

Developing an Innovation Ecosystem for Saskatchewan's Minerals Industry

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Innovation is a process by which economic and social value is extracted from knowledge by generating, developing and implementing ideas to produce new or improved strategies, capabilities, products, services, or processes.

Conference Board of Canada – Centre for Business Innovation

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1. Introduction

The International Minerals Innovation Institute (IMII) is an innovation supporting network driven by the needs of its minerals industry members.

In the fall of 2016 IMII adopted its strategic plan for 2017 to 2019. As part of this plan, it identified the need to develop a model for a long-term innovation strategy that could be adopted by its minerals industry members and the provincial government to facilitate/foster the achievement of several desired business outcomes: greater leveraging of government funding agencies, greater innovation success rate, greater member innovation capture rate and greater likelihood of commercialization. One part of this model involves developing an innovation ecosystem for the purpose of identifying the players willing and able to help make innovation happen and bring forward complete solutions to industry's needs. Innovation is pivotal to the performance of any industry, and in a minerals sector with weak markets it is imperative in realizing sustainable and long-term economic, environmental and social goals.

(Intergovernmental Working Group on the Mineral Industry, 2016)

Saskatchewan's minerals industry, which comprises mining companies and mining-related suppliers and service providers, is one of the mainstays of the provincial economy that supports jobs and economic activity in both the north and south. In 2015, mineral production in Saskatchewan exceeded \$8.5 billion in value and ranked as the second largest producer in Canada. (Natural Resources Canada, March 2016)

The province has the largest potash industry in the world, accounting for 45% of known global reserves. Existing Saskatchewan potash producers – Agrium, The Mosaic Company and PotashCorp, have undertaken major expansions in the past several years, while international mining companies are developing new operations here or have announced intentions to do so. German-based mining company K+S Group is building the first new potash mine in the province in over 45 years, with production scheduled for 2017. BHP Billiton has been developing the Jansen potash project. The world's richest uranium deposits are located in northern Saskatchewan, which accounted for just over 22% of the world's primary uranium production in 2015. This ranks Saskatchewan as the second largest producer of uranium in the world. (Innovation Saskatchewan, 2016)

With world leading production and producers, Saskatchewan is recognized nationally and globally as an important mining jurisdiction. It is also becoming recognized as an innovative mining jurisdiction. Since 2012, the principal potash and uranium producers in the province have collaborated on innovations in both education & training and research & development through the IMII. IMII's membership consists not only of its major industry members, but also the province's key post-secondary institutions and research organizations, and representatives of the industry and its suppliers as a whole. Appendix 1 provides a list of IMII members as of December 2016.

In this paper, IMII sets out a comprehensive view of the minerals industry's innovation ecosystem to better link its components together and increase opportunities for collaboration on advancing innovations that matter to mining.

2. Saskatchewan Minerals Industry Innovation Ecosystem Overview

IMII defines an innovation ecosystem as a model of the economic dynamics formed between actors or entities whose functional goal is to enable technology development and innovation. Innovation is further understood to be a process by which economic and social value is extracted from knowledge by generating, developing and implementing ideas to produce new or improved strategies, capabilities, products, services, or processes. (Conference Board of Canada, 2016)

An innovation ecosystem includes the array of participants and resources that contribute to and are necessary for ongoing innovation in an economy, region or industry. As such, it includes entrepreneurs, investors, researchers, university faculty, venture capitalists, business development and technical service providers. For IMII, investors are its funding members – industry and the Province of Saskatchewan.

As such, IMII’s innovation ecosystem is comprised of three core elements:

- The education and research capacity available to the minerals industry;
- The business enterprises that make up the minerals industry; and
- Those agencies and entities which can provide capital and services (see Figure 1).

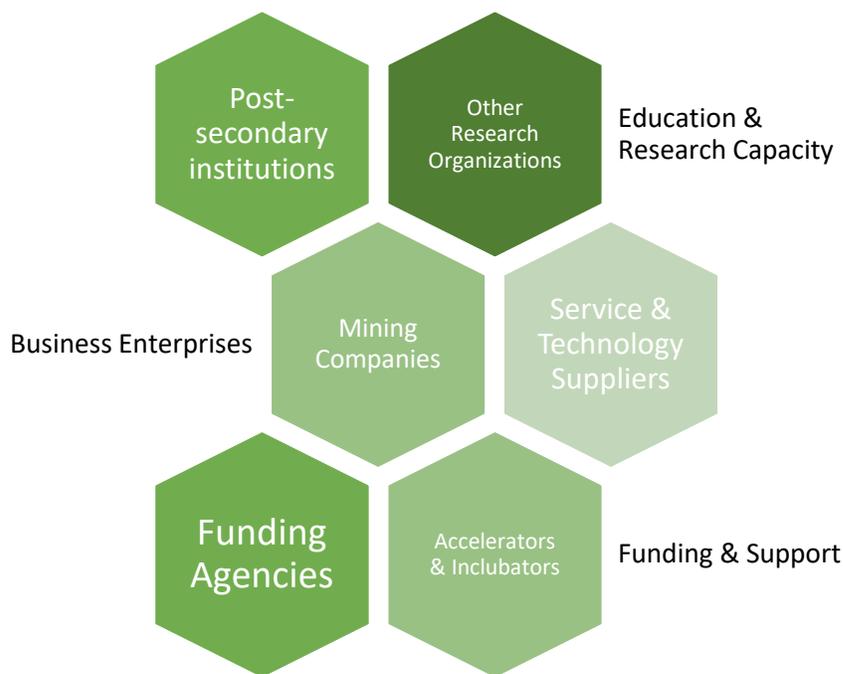


Figure 1: IMII's Innovation Ecosystem

These core elements represent the provision of research and creation of “highly qualified persons” (e.g., professionals, researchers, technicians and tradespeople) that meets industry needs; the industry that both demands and develops innovations; and the resources necessary for the commercialization of the innovations that provide solutions for industry. They are the inputs necessary for innovation.

