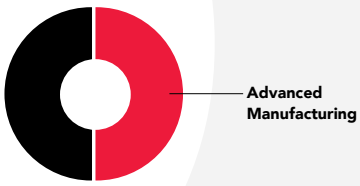
The broader story is that manufacturers are producing more than they ever have, but with fewer workers. Factory job numbers are relatively flat, but output continues to rise. Manufacturing employment is up 7 percent in Ontario in the decade since the Great Recession, but factory output (as measured by GDP) rose 16 percent between 2010 and 2019. The trend is similar in the rest of Canada. Part of the job-loss story is that robotics, automation, artificial intelligence and other new technologies are making manufacturers more productive. As they embrace advanced manufacturing, factories need fewer workers on the factory floor, but more engineers, scientists and programmers.

Canada is poorly equipped to win a wage-driven mass-production contest. But it can compete on brain power and technology.

The remaining players, including a vast homegrown ecosystem of technology suppliers, are remaking the face of Canadian manufacturing. In some cases, old industries are being brought back and reimagined with the help of new materials or embedded smart technology. Elsewhere, entirely new industries are being created in mass-production cell-based drug therapies.

Over 1 in 10 Ontario jobs are in manufacturing.

Since the last recession, manufacturing employment is up a meagre 0.5 percent in Ontario. On the other hand, factory output (as measured by GDP) rose 16 percent between 2010 and 2019.



Half of the 45,000 factory jobs created in Ontario since 2010 are in advanced manufacturing.

This report highlights the expanding number of companies that are helping to sustain and grow Canada's advanced manufacturing sector. Ontario has a flourishing network of tech companies, including the hundreds of startups supported by innovation hubs. Many of these companies are focused on speeding the pace of factory automation or making manufacturers better at what they do.

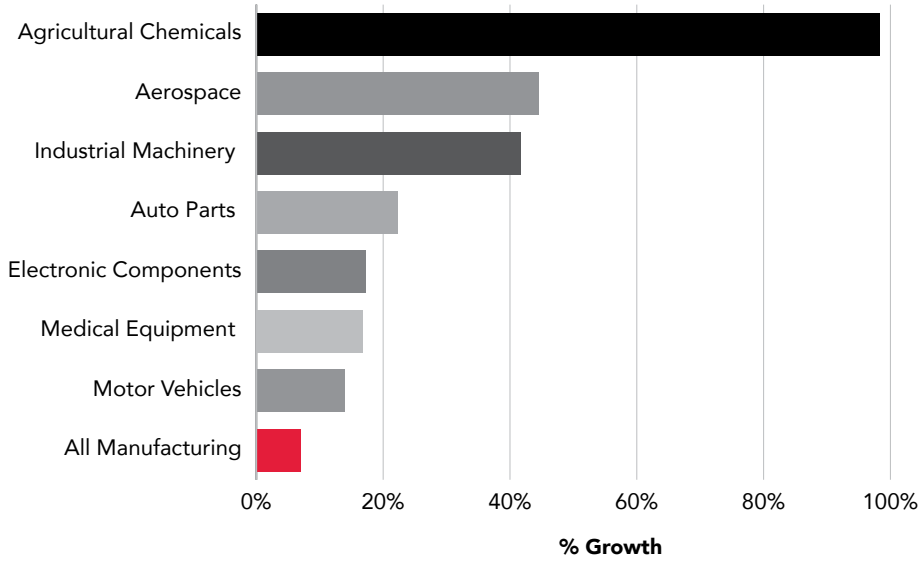
Take Otto Motors, based in Waterloo, which makes battery-powered robotic vehicles that can shuttle loads of up to 1,500 kilograms around a factory floor at high speed. It has sold 100 of these robots to manufacturing customers such as Nestlé SA, General Electric Co. and Toyota Motor Corp. in Cambridge. The company, a division of Clearpath Robotics Inc. of Kitchener, recently raised $29 million (U.S.) in venture capital from a group led by Kensington Private Equity Fund. Part of the attraction of the robots is that they reduce the need for labour and support physical distancing on the shop floor in the COVID-19 environment. Clearpath is among a clutch of Canadian startups in this space that have been fundraising hard in the past few years — $2.36 billion in venture-capital deals for advanced manufacturing and cleantech alone in 2018 and 2019.

In the narrowest sense, advanced manufacturing is defined as those industry sectors that spend an average of at least $450 annually per worker on research and development and employ at least 20 percent more science, technology, engineering and mathematics (STEM) workers than the national average. These sectors are vital to the economy because they account for an oversized share of economic output, exports and research and development, according to a 2018 report by the Martin Prosperity Institute and the Brookings Institution, *Canada's Advanced Industries: A Path to Prosperity*.

