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Global Expert Mission Advanced Manufacturing in Canada 2017

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Welcome

Innovate UK's global missions programme is one of its most important tools to support the UK's Industrial Strategy ambition for the UK to be the international partner of choice for science and innovation. Global collaborations are crucial in meeting the Industrial Strategy's Grand Challenges and will be further supported by the launch of a new International Research and Innovation Strategy.

Innovate UK's Global Expert Missions, led by Innovate UK's Knowledge Transfer Network, play an important role in building strategic partnerships, providing deep insight into the opportunities for UK innovation and shaping future programmes.

The Advanced Manufacturing Expert Mission travelled to Waterloo, Winnipeg and Montreal in December 2017 and in this publication we share the information and insights gathered during the delegation's time in Canada.

1. Introduction

1.1 Canada Advanced Manufacturing Mission

On 18 September 2017, Canada and the UK signed a Memorandum of Understanding (MoU) on science, technology, and innovation[1]. The MoU recognises Canada and the UK as global leaders in research, development and innovation, and will enhance bilateral cooperation in complementary areas of research, technology, entrepreneurship and innovation. This will be achieved by strengthening ties between the UK and Canada's government bodies, knowledge-based institutions, innovation clusters, and businesses. The goal is to accelerate the commercialisation of emerging technologies, grow domestic firms and create jobs in both countries.

Initial areas of focus include advanced manufacturing, agricultural technologies, clean technologies and quantum technologies, with the potential to include additional sectors of mutual interest. It will also look to include under-represented groups and sharing the benefits of economic growth in both countries.

In December 2017, KTN in collaboration with the Industrial Research Assistance Program (IRAP)[2] at the National Research Council Canada (NRC)[3], led an Advanced Manufacturing Expert Mission to Waterloo, Winnipeg and Montreal with fifteen representatives from UK manufacturing companies, Innovate UK, the High Value Manufacturing (HVM) Catapult and KTN.

With a focus on the four key advanced manufacturing areas of (1) Robotics, (2) Artificial Intelligence (AI), (3) Manufacturing Resource Planning (MRP) and (4) Additive Metal Manufacturing (AMM), a series of workshops and visits were held in the three cities with over eighty attendees representing over fifty Canadian organisations from a cross-section of SME organisations, large, federal and provincial government agencies and academia.

A full list of UK and Canadian participating organisations is in Annex 1.

[1] https://pm.gc.ca/eng/news/2017/09/18/prime-minister-canada-announces-closer-collaboration-united-kingdom
[2] www.nrc-cnrc.gc.ca/eng/irap
[3] www.nrc-cnrc.gc.ca/eng

2. Manufacturing in Canada and the UK

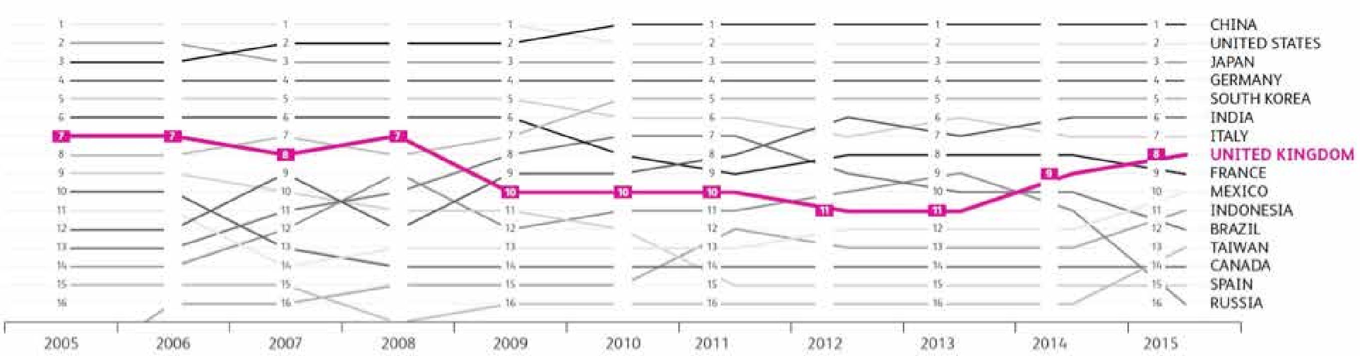
At approximately C$175 billion (£102 billion) and employing more than 1.7 million people, the manufacturing sector contributes to more than 10% of Canada's total gross domestic products (GDP). Moreover, its annual export value of circa C$35 billion amounts to nearly 68% of all of Canada's merchandise exports. It is the fourteenth biggest manufacturing nation in the world. In 2016, the manufacturing sector was responsible for 32% (C$6.6 billion) of all business enterprise R&D investments[4], predominantly in information technologies, additive manufacturing, automation systems, nanotechnology and biotechnology.

Comparatively, as the world's eighth largest global manufacturer (see Figure 1) in 2015, the UK's manufacturing sector sustains 2.6 million jobs (c.8% of total jobs), contributes to 11% of its GVA (c.£180 billion of economic output, down from 17% in 1990) and 44% of its export. It also represents 70% (£14.6 billion) of business R&D[5] in 2015 (combined R&D spending of all services sectors totalled 27% [£5.7 billion] but accounted for 80% of UK economic output).