In its first five years, IMII used its industry and Innovation Saskatchewan funding to undertake projects with post-secondary institutions, on behalf of its mining companies, with the financial assistance of federal funding agencies such as the Natural Sciences and Engineering Research Council (NSERC) and Mitacs. Going forward, IMII recognizes that in order to better meet the innovation needs of its members, its mining company members will need better access to all of the sector's innovation ecosystem, including other research organizations that exist in Saskatchewan, the service & technology suppliers that make up the minerals industry supply chain, and those with the capacity to commercialize innovations with funding and support.

This report represents IMII's first effort at documenting the Saskatchewan mineral industry's innovation ecosystem. This is seen to be important as business ecosystems, while they may differ in size and makeup, are characterized by three factors:

- Ecosystems encourage participation by a diverse range of organizations, which provides for ecosystem health and broad solutions;
- Ecosystems are characterized by increasing engagement between actors that would be difficult to organize in a top down manner; and
- Participants are bonded by some combination of shared interests, purposes and values which makes the ecosystem a "shared commons". (ovoinnovation, 2016)

The next section of this report expands on the education & research capacity available to the minerals industry within the Province of Saskatchewan. Its participants are members of IMII and as such they share the interests, purposes and values of IMII and its funders.

It should be noted however, that the possibility may exist that the innovation needs of the minerals industry may not be able to be met by the expertise that presently resides in these participants. As they are members, IMII will always first look within its membership for potential solutions. Should solutions not be forthcoming, IMII will then look outside of its membership, nationally and if necessary internationally, for others who may be prepared to work collaboratively to meet industry needs.

IMII's Strategic Plan for 2017 to 2019 has identified, at a high level, four areas of industry need with respect to research, development and demonstration (RD&D) and education and training:

- Exploring Innovations – seeding research into potentially transformative solutions to longer-term needs of future mines;
- Developing Innovations – applied research & development into emerging innovations or adaption of innovations from other industries for next generation mines & mills;
- Operationalizing [Commercializing] Innovations – demonstration & deployment of innovations focused on existing operations; and
- Innovations in education & training that improve diversity and inclusion in the minerals sector's workforce.

3. Education & Research Capacity



Figure 2: Education & Research Capacity in the Innovation Ecosystem

The Government of Saskatchewan is, through Innovation Saskatchewan, one of the founding members of IMII. It is also one of the organization’s core funding members, and represented in IMII activities by both Innovation Saskatchewan and the Ministry of Advanced Education. The post-secondary institutions and government-owned research organizations that are also members of IMII and represented in its innovation ecosystem receive funding from the Province. For example, in 2015-16, Advanced Education provided the post-second institutions with \$650 million in operating grants, which the institutions used in part to leverage industry and federal funding, for research. The minerals industry also benefits from this funding in terms of accessing an educated workforce. Further, the introduction of innovations, for example through the introduction of new technologies, often results in a requirement for training in both mining and supplier firms in the minerals sector. The province also invests in other research organizations, such as the Prairie Agricultural Machinery Institute and Canadian Light Source. In these ways, the government, IMII, post-secondary institutions and research organizations have complementary interests such as increasing Saskatchewan’s competitiveness, improving education outcomes and connecting workers and employers, and investing in skills training.

3.1 Post-Secondary Institutions

The post-secondary institutions in IMII’s innovation ecosystem are focused in whole or in part on three main areas: education, research and early stage commercialization. Saskatchewan’s regional colleges focus on education, delivering programs developed by others, while the Saskatchewan Polytechnic and Universities of Regina and Saskatchewan focus on all three.

The post-secondary institutions can also be placed in IMII’s innovation ecosystem on the basis of their timeframe of focus – current operations, next generation mines and mills, and future mines. **Table 1** presents where the credit granting post-secondary institutions are best suited to be approached as innovation partners.

	Education	Research	Early Stage Commercialization
Current Operations	Saskatchewan Indian Institute of Technologies Saskatchewan Polytechnic University of Regina University of Saskatchewan	Saskatchewan Polytechnic	Saskatchewan Polytechnic
Next Generation Mines & Mills	University of Regina University of Saskatchewan	University of Regina University of Saskatchewan	University of Regina University of Saskatchewan
Future Mines	University of Regina University of Saskatchewan	University of Regina University of Saskatchewan	University of Regina University of Saskatchewan

Table 1: Placement of Post-Secondary Institutions as Innovation Partners

Descriptions of each post-secondary institution in context of IMII’s innovation ecosystem follow:

Saskatchewan Indian Institute of Technologies (SIIT)

Partner type and focus: Education and Current Operations

Established in 1976, SIIT is one of the four educational institutions with credit granting authority in Saskatchewan. It offers certificate and diploma programs in the areas of trades and industrial, business and technology, health and community studies, and adult basic education to more than 2,400 students annually.