They are also more likely to pay higher wages. The average worker employed in an advanced industry earned nearly $60,000 a year, 50 percent higher than the Canadian average. And while manufacturing job growth has been sluggish over the past decade, several advanced manufacturing industries did much better, accounting for half of the more than 45,000 factory jobs created in Ontario since 2010, according to data compiled by the Innovation Economy Council. Over the past decade, employment has grown 98 percent in agricultural chemicals, 45 percent in aerospace, 42 percent in industrial machinery, 22 percent in auto parts, 17 percent in electronic components, 17 percent in medical equipment, and 14 percent motor vehicles. That compares to the average of 7 percent job growth across all manufacturing industries.

Even those numbers don't capture the full range of advanced manufacturing activity, nor the vast ecosystem of technology suppliers that sustains them. Such companies are often not narrowly defined by Statistics Canada as manufacturers, including companies selling software-based solution and data analysis. Advanced manufacturing also encompasses sectors as diverse as clean technology and the emerging sector of producing cell and gene drug therapies, even though Statistics Canada may not recognize companies in these sectors as manufacturers.

ONTARIO ADVANCED MANUFACTURING JOB GROWTH 2010-2019, COMPARED TO ALL MANUFACTURING



The data point to a shift now under way in manufacturing. Talent and capital are gravitating to high-skill, high-value, technology-driven sectors. Meanwhile, lower-skilled factory work is moving to places where wages are lower, including the southern United States and Mexico.

Competing based solely on low wages and volume is no longer viable in Canada, according to Jason MacFarlane, who leads the advanced manufacturing cluster at MaRS Discovery District. At least part of the solution is for players to embrace innovation throughout the manufacturing ecosystem, from colleges and research institutions through to the factory floor.

"We'll never be totally on par in terms of costs. So we have to bring enough additional value and get those costs closer in line," MacFarlane says. "We are a laggard in adopting technology, but it's also our biggest advantage going forward."

Ontario's advantages are its education system and the tech innovators it's producing in areas such as artificial intelligence. But success may depend on the entire ecosystem pulling in the same direction. "There is so much opportunity to kill it in this space, but we need to be 100-percent committed to doing it," MacFarlane says.

Getting companies to work together and share the benefit of their intellectual property can be challenging. Bob Magee, chairman of automotive supplier Woodbridge Group of Mississauga and a director of NGen, says his company has sometimes struggled to forge innovation partnerships and clusters with other Canadian companies. He blames it on tech companies' reluctance to share intellectual property, even when it may be the key to commercialization. "It's going to take a lot of positive stories and experience to shake this thing loose and properly cluster," Magee says.

Co-operation isn't easy, acknowledges NGen's Jayson Myers. Manufacturers want solutions to their problems, but they often don't fully understand the range of technology available to them. And tech companies "rarely come

to the table with the whole solution," he says — their products often land not quite fully formed or ready to integrate into the manufacturing process without further R&D.

The good news is that Ontario has a critical mass of advanced manufacturing companies, ranging from large multinationals to startups (which make up approximately 20 percent of NGen's member manufacturers and 27 percent of member tech providers, if defined as having been in business less than five years). Companies in these sectors are helping to develop new manufacturing niches, and high-paying jobs — in clean technology, advanced medical (cell and gene) therapies, medical devices, autonomous vehicles and beyond.

Digitization is driving automotive innovation

The automotive industry is the most obvious example of the merging of manufacturing and new technology. Building vehicles used to be about better engines, transmissions and industrial design. Today, it's about disruptive technologies, such as onboard computing power, diagnostic software, GPS tools, sensors and battery capacity. A new vehicle now includes up to 150 million lines of computer code. The ongoing shift to electric vehicles and autonomous control is further accelerating this digitization. Software, robotics and machine-learning companies are now as integral to car making as brake-pad manufacturers.

Canada has all the tools to be a major player on the technology side of the automotive business. Ontario boasts a cluster of 19,000 information and communications technology companies, ranking it second only to Silicon Valley in North America, according to the Global Affairs Canada report *Invest in Canada: Canada's Competitive Advantage*. The Greater Toronto Area now has the world's highest concentration of AI startups and nearly 80,000 people in the region work for 1,750 knowledge-based businesses, including multinationals such as Microsoft, Oracle, SAP, IBM and EMC-Dell.