The manufacturing sector in Canada experienced a similar growth trend as the UK in the last few decades. The Canadian manufacturing sector experienced generally strong growth in the 1990s, spurred by trade liberalisation, the depreciation of the Canadian dollar and innovations related to the adoption of information and communications technologies. However, the economic conditions changed after 2000, and for the first time manufacturing growth in Canada stalled for over half a decade while the overall business sector continued to expand. The weakened demand for Canadian manufactured goods was partly due to the global commodity boom, appreciation of the Canadian dollar against the US dollar, stronger overseas competition, lagging productivity growth and cyclical changes in demand[6].

The 2008/09 recession exacerbated the challenges faced by the Canadian manufacturing sector. While it affected virtually all business sector industries, the effects were particularly strong for manufacturing. GDP volumes in the manufacturing sector declined at an annual average rate of around 9% in 2008/09, compared with an average annual contraction of less than 2% in the business sector, and took much longer to regain its pre-recession levels. And while the business sector

Figure 1: World manufacturing output ranking 2005-2018[8]



Source: UNCTAD, USD in current prices

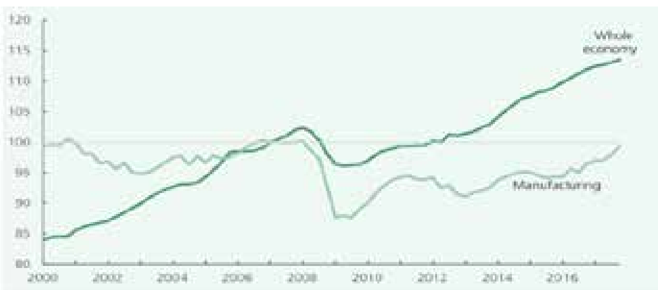
[4] https://www.ic.gc.ca/eic/site/mfg-fab.nsf/eng/home
[5] www.eef.org.uk/campaigning/campaigns-and-issues/manufacturing-facts-and-figures
[6] www.statcan.gc.ca/pub/11-626-x/11-626-x2017074-eng.htm

returned to pre-recession levels in less than two years, it took about six years for manufacturing to return to pre-recession levels (refer to Figure 2). Investment in process innovation by Canadian businesses also fell from 33.5% in 2007-09 to 29% in 2010-12. This post-recession recovery period for manufacturing was the slowest since the Second World War and yet to recover to pre-crisis levels by 2016.

Similarly, the 2008/09 recession hit the manufacturing sector especially hard in the UK (see Figure 3 GDP index for manufacturing sector in relation to the whole economy in the UK 2000-2016)[7]. Manufacturing output fell by 13% in real terms between Q1 2008 and Q3 2009, compared to a 6% fall for the whole economy. Unlike the rest of the economy, manufacturing output has not recovered to the pre-crisis level. The initial recovery in manufacturing output stalled in early 2011 and declined for the following two years. A more sustained recovery began in 2013, and manufacturing output grew by 8% between 2013 and 2017. However, output by Q4 2017 was still 1% below its pre-recession peak[7].

Figure 2: Real GDP index for manufacturing sector in relation to overall business sector in Canada 2000-2016[6]

Figure 3: RGDP index for manufacturing sector in relation to the whole economy in the UK 2000-2016[7]

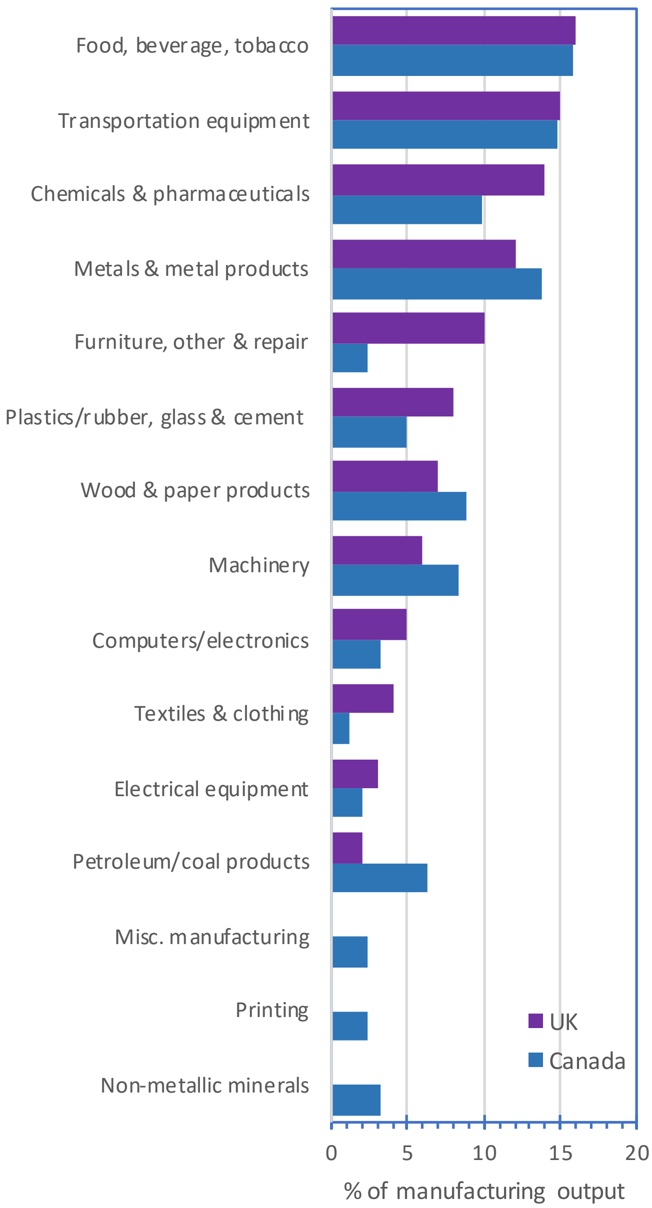


The manufacturing industry landscapes between the UK and Canada are economically and technically aligned after the changes in the last decades. Today both countries boast an almost identical breakdown of manufacturing output categories, as seen in Figure 4, dominated by the following common outputs:

- Food, beverage and tobacco
- Transportation equipment
- Chemicals and pharmaceuticals
- Metals and metal products

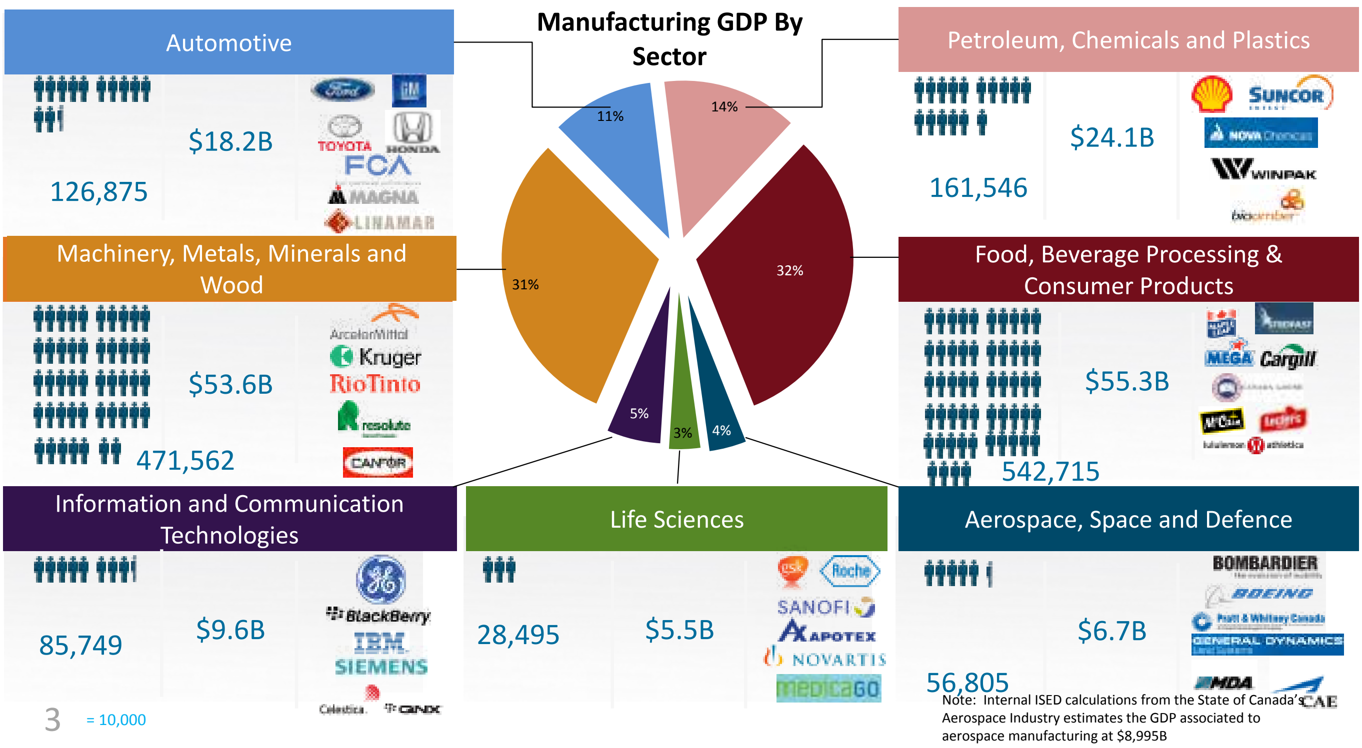
These are sectors that rely heavily on investment in advanced manufacturing processes, automation systems, information technologies, advanced materials and biotechnology. The economic contribution from the key Canadian manufacturing sectors is further detailed in Figure 5 (overleaf).

Figure 4: UK and Canada manufacturing categories as a percentage of total manufacturing output 2015
Source: Office for National Statistics Canada



[7] http://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN01942

Figure 5: The diversity of Canadian manufacturing sector *Source: National Research Council Canada*



According to the Brookfield Institute for Innovation and Entrepreneurship, the technology sector in Canada provides high paying jobs, with an average salary of C$67,000 compared to the national average of c.C$48,000. Also, 69% of Canadian technology firms have only 1-4 employees, but they generate 7.1% (C$117 billion) of Canada's total economic output[8]. To further strengthen this national innovation foundation, the Canadian government committed the following investments in its 2016 budget:

- C$2 billion on renewal and expansion of infrastructure at universities to promote research excellence.
- Over C$1 billion to support the development of clean technologies to reduce pollution and increase energy efficiency.
- C$800 million over four years to strengthen innovation networks and clusters.