Programming is delivered through three principal campuses in Regina, Saskatoon, and Prince Albert, plus eight Career Centres and a number of learning centres located across the province. SIIT also operates the Saskatchewan Aviation Learning Centre at the Saskatoon airport governed by First Nations leaders and representatives from across the province. Programming of interest to the minerals industry in 2016 includes the:

- Mining Industry Pre-Employment Program – designed to prepare Indigenous learners who are interested in moving forward on a career path into this industry. The program provides learners with an understanding of the many job possibilities and related requirements for employment in the mining industry, as well as basic hands-on skill development. Learners also develop specific, individual career action plans to guide them in achieving their career goals;
- Aircraft Maintenance Engineer Program – which trains learners to maintain, repair, and overhaul aircraft to ensure that aircraft meet Transport Canada’s standard of safety and performance;
- Process Operation Technician Program – learners develop the knowledge and skills to become process operators in a wide range of processing industries, including mining; and

- Power Engineering Program – 4th Class – learners develop the knowledge and skills to become operating personnel in plants that use high pressure boilers. Learners gain the necessary skills to operate and maintain, in a safe and efficient manner, the equipment found in industrial settings and steam-generating facilities; among others.

Saskatchewan Polytechnic (Sask Polytech)

Partner type and focus: Education, Research and Early Stage Commercialization for Current Operations

Sask Polytech is, in some ways, the newest of the four credit granting post-secondary institutions in the province. In 2014-2015, SIAST transitioned from a technical institution to Saskatchewan Polytechnic and so became the province’s first polytechnic. As a polytechnic, it is now a degree-granting institution, along with the Universities of Regina and Saskatchewan, and has a focus on applied learning (including trades and technical training) and applied research.

Sask Polytech offers more than 150 programs through a schools’ model, many of which may provide graduates of potential interest to the mining industry (e.g., School of Business and human resources, School of Human Services and Community Safety and occupational health and safety, School of Information and Communications Technology and computer engineering). Notable from an education perspective is the School of Mining, Energy and Manufacturing which graduates many technicians relevant to the needs of the industry.

Appendix 2 provides a “mapping” of Saskatchewan Polytechnic programs to 71 selected occupations identified in a 2015 study by the Mining Industry Human Resources Council (MiHR), undertaken in partnership with the Saskatchewan Mining Association and IMII, that identifies talent gaps that may impact the industry if not addressed. The MiHR study shows that, among the occupational categories, technical occupations collectively exhibit the largest gap between hiring requirements and available talent for Saskatchewan. (Mining Industry Human Resources Council, 2015)

As the education for technical occupations is largely provided by Sask Polytech programs – offered either directly by the Polytechnic or through the regional colleges, Saskatchewan Polytechnic could fill a critical role in IMII’s innovation ecosystem with regards to innovation in education & training as the minerals industry seeks to improve on diversity and inclusion in its workforce.

With respect to research and early stage commercialization, Saskatchewan Polytechnic’s Office of Applied Research and Innovation (OARI) offers internal support and structures that may facilitate the Polytechnic’s participation in IMII’s innovation ecosystem as a partner for applied research. IMII has asked OARI for assistance in mapping expertise and labs that exists in the four Sask Polytech campuses (such as the Bioscience Applied Research Centre in Saskatoon). When provided, IMII will include this information in its innovation ecosystem documentation.

In 2009, Saskatchewan Polytechnic became eligible to receive funding from Canada’s three federal granting agencies (such as NSERC), and in 2015 adopted an Applied Research and Scholarship Action Plan. Under this plan, applied research activities will focus on five sectors, including manufacturing, mining and minerals. Sask Polytech has also identified four areas of

applied research expertise, all of which may be of interest in IMII's innovation ecosystem going forward:

- Business and process efficiencies;
- Environmental and natural resources;
- Information and communications technology and digital integration; and
- Social capital, health and wellness. (Saskatchewan Polytechnic, 2015)

University of Regina (UofR)

Partner type and focus: Education, Research and Early Stage Commercialization for Current Operations, Next Generation Mines & Mills, and Future Mines

The University of Regina is home to 10 faculties, two academic units and approximately two dozen academic departments which have established reputations for excellence and innovative programs leading to Bachelor's, Master's, and doctoral degrees.

In Fall 2016, more than 14,500 full-time and part-time undergraduate and graduate students enrolled at the University and its three federated colleges: Campion College, First Nations University of Canada, and Luther College.

The UofR offers more than [120 undergraduate programs](#) and [78 graduate programs](#), including many specialized programs. Their [Faculty of Engineering and Applied Science](#) offers a number of undergraduate programs aimed at preparing students for careers in petroleum engineering, software systems engineering, environmental systems engineering and electronic and industrial systems engineering.

The UofR is home to more than 400 active researchers, including faculty members, graduate and undergraduate students, post-doctoral fellows, and seven Canada Research Chairs. Several institutes, centres, laboratories, and facilities on campus support research collaboration and partnerships focused on our research strengths. Indigenous research is a growing focus as they encourage and support Indigenous ways of knowing. Several centres and institutes reflect this in their projects and partnerships.