Even within the automotive industry, much of the new investment is going into R&D, rather than assembly capacity. The big players are increasingly recognizing how much talent and technology resides here — Ontario in particular has a vibrant tech sector with expertise in vital automotive fields such as artificial intelligence, cybersecurity and batteries.

"Automation isn't just robots. We automate stuff every day," says Woodbridge's Bob Magee, whose company makes foam interiors for vehicles at 50 plants around the world. Increasingly, he says, advanced manufacturing is about harnessing data and forging partnerships with technology companies.

That's why BlackBerry, Apple, Ford, Linamar and GM are all doing autonomous driving research in Ontario, helping to make the province a hub for automotive R&D. GM Canada, for example, is hiring as many as 1,000 engineers to work at its new technical centre in Markham. Ford has also expanded its research workforce in Ottawa, Waterloo and Oakville, drawing on the steady stream of graduates with STEM degrees.

Last year, Tesla acquired Hibar Systems of Richmond Hill to gain access to the Canadian company's innovative process for mass-producing lithium battery cells. Tesla has also forged a research partnership with Dalhousie University physics professor and battery pioneer Jeff Dahn.

Ontario has a growing ecosystem of mobility technology suppliers. They range from established players, such as BlackBerry's QNX division, to startups, such as Acerta (automotive data analytics), Pantonium (transit software) and Gatik (autonomous vehicles for short-haul shipping).

The province is also building R&D infrastructure so that Ontario can be a player in the next wave of automotive technology: autonomous vehicles. The Ontario government's Autonomous Vehicle Innovation Network (AVIN), led by OCE, is an $85-million, five-year initiative that funds R&D and helps homegrown SMEs commercialize new technology developed in Ontario. AVIN is part of the government's Driving Prosperity: The Future of Ontario's Automotive Sector automotive-sector plan and includes regional technology development sites across the province, including the L5 Smart City Living Lab and CAV Test Facilities established by Invest Ottawa.

The initiative has sparked interest from several global automotive parts suppliers, who are scouring the world for promising new tech.

Valeo of France, a large Tier 1 supplier with a plant in Alliston, is working with Ottawa-based Sensor Cortek Inc. to build high-definition imaging radars, powered by AI, for autonomous vehicles. The smart sensors can collect much more information than conventional radars, even in poor light and bad weather.

Faurecia, another French-based Tier 1 supplier, has partnered with Cloud DX Inc. of Kitchener to adapt a biometric monitoring system that tracks human vital signs — including heart rate, temperature and blood pressure — for use inside vehicles.

"There is a global race to get new technology," says Raed Kadri, senior director of automotive technology and mobility innovation at OCE. "We have everything we need to supply technology to the global auto sector."

Ontario's automotive sector does face some key challenges, though.

The industry remains an economic force, generating $20 billion a year in GDP, employing a total of 125,000 Canadians and driving billions of dollars in exports. In addition to the seven assembly plants, five of the world's leading Tier 1 parts suppliers are headquartered in Ontario: Magna, Linamar, Martinrea, Multimatic and ABC Technologies.

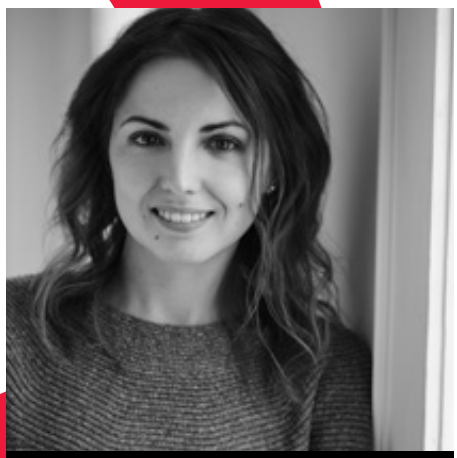
The problem is that the number of vehicles assembled in this country has been in steady decline for 20 years. Canada produced approximately 1.9 million vehicles in 2019, down from three million in 2000. And it will make fewer still in 2020 because of the Oshawa closure and pandemic-induced plant shutdowns. Two decades ago, this country made two cars for every one sold here. Now, the ratio is one to one, and it will decline further if the trend continues. Over the same period, Canada has fallen from fifth to 12th among auto-making countries.

This matters because the location of manufacturing has historically driven where innovation, R&D and capital investment happens.

A key challenge for Ontario is that it is at the "semi-periphery" of the automotive industry, rather than the core, explains Greig Mordue, a former Toyota executive who is now assistant professor of engineering at McMaster University. None of the leading automakers are headquartered here and the province isn't a low-cost vehicle assembly location like Mexico or Eastern Europe. Mordue's research suggests that Canada is punching well below its weight in automotive innovation. Canada produces roughly 3 percent of the world's vehicles, but generates just 0.4 percent of auto-related patents. Canada does only slightly better in its output of autonomous vehicle innovation, producing 1 percent of global patents.