The Canadian Government also committed to an investment of up to C$950 million over five years to launch the Innovation Superclusters Initiative (ISI)[9] in 2017. The ISI will invite industry-led consortia to lead and to invest in bold and ambitious supercluster proposals that will supercharge their regional innovation ecosystems. By pulling in large firms, innovative SMEs and industry-relevant research institutions, the business-led innovation superclusters will be built on shared private sector commitment – demonstrated through matched industry funding – to leverage strengths, address gaps, and incentivise innovation ecosystem players to work together more strategically for the collective benefit of their clusters. It is expected there will be a supercluster on advanced manufacturing. The day-to-day administration of the superclusters will be provided by Innovation, Science and Economic Development Canada (ISED)[10].

2.1 Additive Metal Manufacturing (AMM)

Canada's experience in the field of Additive Metal Manufacturing (AMM) is relatively new compared to the UK. However, it has the benefit of having a number of global metal powder manufacturers based in the country.

The Canadian Government is supporting the development of AMM capabilities through programmes of support and funding managed by the NRC. It delivers bespoke programmes of support and works in partnership with provincial organisations, such as CRIQ[11] in the province of Quebec. In general, R&D centres focussing on additive manufacturing are made up of three main types:

[8] http://brookfieldinstitute.ca/research-analysis/the-state-of-canadas-tech-sector-2016
[9] www.ic.gc.ca/eic/site/093.nsf/eng/00003.html
[10] www.canada.ca/en/innovation-science-economic-development.html
[11] CRIQ is a state-owned company dedicated to industrial research and innovation that reports to Quebec Minister of the Economy, Science, and nnovation (MESI). See www.criq.qc.ca

1. NRC Research Centres listed in Table 1 specialising in unique and complementary competencies for AMM research and development. NRC also works with the metal powder manufacturers on the development of next-generation materials.

Table 1: RC AMM Research Centres in Canada

NRC Research Centre	Areas of AMM Research
Montreal	Additive metal forming Robotised processes Materials removal
Ottawa	New materials and coatings Non-destructive inspection Materials characterisation Static and dynamic testing High-temperature testing Structural testing Residual stress measurement Qualification testing Risk-based life management Gas turbine engine testing Flight testing Wind tunnel testing
Boucherville	Nanomaterials Metal casting Powder fabrication Cold/thermal spray Metal and ceramic processing Non-destructive inspection
London (Ontario)	Laser materials processing High-performance coatings

2) Independent research centres by large organisations into AMM materials, technologies and applications.

3) Colleges and universities undertaking basic research into additive manufacturing technologies and processes, including the development of appropriate skills at technician, engineer and scientist levels.

AMM service providers use a range of installed machines from recognised machine suppliers such as Renishaw[12] and EOS[13] . The number of service providers is growing to meet the increasing demand for AMM components in Canada. Within the field of cold spray additive manufacturing, Canada is recognised as a world leader in the application of this technology.

2.2 Artificial Intelligence (AI)

In March 2017, Canada introduced the C$125 million Pan-Canadian Artificial Intelligence Strategy, delivered through the Canadian Institute for Advanced Research (CIFAR)[14] to promote collaboration between its main Artificial Intelligence (AI) and machine learning centres of expertise in Toronto–Waterloo, Montreal and Edmonton and to position Canada as a world-leading destination for AI investment. The subsequent launch of the C$170 million Vector Institute,[15,16] a public-private research institute hosted by the University of Toronto, further bolstered Canada's global recognition as one of the fastest growing and innovative hotspots for AI businesses and research.

While there are significant common experiences and competencies in AI and machine learning between the UK and Canada, the adoption of AI technologies is beginning to accelerate in Canada with survey data from NRC indicating that 20% of businesses will have some cognitive technologies in place by Q1 2018. This development is built on Canada's recent investment and policy.

The primary early adopters of AI are reported to be the manufacturing (including aerospace and automotive), healthcare and retail sectors. Other sectors are still slow in recognising the potential benefits of AI. The application of AI to manage quality control requirements in the food sector was an example of a new opportunity.

Challenges such as the need for collaboration between solution providers of AI software, sensors and hardware for advanced manufacturing are recognised and addressed by a number of key initiatives. In the Waterloo/Kitchener area, an active network of AI solution providers is supported by innovation centres such as Communitech[17] and Catalyst137[18]. Businesses are supported from start-up stages onwards with access to facility, IP expertise, business advice, entrepreneurial peers, public funding and private investment required to bring a new technology to market.