The UofR is also home to the main campus of the First Nations University of Canada, and provides an opportunity for students of all nations to learn in an environment of First Nations cultures and values. The First Nations University of Canada is a First Nations' controlled university-college which provides educational opportunities to both First Nations and non-First Nations university students selected from a provincial, national and international base. The university offers programs and services on three campuses: Regina, Saskatoon and Prince Albert (Northern Campus). (First Nations University of Canada, 2016)

The University of Regina has emerged as a centre of excellence on a number of research fronts. Based upon research impact, critical mass of highly qualified personnel, distinctiveness, and commitment to partners in the community and the Province of Saskatchewan for high impact research, the UofR has identified five thematic areas of research priority which represent clusters of researchers:

- Anxiety, stress and pain;

- Digital future;
- Integrated human health: Equity, disease and prevention;
- Social justice and community safety; and
- Water, environment and clean energy. (University of Regina, 2016)

Research centres and institutes at the UofR that may be of particular interest to the minerals industry include the:

- Clean Energy Technology Research Institute;
- Institute for Energy, Environment and Sustainable Communities; and
- Prairie Adaptation Research Collaborative.

Canada Research Chairs of potential note at the UofR (Fall 2016) are:

- Gordon Huang, Canada Research Chair in Energy and Environment; and
- Peter Leavitt, Canada Research Chair in Environmental Change and Society.

University of Saskatchewan (UofS)

Partner type and focus: Education, Research and Early Stage Commercialization for Current Operations, Next Generation Mines & Mills, and Future Mines

Established in 1907, the University of Saskatchewan has a long history of excellence. The U of S is the core of a dynamic research hub working to address critical challenges faced by people locally and around the world. World-class research centres on campus include global institutes for food and water security, the Canadian Light Source synchrotron, the Crop Development Centre, and the Vaccine and Infectious Disease Organization-International Vaccine Centre (VIDO-InterVac), plus an impressive array of national and provincial bio-science research labs. With stellar research teams and annual research income of about \$200 million, the university has earned a place among the U15 group of Canada's top research universities. The university is committed to First Nations, Métis and Inuit student success and to welcoming diverse perspectives and ways of knowing, both from across Saskatchewan and around the world.

Research centres and institutes at the UofS that may be of particular interest to the minerals industry include the:

- Global Institute for Water Security;
- International Centre for Northern Governance and Development; and
- Toxicology Centre.

Canada Research Chairs of potential note at the UofS (Fall 2016) are:

- Graham George, Geological Sciences – Canada Research Chair in X-ray Absorption Spectroscopy;
- John Giesy, Toxicology—Canada Research Chair in Environmental Toxicology;
- Ingrid Pickering, Geological Sciences – Canada Research Chair in Molecular Environmental Science; and
- John Pomeroy, Geography and Planning – Canada Research Chair in Water Resources and Climate Change.

Other research chairs of interest to the minerals industry at the UofS is Matthew Lindsay, Geological Sciences – NSERC/Syncrude Industrial Research Chair in Mine Closure Geochemistry, and Ha Nguyen, Electrical and Computer Engineering – CISCO Chair in Mining Solutions.

3.2 Other Research Organizations

In addition to the research capabilities found within the SP, UofR and UofS, the minerals industry has access to four research organizations in the province. These can also be placed in the innovation ecosystem by their partner type (e.g., research, early stage commercialization) and mine period focus (e.g., current operations, next generation mines & mills).

	Education	Research	Early Stage Commercialization
Current Operations		Canadian Light Source Genome Prairie Saskatchewan Research Council	Prairie Agricultural Machinery Institute Saskatchewan Research Council
Next Generation Mines & Mills		Canadian Light Source Genome Prairie Prairie Agricultural Machinery Institute Saskatchewan Research Council	Saskatchewan Research Council
Future Mines		Saskatchewan Research Council	

Table 2: Placement of Other Research Organizations as Innovation Partners

Canadian Light Source (CLS)

Partner type and focus: Research for Current Operations and Next Generation Mines & Mills

The Canadian Light Source offers a unique-in-Canada service to companies: synchrotron-based measurement techniques such as X-ray absorption spectroscopy, X-ray photoelectron and Auger spectroscopies, scanning transmission X-ray microscopy, X-ray fluorescence, X-ray diffraction and infrared spectroscopy that can provide exceptional insight into industrial materials.

By increasing understanding of chemical bonding and structure, the CLS provides powerful insights into substances as varied as soils, mine wastes, catalysts, ores and minerals, biological tissues, functional foods and nutrient supplements, forensic evidence and manufactured materials such as metals, alloys, ceramics and polymers. (Canadian Light Source, 2016)

Mining and the environment are one of the CLS’ five focus areas. Synchrotron techniques can provide valuable information in many areas of the mining process, from metals recovery to tailings management, by identifying metallic phases and amorphous compounds in effluents and mine tailings. For example, researchers from the UofS have modelled the water treatment process at Cameco’s Key Lake uranium mill, and used the advanced X-ray techniques available at CLS to understand chemical reactions in the process.