Mordue says this relatively low output of intellectual property comes from the fact that the industry still tends to do the bulk of its R&D close to where the major vehicle manufacturers are headquartered. Getting them to change their ways may require "bold, strong industrial policies" on the part of the Ontario and federal government to force vehicle manufacturers to invest more in Canada. "This pandemic reminded everyone that manufacturing matters, and that it drives a lot of good stuff, including R&D," says Mordue, who also holds the chair in advanced manufacturing policy at McMaster.

But Canada's advanced manufacturing sector can only be as strong as its essential companies. Here are some examples of Ontario-based startup companies and products working in this sector, and lessons from their experience:



Greta Cutulenco
Co-founder and CEO,
Acerta Analytics Solutions

Acerta Analytics Solutions reduces failure in auto parts

The move by the world's leading auto manufacturers to reinvent themselves as tech companies is changing the look of vehicle supply chains. Software, electronics and data suppliers are now as important as makers of engines and brakes.

The shift to smarter cars made in smarter factories is creating new opportunities for Ontario technology companies, such as Kitchener-based Acerta. It's using AI to help GM, Fiat Chrysler, Daimler, Nissan and other automakers detect defects and part wear at an early stage. The company, which has 30 employees, harnesses data from on-board and assembly-line sensors to identify looming problems based on such factors as vibration patterns and material irregularities.

"Generally, we're looking for long-term wear that could lead to warranty issues or recalls," explains co-founder and chief executive Greta Cutulenco.

Acerta is part of a growing network of Canadian technology companies that are helping local vehicle and parts manufacturers get better at what they do. Among its latest Ontario projects: using machine learning to reduce the number of engine assemblies that fail leak testing for a major foreign automaker. It's also working with a Tier 1 auto-parts supplier to clear assembly-line bottlenecks in the testing of electric oil pumps.

Data is more important than ever as the industry shifts to making more data-dependent electric and autonomous vehicles. Plant assembly lines are also being digitized, particularly as the pandemic pushes manufacturers to operate machines remotely. All that data is spawning a new industry, forecast to be worth more than $200 billion (U.S.) by 2023.

Cutulenco doesn't worry that foreign vehicle manufacturers may favour suppliers closer to home as vehicle production declines in Ontario. "Data is cloud-based. So it doesn't matter where we are," she says.

BlackBerry QNX supplies on-board software, ecosystem depth

The digitization of vehicles is upending the notion that vehicle makers need to keep their suppliers geographically close, according Grant Courville, vice-president of products and strategy at BlackBerry QNX.

"They need the talent more than the localization," Courville says. "To develop software, you can literally be anywhere in the world."

Automakers increasingly see Ontario as a key hub for automotive software and cybersecurity, he says. That has prompted Ford, GM and others to assemble large research and development teams to tap into this expertise.

BlackBerry's Ottawa-based QNX division, which supplies on-board software to most of the major automakers, has also become a catalyst for growing and deepening Canada's tech-related automotive supply chain. The company is a founding partner in the L5 Test Facilities, which enables companies to pilot and test different technologies and collaborate with connected and autonomous vehicle startups and innovators in a highly productive way. It has also sponsored two corporate innovation programs with Ottawa's L-Spark accelerator to further spur mobility and autonomous vehicle R&D. More than a dozen startups are in the program or have gone through it, including Acerta. The aim is to help commercialize promising technology and introduce it to Tier 1 automotive suppliers.

"We are competing globally for talent, so we have to make sure that Ontario is top of peoples' minds," Courville says. "The talent will gravitate to where interesting and innovative things are happening — whether it's in cars, trucks, transit or rail."

Myant Inc. makes textiles smarter

Most of the textile industry abandoned Canada and other developed countries long ago in search of cheaper labour. And with those manufacturers went the innovation.

Myant Inc. is turning that narrative on its head by making high-tech textiles in an 80,000-square-foot plant near Toronto Pearson International Airport. But it's not making fabric for clothes. For Myant, textiles are a "gateway"

to all sorts of wearable and interactive electronics. By weaving tiny sensors and actuators into the material, it's creating devices that can actively sense and react to the human body.

The company is looking at applications as varied as health care, fitness and protective gear for the construction industry.

Myant is also working with Stoll, a German knitting-machine maker, to build cloud-connected 3D printing machines to make computerized textiles on an even larger scale.