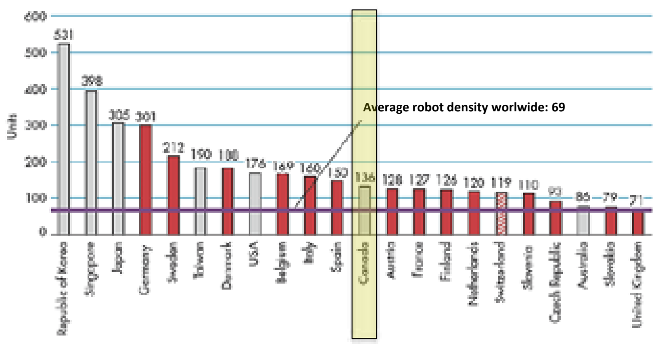
[12] www.renishaw.com
[13] www.eos.info
[14] www.cifar.ca/assets/pan-canadian-artificial-intelligence-strategy-overview
[15] www.ft.com/content/3110b1bc-148a-11e7-b0c1-37e417ee6c76
[16] The Vector Institute's sponsors, which includes Accenture, BMO Financial Group, Google and Loblaw Companies, contribute about C$80m.
[17] www.communitech.ca
[18] http://catalyst-137.com

With its inventor-owned IP policy, Waterloo University actively incentivises its academic and research staff and students to spin out new research findings with full equity ownership. Such practice is common across Canadian universities in most faculties, with some exceptions funding-intensive areas such as in medical research. The resulting technology community is strong and vibrant, attracting new talent and potential clients. Similar ecosystems are growing in Toronto, Montreal, Edmonton and Vancouver.

2.3 Robotics in Manufacturing

The demand for multi-purpose robots by manufacturers in Canada increased by 35% from 2010 to 2015. By 2016, Canada was ranked twelfth globally in robot density, defined as the number of robots per 10,000 persons employed in manufacturing, with an average of 136 robots per 10,000 employees (see Figure 6). Comparatively, the UK was ranked twenty-second with 71 robots per 10,000 employees.

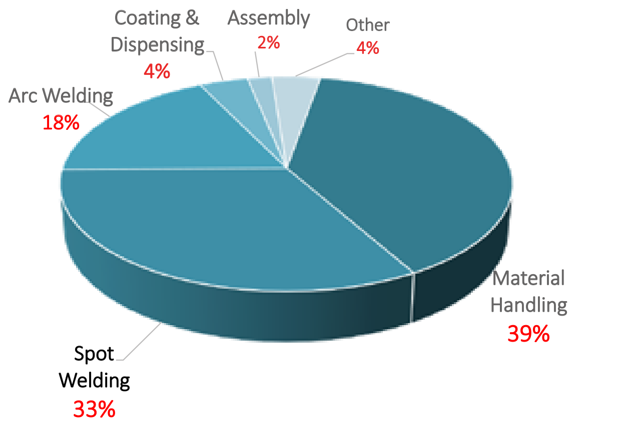
Figure 6: Number of multipurpose robots (all types) per 10,000 employees in the manufacturing sector in 2015



Sources:
International Federation of Robotics (IFR) Statistical Department 2016
Canadian Industrial Machinery (CIM) 2015
Global Affairs Canada (GAC) Invest in Canada 2016

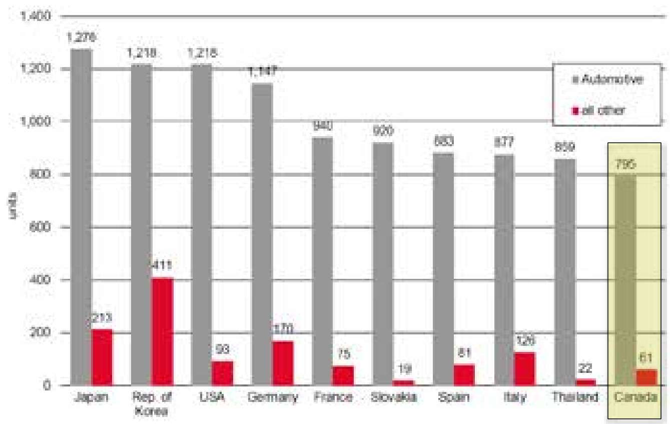
By 2015, robotics in the Canadian manufacturing sector were most widely used in materials handling and spot and arc welding (Figure 7), predominantly in the automotive and aerospace sectors. For instance, nearly 70% of its automotive businesses deployed robots, as compared to 55% in NAFTA[19] countries, and had a very substantially higher density of 795 robots per 10,000 employees, as compared to an average 61 robots per 10,000 employees in other sectors (Figure 8).

Figure 7: Canadian robot orders breakdown by applications in 2015.



Sources:
International Federation of Robotics (IFR) Statistical Department 2016
Canadian Industrial Machinery (CIM) 2015

Figure 8: Number of multipurpose robots (all types) per 10,000 employees in the automotive and other industries in 2015.



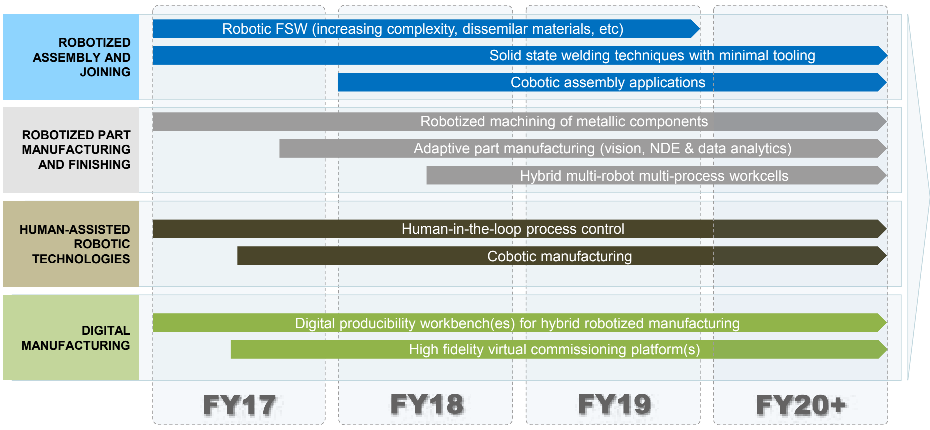
Sources:
International Federation of Robotics (IFR) Statistical Department 2016
Canadian Industrial Machinery (CIM) 2015

Within the aerospace sector robotic applications are similar to those within automotive with some additional aerospace specific needs:

- Material handling and machine tending
- Automated fibre placement
- Profiling, deburring and finishing
- Shot peening
- Component assembly
- Circumferential joining at final assembly
- Non-destructive inspection.