Genome Prairie (GP)

Partner type and focus: Research for Current Operations and Next Generation Mines & Mills

Genome Prairie is a non-profit organization that supports stakeholders across Manitoba and Saskatchewan in capturing and maximizing the benefits of advanced research in genomics and related biosciences. This role is achieved by aligning the partners and resources needed to develop and manage targeted projects addressing regional priorities. Genome Prairie also enables participation among regional researchers in Genome Canada's competitive granting process for large-scale projects.

GP believes that mining and energy activities have long employed research to assess and develop various operations, from exploring the microbial basis of well and mine sites, to extraction and processing strategies, and remedial environmental treatments. However, scientific progress since the sequencing of the human genome more than a decade ago now provides modern tools for deeper analysis of sector environments, extraction processes and environmental impacts. For example, from 2011 to 2013, GP undertook the MAVEN project – *Microbial Assessment for Value-Add, Environment and Natural Resources*. For the purpose of developing novel genomic-based approaches for the identification of microbial communities associated with mining, milling, treatment and remediation operations. This project was funded by the Western Economic Partnership Agreement, Cameco, and Contango Strategies. (Genome Prairie, 2016)

In 2013, a sector strategy for advancing Canada's energy and mining sector through state-of-the-art genomics applications was published by Genome Canada.

Prairie Agricultural Machinery Institute (PAMI)

Partner type and focus: Research and Early Stage Commercialization for Current Operations and Next Generation Mines & Mills

PAMI is an [ISO 9001:2008](#)-registered and [ISO/IEC 17025:2005](#)-accredited applied research, development, and testing organization serving agriculture and industry in Western Canada and beyond.

PAMI's diversified engineering expertise has direct application for agriculture, transportation, military, aeronautics, forestry, and mining. Services include: design, development, fabrication and evaluation of vehicles, machinery and components as well as value-added process reviews, pilot plant design, and optimization. PAMI has developed broad expertise in "mechanical problem solving," finding technological solutions to sometimes very complex problems in the space between "should work" and "does work."

For mining, PAMI offers services related to equipment design, evaluation and assessment. PAMI is able to test industry equipment such as underground vehicles and surface equipment to meet safety standards as well as address structural durability challenges, engine and cooling system application validations, and stability analysis. (Prairie Agricultural Machinery Institute, 2016)

PAMI may also offer a vehicle through with key steps between research and commercialization in technology development and demonstration, such as proof-of-concept, engineering and scale up activities, could be undertaken.

Saskatchewan Research Council (SRC)

Partner type and focus: Research and Early Stage Commercialization for Current Operations, Next Generation Mines & Mills and Future Mines

The Saskatchewan Research Council is one of Canada's leading providers of applied research, development and demonstration (RD&D) and technology commercialization. Mining is one of four industrial areas of focus for the SRC, and they offer a wide range of services related to:

- Pre-exploration and exploration;
- Mine development and operation;
- Site reclamation; and
- Mineral processing.

Services include:

- [Kimberlite Processing and Diamond Recovery](#);
- [Mechanical and Electrical Design](#);
- [Mineral Processing and Metallurgical Testing](#);
- [Minerals Analysis](#);
- [Oil-Water Pipeline Testing](#);
- [Product Development and Commercialization](#);
- [Rapid Prototyping Services](#);
- [Slurry Applications](#); and
- [Specialty Sensors, Equipment and Data System Integration](#). (Saskatchewan Research Council a, 2016)

The SRC also offers other services related to mining, including:

- Aerial image acquisition;
- Air quality analysis;
- Air quality monitoring; and
- Analytical services for site remediation. (Saskatchewan Research Council b, 2016)

The SRC's services are supported by several state-of-the-art laboratories of relevance to the minerals industry, including the:

- Advanced Microanalysis Centre (for analytical needs);
- Environmental Analytical Laboratories (for analytical chemistry);
- Geoanalytical Laboratories (for exploration and mining);
- Mineral Processing Lab and Pilot Plant; and
- Pipe Flow Technology Centre. (Saskatchewan Research Council c, 2016)

4. Business Enterprises



Figure 3: Business Enterprises in the Innovation Ecosystem

4.1 Mining Companies

The major international mining companies that make up the IMII's primary membership play a critical role in the mineral industry's innovation ecosystem. They:

- Create the demand for and “pull” innovations from the ecosystem with respect to both education & training and research & development;
- Engage in their own research, development and deployment (RD&D) efforts;
- Fund collaborative RD&D efforts (such as those through the IMII); and
- Adopt innovative processes or services arising out of the ecosystem.

They are, therefore, central to the functioning of the innovation ecosystem and key to it being an industry-driven business ecosystem.

The mining companies at the centre of IMII's innovation ecosystem are:

- Agrium – the global leader in the crop input retail market and a major producer of primary crop nutrients including potash;
- BHP Billiton – among the world's top producers of major commodities including iron ore, metallurgical coal, copper and uranium - in Saskatchewan they are developing the Jansen potash project;
- Cameco – one of the world's largest uranium producers accounting for about 18% of the global production from its mines in Canada, the US and Kazakhstan;
- K+S Potash Canada – part of the K+S Group, an international resources company that has been mining and processing mineral raw materials for 125 years – in Saskatchewan they are expected to bring the Legacy Project potash mine and production facility near Moose Jaw into production in 2017;
- The Mosaic Company – the world's leading integrated producer and marketer of concentrated phosphate and potash - they mine potash from four mines in North America, primarily in Saskatchewan; and

- PotashCorp – the world’s largest fertilizer company by capacity, producing potash (K), nitrogen (N) and phosphate (P) – its Canadian potash operations represent one-fifth of global capacity.