"All the textiles industry that used to be here is gone," says Hannah Fung, marketing strategist at Myant, a 10-year-old company with 100 employees. "We want to bring a culture that's been lost back to Toronto and Ontario."

The novel coronavirus pandemic and the climate crisis are making companies rethink their supply chains, she says. They're looking at reducing dependence on distant foreign suppliers and reducing their climate footprint. This trend to reshoring — bringing manufacturing back from overseas — also boosts the local economy, she adds.

But innovation won't happen without manufacturing. "We need to bring the culture of making things back to Canada," Fung explains. "No one thinks we can make things any more, but it's not true. Governments need to believe that that advanced manufacturing can be done here."

Ibraheem Khan
CEO, Smarter Alloys

Smarter Alloys changes metal's behaviour

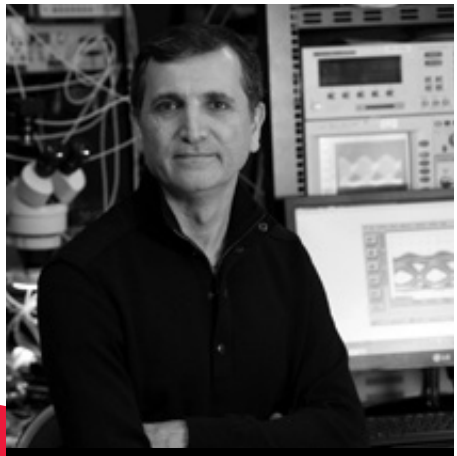
It's a stretch to attribute intelligence to a metal. But nickel titanium, an unusual alloy known as "nitinol," comes close. Smarter Alloys co-founder and chief executive Ibraheem Khan discovered during his PhD research at the University of Waterloo in 2008 that this material can be programmed to behave in specific ways by finely tuning its microstructure with the help of laser beams. For 11 years now, his Waterloo-based company has been working to apply this unique "shape memory" effect to a variety of commercial and industrial applications.

These applications include time-saving orthodontic arches that can be programmed to deliver varying degrees of force on individual teeth, and dental files or drill bits that can bend up to 90 degrees during root-canal procedures. It's also developed a clean technology application for a wide variety of industrial plants, which routinely discard hot water into sewers. A belt containing the alloy converts the hot water into motion, which drives a generator and produces power. The company is testing the system at Last Spike Brewery in Calgary and it's in talks with potential customers in the power generation, automotive and cement sectors.

Now, the company is looking to shorten its supply chain by acquiring its own melting machine to turn nitinol ingots (sourced in the U.S., Europe and China) into wire, sheets and tubes.

The company's journey hasn't been without frustrations. Khan had hoped the company's first major commercial deal would be with a Canadian company. Instead, it was with a large American orthodontic supplier, California-based Ormco Corp. And he's still awaiting Health Canada approval for his dental drill bit, a year and a half after approval from the U.S. Food and Drug Administration.

"It's made here but I can't sell it here," he laments. "It's absolutely critical to have local procurement."



Hamid Arabzadeh
CEO, Ranovus

Ranovus makes efficient chips for data centres

The collapse of Nortel more than a decade ago contributed to the disintegration of Canada's once substantial capacity to make computer chips.

Former Nortel engineer Hamid Arabzadeh, now chief executive of Ottawa-based Ranovus, is trying to rebuild Canada's chip-making infrastructure and expertise by strategically building out his own company's domestic supply chain. "We lost most of that expertise and equipment when Nortel went down," explains Arabzadeh.

Ranovus has developed a patented quantum dot laser that can emit multiple colours of light. Built into a computer chip, it can transmit 40 times as much data as conventional fibre optics. The company sells its chips to customers such as IBM for use in large U.S. data centres run by the likes of Amazon, Microsoft and Google.

Ranovus, which has 60 employees, has moved significant pieces of its production and packaging back to Canada, with $20 million in federal support through the Strategic Innovation Fund.

"We have started to bring more work back to Canada and encourage these Canadian companies to develop their capabilities and buy the right equipment," he explains. "But it doesn't make sense without government help. We have to buy the equipment, set it up, show people how it works. There is a lot of lifting from our side."

Ranovus's Canadian partners include the National Research Council's laser foundry, Edmonton-based ACAMP, IBM in Bromont, Que., and Jabil and DA-Integrated in Ottawa. The company moved nearly all of its supply chain to Canada and the United States when the U.S.-China tariff war broke out.

"You can't think globally these days because of the instability of the geopolitical situation," Arabzadeh says. "We've gone from globalism to localism."