[19] https://ustr.gov/trade-agreements/free-trade-agreements/north-american-free-trade-agreement-nafta

Figure 9: NRC's research and development roadmap in the field of robotics and mechatronics for Canada



The NRC has highlighted production-level applications in which Canadian organisations have specific strengths in Table 2. To support the growth in robotics needs and increasing technical demands, the NRC has developed a roadmap in Figure 9 to enable Canadian organisations to benefit and prepare for future trends and demands. There are in excess of fifteen Canadian universities and R&D institutions performing research in the field of advanced robotics and mechatronics to support the development of new technologies and solutions.

Table 2: Strength of Canada's robotics capability in automotive and aerospace sectors

Production-level Robotic Applications	Automotive	Aerospace
Solid-state welding processes	•	•
Symbiotic human-robot collaboration	•	•
Assistive robotic devices	•	
Dexterous robotic assembly	•	
Intuitive programming methods	•	
Intelligent tooling	•	
Machining and finishing of components		•
Hybrid manufacturing of topologically optimised components		•
Maintenance and repair		•

2.4 Manufacturing Resource Planning (MRP)

Manufacturing Resource Planning (MRP) systems are integral to efficient operations management in any manufacturing organisation and, as such, challenges faced in the UK and Canada are very similar. MRP systems have several challenges that they must address if they are to continue to be relevant to modern manufacturing processes, organisations and supply chain.

The integration of MRP systems with Industry 4.0 is a key element of development that is needed now. MRP needs to cope with shorter development cycles, have the ability to accommodate mass customisation and be capable of interfacing with robotic and AI solutions to offer increased productivity, improved quality, cost savings and supply chain integration in real time.

Also, the implementation of a Total Flexibility Management (TFM) solution for operational planning is seen to be as important as Total Quality Management (TQM) and Total Production Management (TPM) for all future operations managers. The flexible manufacturing and scheduling functionality requires agile MRP systems both within an organisation and within respective supply chains. However, knowledge, system principles and skills have not kept up with these rapidly changing needs.

3. Future Canada-UK Collaboration

Given the strong overlaps between UK and Canada manufacturing priorities and the strong bond between the two nations, future partnership activities will focus on creating win-win opportunities to develop new technologies for our respective markets as well as other global markets such as the EU, the US and Asia Pacific.

There are a number of positive factors to encourage a UK-Canada collaboration in advanced manufacturing:

- The cultural heritage shared between Canada and the UK makes it easier for cross-border collaborations to take place, and there is no language barrier.
- Awareness in Canada of technology as a solution appears to be greater than in the UK; this presents an opportunity for British organisations to operate in and sell to Canadian markets.
- UK expertise in additive manufacturing appears to be greater than that seen in Canada.
- An estimated 75% of Canadian Manufacturing exports are to the USA. Collaboration may enable UK businesses to increase access to the North America market.

3.1 Additive Metal Manufacturing (AMM)

Additive metal manufacturing capabilities in Canada are not as advanced as the UK with two exceptions. Canada has a globally-recognised expertise in cold spray additive metal manufacturing and also has knowledge on surface finishing of AM components. Common issues regarding processing and post-processing capabilities appear to exist and are areas where collaboration could prove of benefit. The challenge to reduce AM costs and improve cycle times is also an area of opportunity. Process integration of quality assurance (QA) and non-destructive testing (NDT) and post-processing operations was highlighted as areas where improvements need to be made to bring AMM into mainstream production processes. As AMM use increases, opportunities are becoming evident with the current hi-tech and aerospace sectors.

The key challenges and opportunities for AMM highlighted from during the Expert Mission were:

Opportunities or challenges	R&D	Industry
Create tools for technology selection	•	
Provide guidance on the adoption of AMM, including costing models, design guides, applications and scalability	•	•
Reduce machine cycle times	•	
Improve processes such as conformal coating and increase the use of higher performance alloys offering better wear performance	•	
Increase process automation of QA and NDT tasks and reduce or simplify post-processing operations. Full automation and the removal of post-processing steps or inclusion of processes such as Hot Isostatic Pressing (HIP) alongside AMM processes is desired by industry	•	•
Simplify the manufacture of complex internal geometries	•	
Repair and refurbishment of damaged or worn components	•	
Integration of complementary technology and design analysis such as FEA and CFD	•	
Collaboration on software and platform development	•	
Manufacture of tooling using AMM	•	
Increase the size of product manufacturing envelopes	•	
Develop AMM for applications outside of aerospace and hi-tech sectors	•	
Use AMM to design and produce lightweight, low-cost components that can offer aerospace customers cost savings from reduced fuel usage	•	•
Improve knowledge on material properties so that they are predictable, including strength, residual stress and performance at elevated temperatures. AMM powders require characterisation before they can be used confidently	•	•
Develop portable AMM solutions that can be used on-site	•	
Create an open collaborative way of working using catapults and superclusters to encourage academic sharing and co-operative working that also involves industry at all levels of the supply chain	•	
De-risk the R&D for SMEs through suitable government support. Helping to leapfrog the competition by leveraging collaborative projects in the UK, Canada and the EU		•
Cost of investment in AMM processes can be prohibitive. Production costs are not yet competitive with established processes		•
Need to establish common design rules to enable good use of the AMM technology for repeatability and reliability of performance that satisfies validation and verification needs within industry and regulatory bodies. This will require the recognition of Design for Additive Manufacturing (DFAM) as a core engineering skill		•
Certification and specification of materials and processes before use in sectors such as aero, auto and medical is necessary and needs to be as common as possible. The metallurgical and dimensional accuracy of parts needs to be accurate and repeatable		•
Data security for data transferred between sites or customer to client needs to be trustworthy and reliable		•

3.2 Artificial Intelligence (AI)

The use of AI presents an opportunity for industry to gain improvements in productivity, reliability and real-time decision making. It was noted that in the greater Montreal area there are a significant number of organisations with relevant knowledge and skills gained from working in compatible sectors such as gaming. Additional expertise is located at the University of Windsor and University of British Columbia. There are strengths within this sector in both countries and collaboration would be of benefit, particularly if aligned with robotics development.

There are challenges around the use of AI within manufacturing environments, such as around data reliability and ease of processing, confidence in automated decisions made and their traceability that are critical in process validation and repeatability. Manufacturing requires faster, more reliable and agile processes capable of satisfying low-to-high volume and high-product variability. AI still needs to be able to demonstrate its effectiveness and value in such an environment.

The key challenges and opportunities for AI highlighted from during the Expert Mission were:

Opportunities or challenges	R&D	Industry
Need to identify the impact AI will have on manufacturing and the robustness of manufacturing processes.	•	•
Data capture, storage and retrieval, including identification of key data, with rapid real-time data analysis and support. Large amounts of data used will require data consistency to work. Areas of concern include: • Cybersecurity • Data integrity • Provision of fast and reliable networks • Real-time data processing • Big Data management	•	•
Managing of risks when using AI and ensuring accountability	•	
Co-ordinated collaboration between industry, academia and institutions. Academia needs to be fully-aware of industry's needs and concerns regarding AI	•	
Machine-centre learning that manages wear, damage, self-analytics	•	
Servitisation and condition-based servicing/maintenance using AI, including the ability to undertake self-service or maintenance tasks	•	
Understand the impact of AI on jobs within manufacturing and perceived threats to employees	•	•
Develop autonomous capabilities of AI enabled machines	•	
Understanding, demonstrating and managing the industrial impact of AI and the needs for appropriate software, sensors, networks and equipment	•	
Capability of AI in operating in both high volume, high accuracy and high-value situations with high levels of confidence and reliable data to address productivity gap	•	•
Industry acceptance, regulatory and liability protocols for AI need to be defined, such as in: 1. Overcome workforce resistance to use of AI and educate the public to the benefits by demonstrating that it has universal application, not just hi-tech 2. Identify areas of opportunity for AI such as QA inspection and validation 3. Need agreement on data standards to enable data sharing and common machine protocols across supply chains and sectors		•
Insufficient skilled AI-capable people in industry. New AI technology requires a new generation of highly-skilled, technically-capable personnel at all levels		•
Creating opportunities • Need roadmaps at National and OEM levels to be created and shared, specifically with SMEs and integrators • Opportunities for integration to be explored, i.e., integrate AI with ERP, Robotics and AM/CNC • How to build AI into legacy installations and systems	•	•
Support to prepare suitable ROI arguments for AI implementation		•

3.3 Robotics in Manufacturing

Adoption of robotics is hindered by organisations inability to fully justify ROI decisions and the current costs also prevent SMEs from investing. With the increasing adoption of Industry 4.0 solutions, it is necessary for all sizes of industrial organisation to be considering how best to implement robotics within their manufacturing facilities.

The ability to correctly specify robotic needs is an area lacking knowledge and expertise. In partnership with Artificial Intelligence developments, it is possible to develop autonomous systems that can provide productivity improvements, but such solutions need to reflect the needs of modern manufacturing facilities that have to be agile and cost-competitive on a global scale.

The key challenges and opportunities for robotics in manufacturing highlighted from during the Expert Mission were:

Opportunities or challenges	R&D	Industry
ROI and Cost • Implementation is expensive and difficult to maintain flexible manufacturing. Industry needs guidance on how to implement robotics • Robot efficiency and downtime need to be understood and maintained at high levels. Industry needs guidance on how to achieve these efficiencies	•	•
Adoption issues • Adopters will be hit with a large amount of data to manage; they need advice on how best to complete the implementation and use the data • Integration with legacy systems requires skill and knowledge • “First to File” patent laws in USA preventing innovation and adoption by SMEs • Changes in legislation are preventing adoption	•	
Material handling abilities Robotics need to have the ability to handle various products and shapes and to multi-task in a production environment	•	
Flexibility • Robotic solutions have to satisfy needs for flexible manufacturing within modern facilities, be capable of complex tasks and configurable to allow for product variation and complexity • Re-manufacturing and re-cycling is an area that requires robotic solutions for dis-assembly and material handling	•	
Workplace safety Robotics are an opportunity to make the workplace safer. Industry needs to be made aware of the opportunities and how to take them, particular focus on co-robot (cobot) operations is required	•	•
Measurement and Instrumentation • The use of wireless systems and vision measurement systems has to be developed • Opportunity to implement AI and predictive monitoring and/or feedback loops for machine performance and product quality	•	
Labour and productivity Robotics offer the opportunity to undertake dirty, dangerous or repetitive tasks without the need for human intervention and can provide significant productivity gains. Industry needs to be made aware of the benefits and how to make valid assessments that will enable the introduction of robotics within all sizes of manufacturing organisation	•	
How to select an appropriate application to utilise robotics and to cope with the concerns regarding job losses		•
Applications suitability • Use of robotics in low volume or high variability production situations • Flexible/re-configurable operations ability • Heavy lifting or sensitive/tactile applications • Productivity challenges		•
Skills • Operator v machine comparisons • Availability of operator, programming and maintenance skills for the new technologies		•
Integration How to integrate robotic technologies such as vision systems and material handling systems with existing robot technology and factory layouts.		•

3.4 Manufacturing Resource Planning (MRP)

Manufacturing Resource Planning (MRP) faces significant challenges with the advent of Industry 4.0. Demands for fast-paced, high-variety manufacturing that needs to be flexible to meet varying demands and requires operational planning with a high degree of accuracy. Many existing systems are not capable of meeting these new demands, therefore, the need to identify systems that can enhance legacy installations or offer cheaper Industry 4.0 capable solutions is high on the agenda for anyone considering an MRP installation.

The software-driven nature of MRP systems and difficulty in achieving cross-system communications exacerbates the situation, particularly with SMEs. Canadian organisations face the same issues as UK organisations and discussions indicated that there is some focus in Canada on the development of flexible planning systems to meet future needs.

The key challenges and opportunities for MRP highlighted from during the Expert Mission were:

Opportunities or challenges	R&D	Industry
MRP integration with Industry 4.0: How to best assist organisations to integrate MRP with Industry 4.0 needs	•	
Common Standards for MRP use: Creation of standards and process chains across supply chains	•	
Data: How to manage data across supply chains and how to get value from Big Data	•	
How to quantify the value of Enterprise Resource Planning (ERP) with respect to business case development and Return on Investment (ROI) justification	•	•
Development of Cloud-based MRP solutions	•	
System deployment: How to cost-effectively replace or upgrade legacy systems with minimum disruption	•	•
Improve the effectiveness of MRP systems: Improve operator skills and knowledge for effective use of MRP/ERP systems. Many MRP installations are not operating effectively due to lack of understanding and abilities • Data is not always accurate enough to make good decisions • Integration with other systems is always a problem • Greater ability to implement process knowledge into resource planning is needed • MRP requirements have changed but knowledge, system principles and skills have not kept up	•	•
Understand best practice for the use and control of MRP within organisations and supply chains	•	
Complexity: Modern industry requires an MRP system that can support high variability, low volume, flexible production systems to suit the principles of mass customisation and batch size of one • Flexible manufacturing and scheduling requires agile MRP systems • Most system solutions are too complex for SME needs • SME solutions cannot interface with LE/OEM solutions • Integrated supply chains need a seamless system that is irrespective of organisation size and needs • Existing system architecture is archaic and needs to change		•
Software developer skills are not good enough to meet the changing needs of manufacturing requirements and the adoption of Industry 4.0 solutions		•
Changing employee cultures to achieve full implementation and enterprise-wide effectiveness in use		•
Frameworks that allows leaders to plan for the future: MRP systems need to fit with shorter development cycles and be included within an organisation's strategic objectives		•

Annex 1
List of UK Participants

Homeodynamic Autonomy
HVM Catapult - National Composites Centre (NCC)
Innovate UK
Knowledge Transfer Network (KTN)
North East Automotive Alliance (NEEA)
Renishaw
Rolls-Royce
Shadow Robot Company
Valuechain

Canada Participants

3DSemantix

Abzac Canada

Acerta Analytics Solutions Inc.

AddUp

AV&R

Bluewrist Inc

Boeing Canada Winnipeg

Canadian Tool and Die

CARIC

Cloud Constable Inc.

CMS Montera Inc.

Communitech

Composite Innovation Centre

CRIAQ

Eascan Automation Inc.

Elmer’s Manufacturing

Fiix

FZ Engineering

Global Affairs Canada

Hydro-Québec

I-Cubed

In-House Solutions Inc.

Industrial Technology Centre

Innovative Automation Inc.

Innovation Canada

Innovation, Science and Economic Development Canada (ISED)

Kinova

MAJiK Systems

Manitoba Aerospace Inc.

Manitoba Growth, Enterprise and Trade

MDA

Melet Plastics Inc.

MicroPilot

Mitacs

Modern Manufacturing Ltd

NRC

NRC-IRAP

Robotics Design

Rockwell Collins

Seradex

Soleno

StandardAero

Tektite

Teledyne Dalsa

University of Waterloo

WestCaRD

Western Economic Diversification Canada

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