4.2 Service & Technology Suppliers

Partner type and focus: Research (potential) and Early Stage Commercialization for Current Operations

Given the nature of both the world-class mines and companies in the centre of Saskatchewan’s minerals industry, it is not a surprise that a strong suite of service & technology suppliers has grown up along with and around the mines and mills in operation today. These suppliers are represented, in large part, by SIMSA – the Saskatchewan Industrial and Mining Suppliers Association, and are supplying everything from underground mining vehicles to centrifuges and many other goods and services to support the mining industry.

With the support of the Ministry of Economy in 2016, SIMSA has prepared a number of case studies which highlight the capabilities of the province’s industrial suppliers and how Saskatchewan industrial suppliers are meeting the mining industries’ needs. These include:

- Fortis Mining Engineering & Manufacturing and the development of the Fortis Mobile Reel Handler which effectively and safely supports re-roping of hoists in mine shafts; (Saskatchewan Industrial & Mining Suppliers Association a, 2016)
- DynaIndustrial and the development of the DynaBolter, an advanced single-operator machine that keeps the operator in an underground mine on safe ground while installing massive bolts to secure the ceiling overhead in drifts; (Saskatchewan Industrial & Mining Suppliers Association b, 2016)
- JNE Welding and the fabrication of two Crystallizer pressure vessels – each nearly four storeys high and wide for the K+S Legacy potash project; and (Saskatchewan Industrial & Mining Suppliers Association c, 2016)
- Continental Mine and Industrial Supply/Deca/International Machine/Saskatoon Metal Manufacturing Consortium to deliver a boring machine to the potash industry more timely than a European manufacturer and in so doing displacing the European company from several mines. (Saskatchewan Industrial & Mining Suppliers Association d, 2016)

A list of SIMSA members can be found in Appendix 3 and at <https://simsa.ca/members/>.

The suppliers’ community also has an interest in improving their understanding of, and access to, the academic research community to help them advance new products and services in response to the needs of the minerals industry. They have, for example, advocated for a “voucher system” to allow small & medium sized enterprises to improve access to technical expertise and facilities required to support their research and development activities.

5. Funding and Support Agencies

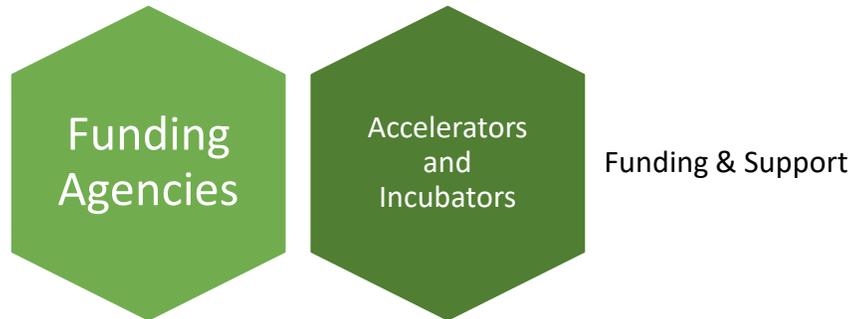


Figure 4: Funding & Support in the Innovation Ecosystem

5.1 Funding Agencies

Funding agencies in the minerals industry’s innovation ecosystem are generally associated with the provincial and federal governments. Their funding programs provide frameworks which may serve to help guide innovation and can help to incent industry-driven research, development and demonstration (RD&D). They also help to advance ideas through R&D to early stage commercialization.



Figure 5: Interrelated activities of innovation

These agencies can also be placed into the minerals industry’s innovation ecosystem by the stages they are able to fund and outcomes they support:

Use-inspired basic & applied research	Technology development & demonstration	Early-stage commercialization & market entry
Innovation Saskatchewan Canadian Foundation for Innovation Canada Revenue Agency Mitacs Natural Sciences & Engineering Research Council National Research Council NRC-IRAP Western Economic Diversification	Innovation Saskatchewan NSERC NRC-Industrial Research Assistance Program Sustainable Development Technologies Canada Western Economic Diversification	Innovation Saskatchewan NRC-Industrial Research Assistance Program Western Economic Diversification
Output – Proven Research	Output – Real World Testing & Proving	Output: Market Ready Product or Process

Table 3: Placement of Funders as Innovation Partners

Innovation Saskatchewan (IS)

Partner type and focus: Funding and support for research, development and early stage commercialization for Current Operations, Next Generation Mines & Mills, and Future Mines

As noted above, Innovation Saskatchewan is one of the founding and funding members of IMII, and a significant portion of its funding is directed through the IMII to seed both E&T and R&D projects. IMII is one of six funded program partners of IS, and one of two driven by industry needs.