Intellijoint Surgical Inc. helps doctors navigate surgery

Building a medical equipment company in Ontario doesn't always make sense from a business perspective. Venture capital is more plentiful in the United States, particularly for companies that are eager to scale up. Commercial opportunities are better there, too. Many of the world's largest medical equipment manufacturers are headquartered there. And U.S. for-profit hospitals are more willing to spend money on innovative technologies.

Andre Hladio, Armen Bakirtzian, Richard Fanson
Intellijoint Surgical Inc.

But Intellijoint co-founder and chief executive Armen Bakirtzian says he stays because he's committed to paving the way for other medical technology companies in Canada.

"We want to invest in our ecosystem because there is so much benefit for other companies, for taxpayers and for Canadians at large," he says. "It is not yet a destination for medical technology companies, but that's what we want to make it — a place where companies can scale up and become global powerhouses."

Kitchener-based Intellijoint, which has 80 employees, makes miniature navigation systems that help doctors better select and align knee and hip replacements during surgery. Bakirtzian likens the company's tools to having an on-board GPS guiding you to a destination, instead of printed MapQuest directions. Its products have been used by surgeons in thousands of operations in the United States, Canada and Australia.

But like many other Canadian medical equipment manufacturers, selling at home has been a challenge for Intellijoint, which sells 95 percent of its devices abroad. And that's unfortunate given the lessons of COVID-19 — most notably, the need to produce more medical equipment domestically.

Fixing that problem may require government procurement policies that encourage Canadian hospitals and healthcare networks to purchase homegrown innovative technology, according to Bakirtzian. He points out that U.S. hospitals are far more willing to take risks because they are always looking for ways to gain an edge on rival facilities. That competition is less intense in Canada, making customers inherently more averse to risk.

"If we want Canada to be a powerhouse in medical technology, we have to play to the home team," Bakirtzian argues. "We have to double down on domestic procurement. Otherwise, we are not getting a real bang for our buck."

Conavi Medical Inc. transmits live images from the heart

Starting a medical devices business in Canada is tough enough. Growing to a size where it can thrive and compete on a global scale is even harder, says Conavi chief executive Brian Courtney, a cardiologist at Sunnybrook Health Sciences Centre in Toronto.

Conavi has developed tiny devices imbedded with lasers and ultrasound that give surgeons live images from inside the heart and arteries during angioplasties and other procedures. The Toronto startup has 90 employees and sales of less than $1 million per year. But the potential worldwide market for the devices is more than $1 billion a year and it's growing at roughly 10 percent annually. Angioplasties — implanting catheters and stents to clear blockages is arteries — are the most common coronary procedure in the world, accounting for four million operations a year.

Courtney is convinced Conavi can become one of the largest medical technology companies in the world if it can get the sophisticated devices into the hands of enough surgeons. And he'd like to make that happen in Canada.

"This is the future of how complex coronary disease should be treated," Courtney says. "But we have to be supported to fight through to get to that point."

The novel coronavirus pandemic has highlighted why countries need to have the capacity to produce at least some of their own critical medical supplies and equipment, he says. Canadian governments have invested heavily in medical technology R&D. The problem, Courtney says, is that the country will never get the full benefit of all that money unless medical technology companies can raise enough capital to scale up their manufacturing capacity and generate early domestic sales.

"There is a mentality in Canada to not want to be first to adopt new technologies, but also to not want to be last," he says.

What Conavi and other medical equipment makers need are incentives to help hospitals "absorb risk" and adopt new technologies. Courtney says Canadian healthcare will benefit because the technology will help reduce system costs over the long term.

Mosaic Manufacturing brings 3D printing to the masses

Mosaic made its reputation by creating a device that can turn a $1,000, single-colour 3D printer into a machine that handle multiple colours and materials. It's sold tens of thousands of the units, mainly outside Canada.

"We disrupted the price point and we're now the market leader," co-founder and chief executive Mitch Debora says.

Now, the six-year-old Toronto company is working on technology that would enable manufacturers to connect hundreds of these 3D printers on a plant floor. Industrial-scale 3D printers typically cost $250,000 each. Instead, a manufacturer could link up as many as 1,000, low-cost machines at a fraction of the cost, churning out tens of thousands of parts per month.

Mosaic, along with three other Ontario companies, won a $5-million grant from NGen (the federal government's advanced manufacturing supercluster) to develop the software and automation required to scale up 3D factories. Its partners in the project are sport jersey maker Athletic Knit, 3D waste recycler ReDeTec Inc. and 3D equipment distributor Objex Unlimited.