Innovation Saskatchewan is the central agency of the Government of Saskatchewan with responsibility for implementing Saskatchewan’s innovation priorities. Its mandate is to develop policies and programs and conduct activities that assist in the implementation of the innovation priorities of the Government of Saskatchewan. Its mission is to be an innovation catalyst serving the needs of individuals, companies and institutions as well as to enhance the role and benefits of innovation in Saskatchewan through:

- Developing an environment that encourages and rewards innovation;
- Enhancing the ability of the private sector to innovate and implement innovations, leading the commercialization of new, high value-added products and improved competitiveness; and
- Fostering coordinated public sector research, development and technology transfer targeted at economic growth for the Province of Saskatchewan. (Innovation Saskatchewan, 2016)

Innovation Saskatchewan is responsible for the Saskatchewan Advantage Innovation Fund (SAIF). SAIF is a fund managed by Innovation Saskatchewan to help facilitate innovation in Saskatchewan's core economic drivers (agriculture, oil & gas, and minerals) and their industrial ecosystems (industries that supply products, services and technologies to, or process outputs from, the core sectors). SAIF will entertain projects (those initiatives that are intended to develop new technologies, products or services) or institutional development initiatives.

With IMII's new focus on commercialization, a portion of IS funding will be directed to support early stage commercialization from 2017 forward.

Canada Foundation for Innovation (CFI)

Partner type and focus: Funding to enhance the capacity of universities and colleges to support business innovation in Canada

The CFI makes financial contributions to Canada's universities, colleges, research hospitals and non-profit research organizations to increase their capability to carry out high quality research. The infrastructure funded by the CFI includes the state-of-the-art equipment, laboratories, databases, specimens, scientific collections, computer hardware and software, communications linkages and buildings necessary to conduct leading-edge research.

The CFI offers a Research Facilities Navigator – a searchable directory of participating research labs and facilities in universities, colleges and research hospitals across Canada that are open to working with business. The directory identifies four such labs and facilities in Saskatchewan:

- The Geofluids Lab at the University of Regina which characterizes and models geofluids;
- The Toxicology Centre at the University of Saskatchewan which detects and assesses chemicals and other stressors in the environment and associated toxicological risks to people and ecosystems;
- The Canadian Light Source at the University of Saskatchewan – Canada's national synchrotron facility for health, environmental, pharmaceutical, energy, agriculture, and life science research; and
- The Saskatchewan Structural Sciences Centre at the University of Saskatchewan which undertakes molecular structural characterization and analytical services for materials science, physical and life sciences. (Canadian Foundation for Innovation, 2016)

Canada Revenue Agency

Partner type and focus: Tax incentive program for research

The Canada Revenue Agency supports the Scientific and Experimental Development (SR&ED) Tax Incentive Program.

The SR&ED Program is a federal tax incentive that encourages Canadian businesses of all sizes and in all sectors to conduct R&D in Canada in order to develop new materials, devices, products, or processes, or improve existing ones. The SR&ED Program is the largest single source of federal government support for R&D.

Claimants can apply for SR&ED investment tax credits for expenditures such as wages, materials, some overhead, and SR&ED contracts. The program can provide a tax credit of up to 35% of qualified expenditures as defined by the CRA. (Government of Canada, 2016)

Mitacs

Partner type and focus: Funding for applied research collaboration with universities

Mitacs is a national not-for-profit research network, building partnerships that enhance industrial and social innovation in Canada with the help of a coast-to-coast business development team. Mitacs has helped over 3,000 companies, including those in the mining sector across Canada solve their R&D problems in partnership with Canadian research universities. Over the past 15 years, Mitacs has supported more than 10,000 research internships, including those with IMII, trained more than 19,000 graduate students and postdoctoral fellows in business skills, and funded more than 1,300 international research collaborations.

They offer four core programs, two of which are readily available to industry partners:

- Mitacs Accelerate – for shorter-term applied research projects (and the opportunity to test potential employees); and
- Mitacs Elevate – for two-year projects for industrial postdoctoral fellowships (and the opportunity to build research management capacity).

Accelerate projects range in size from \$15,000 to more than \$2 million, with the industry partner providing half of the money on individual projects, and 45% on clustered projects. Elevate projects require industry to contribute \$30,000 per year over 2 years, with Mitacs providing \$25,000 per year.

The Government of Saskatchewan, through Advanced Education, has been partnering with Mitacs since 2007 to fund internships for graduate students, many of which have been with the minerals sector.

National Research Council (NRC)

Partner type and focus: Funding and support for research and early stage commercialization for service and technology suppliers

The National Research Council is the Government of Canada's premier research and technology organization. Working with clients and partners, it provides innovation support, strategic research, and scientific and technical services.

NRC is comprised of four integrated R&D divisions, each guided by advisory bodies composed of industry leaders. Under these umbrella R&D divisions, they have 12 integrated and consolidated portfolios focused on key industry sectors. Mining is found under the Engineering division, along with energy and the environment.

While NRC Energy, Mining and Environment does not have research facilities in Saskatchewan, it does have facilities with the potential to support R&D of interest to our minerals sector, particularly with respect to high efficiency mining and environmental advances in mining.

Within this portfolio NRC offers [technical and advisory services](#), [research facilities](#), [licensing opportunities](#) and [programs and partnership opportunities](#) of potential value in the minerals industry innovation ecosystem. (National Research Council Canada a, 2016) For example, IMII has spoken with NRC about research collaborations (e.g., the NRC has a long standing program related to corrosion which could make some contributions to the Mining Materials Research Cluster) and funding and support for commercialization.