The object of the collaboration is to help sustain specialized niche manufacturers in places, such as Ontario, by neutralizing the low-wage advantage of offshore locations. Instead of making things in China with three-week lead times, manufacturers would be able to build the same components overnight in downtown Toronto, Debora says. Potential customers would include footwear makers, medical device manufacturers, aerospace companies and others.

"Labour isn't a factor any more and that really disrupts the way companies can bring products to market," Debora says.

Mosaic still faces challenges operating in Ontario. Debora says venture-capital companies love app makers, but often shy away from manufacturers. And that tends to depress how VCs value companies such as Mosaic.

Kepler Communications puts low-cost data in orbit

Toronto's downtown Chinatown district is best known for dumplings and dim sum, but it's also home to Kepler Communications' 5,000-square-foot headquarters, where the company is ramping up production of its low-orbit satellites.

Toronto has a robust ecosystem satellite-related expertise and suppliers, explains Jeffrey Osborne, co-founder and vice president of strategy and business development at the five-year-old company. There's MDA Corp. in Brampton, Sinclair Interplanetary and the University of Toronto's Space Flight Laboratory.

"Being able to tap into that local expertise has been incredibly beneficial for us to ramp up quickly," Osborne says.

Kepler, which has 60 employees, is on course to produce up to 10 of the five- to 10-kilogram nanosats per month. Each is roughly the size of a loaf of bread. The company plans to launch 20 next year, and eventually put up to 140 of the satellites in orbit. The network will provide relatively low-cost data communications to remote locations that don't have internet service, such as northern communities, ships, mines and oil-and-gas installations.

Kepler assembles the satellites in Toronto with components from both Canadian and foreign suppliers and contract manufacturers.

Osborne expresses a common frustration among many Canadian technology companies. He's resigned to the likelihood that the company's first customers will likely be non-Canadian. Indeed, the first live trial of its satellites was made possible with funding from the German government, along with use of one of its ice-breaking vessels.

"We've already shown that foreign governments are willing to put up their hand and act on the service we're delivering," Osborne says. "We haven't seen that same level of commitment coming from our folks in Canada."

Having a stable customer like that would encourage new investment, helping startups scale up — if governments are committed to homegrown innovation, they should be more willing to act as "an anchor tenant" for new companies, Osborne says.

Centre for Commercialization of Regenerative Medicine keeps biotech in Canada

Canada spends billions of dollars a year on drugs that are mostly made and developed elsewhere, including the United States, Britain and Europe.

Canada has a rare opportunity to change that narrative by building a local manufacturing base in the emerging science of cell- and gene-based drug

Michael H. May
President and CEO, CCRM

therapies, according to Michael May, president and chief executive of CCRM, a not-for-profit consortium that includes the University of Toronto, McMaster University, various Ontario research hospitals as well as drug and medical-equipment manufacturers.

"The world hasn't really generated a winner yet for manufacturing these projects," says May, a chemical engineer. "We could be a leading manufacturer of these products."

CCRM is in the process of securing financial commitments to build a $200-million commercial-scale biomanufacturing plant over the next two to three years in Southern Ontario. It would eventually employ 500 people. CCRM, with 115 employees now, is already manufacturing small quantities of these therapies for use in drug clinical trials, in collaboration with Cytiva (formerly GE Healthcare Life Sciences). May says the new plant could also be configured to produce large quantities of vaccines.

The biomanufacturing plant would become an anchor that will encourage the emergence and scaling up of homegrown biotech companies, who would otherwise take their intellectual property elsewhere, May says.

"We need to find a way in Canada to create sticky companies," he says. "We've done a great job of creating intellectual property and science. But IP is diffusible. It will go to where the money is. If we become masters of manufacturing, then the companies we create will stay in Canada."

And that, he argues, is more important than ever now that the novel coronavirus pandemic has demonstrated the importance of homegrown medicine supply chains.

GreenMantra Technologies converts plastic waste

Brantford, Ont., has been a great base for GreenMantra to gets its clean technology business off the ground. The company began manufacturing on a commercial scale in 2015 and now has 40 employees, drawn from a deep local pool of engineers, chemists and executives.

The company makes a polymer additive for various construction materials using an advanced plastic recycling process that converts waste materials that would otherwise end up in landfills, including film, fibre, foam, polypropylene and polyethylene. The polymer is then sold to various industrial users, including makers of plastic pipes and asphalt roofing shingles, as well as paving contractors.

Like many other Canadian startups, early customer interest has come mainly from outside of Canada. A majority of GreenMantra's sales are in the United States, including a major asphalt roofing company — Malarkey Roofing of Portland, Ore.

"The world market is very large and it's exciting to have penetrated it," says Domenic Di Mondo, a chemist and GreenMantra's vice president

of technology and business development. "But you want to see adoption in your own backyard as well. It's a patriotic thing."

Selling in Canada would be a lot easier if Ottawa had incentives for companies to buy recycled material. Instead, the federal government is preparing to designate various plastics as toxic substances under the Canadian Environmental Protection Act, giving it the authority to regulate and limit certain products. The Liberals have vowed to ban some single-use plastics as early as 2021.

Ottawa should do more to encourage the diversion of plastics from landfills, rather than banning these materials, according to Di Mondo. For example, he says, Ottawa could require that more recycled materials be used in government-funded infrastructure projects.

"Plastic lasts a long time, so let's make it circular," Di Mondo says.

A call to action

Innovation leaders need to shift the current narrative about manufacturing to align with the reality that it is stronger than ever. We can do that by raising the profile of our new potential champions and by celebrating our established firms that are leading the way in technology utilization. We also need to ensure that we are developing the ingredients to nurture today's manufacturing rather than yesterday's. As a greater share of manufacturing jobs in Canada shift to design and prototyping that means growing the pool of post-secondary educated talent and providing incentives for companies to invest in R&D&I (Innovation). Finally, shifting geopolitics and COVID-19 are driving supply chains to be more local. Canadian firms need to increase their collaboration with each other to increase their supply resiliency and to leverage complementary competencies to further cement our position as a global manufacturing leader for decades to come.

Executive Summary:

The past few decades have been challenging for Ontario, Canada's manufacturing heartland. The 2008 recession wiped out nearly 250,000 manufacturing jobs. In the years that followed, several high-profile factory closures helped reinforce the false perception that manufacturing in Ontario is dead or dying.

The truth is that Ontario is still a manufacturing powerhouse. In fact, more than one in 10 of the province's jobs are in manufacturing. However, the manufacturing sector is undergoing a fundamental transformation that has deep implications for what gets made — and how — in the province. This transformation is creating a sector that bears little resemblance to traditional manufacturing because it has become far more complex.

These were the findings of NGen, the federal government's Ontario-based advanced manufacturing supercluster. The organization recently surveyed their 2,500 members, asking them whether they saw themselves as manufacturers, technology providers or service companies. Most said they were all three.

Other manufacturing leaders are saying pretty much the same thing.

"We've entered a new era in manufacturing," argues Linda Hasenfratz, president and chief executive of Linamar. "It feels like manufacturing is turning into a technology business, more than anything else."

Research by the Innovation Economy Council supports this. IEC data show that advanced manufacturing industries generated half of the more than 45,000 factory jobs created in Ontario since 2010. Over the past decade, employment has grown 98 percent in agricultural chemicals, 45 percent in aerospace, 42 percent in industrial machinery, 22 percent in auto parts, 17 percent in electronic components, 17 percent in medical equipment, and 14 percent motor vehicles. That compares to an average of 7 percent job growth across all manufacturing industries.

These sectors are vital to the economy because they account for an oversized share of economic output, exports and R&D, according to a 2018 report by the Martin Prosperity Institute and the Brookings Institution, *Canada's Advanced Industries: A Path to Prosperity*. And they are more likely to pay higher wages. The average worker employed in an advanced industry earned nearly $60,000 a year — 50 percent higher than the Canadian average.

Advanced manufacturing is not exclusively about new technology. In many cases, advanced manufacturing has overtaken and transformed existing industries — particularly as technology becomes infused into almost every product or service Canadians consume.

For example, Canada has all the tools to be a major player in the technology side of the automotive business — which is increasingly important as cars become more technologically complex, AI-powered and autonomous machines. Ontario boasts a cluster of 19,000 information and communications

technology (ICT) companies, ranking it second only to Silicon Valley in North America, according to the Global Affairs Canada report Invest in Canada: Canada's Competitive Advantage. The Greater Toronto area now has the highest concentration of AI startups in the world. And nearly 80,000 people in the region work for 1,750 knowledge-based businesses, including multinationals such as Microsoft, Oracle, SAP, IBM and EMC-Dell.

These positions, and others across Ontario's manufacturing sector, are high-value, high-tech jobs — a hybrid between manufacturing and technology work. In other words, manufacturing hasn't died or disappeared in 2020. It simply looks nothing like the human-powered assembly lines of the 1970s. It's been reborn into something new, far more exciting and ultimately more lucrative.

This report examines some of the successes among advanced technology manufacturing in Ontario and offers potential approaches to drive further innovation, collaboration, investment and commercialization.

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