From a funding perspective, the NRC has a program called IRAP – Industrial Research Assistance Program, which assists small and medium-sized enterprises (SMEs) by providing technology assistance at all stages of the innovation process, to build their innovation capacity and successfully take their ideas to market. NRC-IRAP helps SMEs identify and understand technology issues and opportunities and provides linkages to the best business and R&D expertise in Canada.

For SMEs, NRC-IRAP offers:

- Advisory services (industrial technology advisors);
- Funding;
- Networking and linkages nationally and internationally; and
- Youth employment programs (for hiring recent graduates to innovative projects in research, development and the commercialization of technologies). (National Research Council Canada b, 2016)

Natural Sciences & Engineering Research Council of Canada (NSERC)

Partner type and focus: Funding and support for research and development for Current Operations and Next Generation Mines and Mills.

NSERC's role is to make investments in people, discovery and innovation to increase Canada's scientific and technological capabilities for the benefit of all Canadians. NSERC invests in people by supporting postsecondary students and postdoctoral fellows in their advanced studies. They promote discovery by funding research conducted by postsecondary professors and foster innovation by encouraging Canadian companies to participate and invest in postsecondary research and training.

Over the last 10 years, NSERC has invested more than \$7 billion in basic research, projects involving partnerships between postsecondary institutions and industry, and the training of Canada's next generation of scientists and engineers. (Natural Science and Engineering Research Council of Canada, 2016) In 2014-2015, NSERC invested \$31.7 million in Saskatchewan, including support for Dr. James Hendry as an Industrial Research Chair in Environmental and Aqueous Geochemistry – a position also supported by IMII members the University of Saskatchewan, Cameco Corporation and PotashCorp.

NSERC offers a wide range of funding programs related to both the E&T and R&D interests of the minerals industry innovation ecosystem, including:

- NSERC's PromoScience Program offers financial support for organizations working with young Canadians to promote an understanding of science and engineering (including mathematics and technology).
- The [Chairs for Women in Science and Engineering Program](#) (CWSE) was launched in 1996. Its goal is to increase the participation of women in science and engineering, and to provide role models for women active in, and considering, careers in these fields. The program is regionally based, with one Chair for each of the Atlantic, Quebec, Ontario, Prairie, and British Columbia/Yukon regions.
- The Aboriginal Ambassadors in the Natural Sciences and Engineering Supplement (AANSE) Program promotes interest and participation in natural sciences and engineering, through the visits of Aboriginal students and fellows to Aboriginal communities and schools.
- Experience Awards (**previously Industrial Undergraduate Student Research Awards [IUSRA]**) offer companies access to talented natural sciences and engineering undergraduate students for a work term. This cost-shared program allows students to address company-specific R&D challenges while gaining valuable industrial experience. Experience Awards also let companies identify potential future full-time employees.
- The Collaborative Research and Training Experience (CREATE) Program supports the training of teams of highly qualified students and postdoctoral fellows from Canada and abroad through the development of innovative training programs that:
 - encourage collaborative and integrative approaches, and address significant scientific challenges associated with Canada's research priorities; and
 - facilitate the transition of new researchers from trainees to productive employees in the Canadian workforce.
- The Postdoctoral Fellowships (PDF) Program provides support to a core of the most promising researchers at a pivotal time in their careers. The fellowships are also intended to secure a supply of highly qualified Canadians with leading edge scientific and research skills for Canadian industry, government and universities.
- The Discovery Grants Program supports ongoing programs of research (with long-term goals) rather than a single short-term project or collection of projects. These grants recognize the creativity and innovation that are at the heart of all research advances. Discovery Grants are considered 'grants in aid' of research as they provide long term operating funds to support the costs of a research program.
- Research Tools and Instruments (RTI) grants foster and enhance the discovery, innovation and training capability of university researchers in the natural sciences and engineering by supporting the purchase of research equipment.
- Applied Research Tools and Instruments (ARTI) Grants to support the purchase of applied research equipment and installations to foster and enhance the ability of colleges to undertake applied research, innovation and training in collaboration with local companies.

- Connect Grants provide targeted financial support to encourage post-secondary researchers at universities and/or colleges to connect with industry and other knowledge end-user communities in order to form new partnerships.
- Engage Grants are designed to give innovative companies that operate from a Canadian base access to the unique knowledge, expertise and capabilities available at Canadian universities and colleges (including the Saskatchewan Polytechnic and Universities of Regina and Saskatchewan). These grants are intended to foster the development of new research partnerships by supporting short-term research and development projects aimed at addressing a company-specific problem; that is, a problem related to the company's core competencies or activities.
- Industrial Research Chairs (IRC) are prestigious appointments, intended to assist universities in building on existing strengths to achieve the critical mass required for a major research endeavour in science and engineering of interest to industry; and/or assist in the development of research efforts in fields that have not yet been developed in Canadian universities but for which there is an important industrial need.
- Industrial Research Chairs for Colleges Grants. These grants support the establishment of applied research leaders and promote their role as catalysts in the advancement of business-focused applied research programs at colleges. The result will be the development of new, or the significant enhancement of existing, applied research capacity in areas that meet local or regional socio-economic needs.
- College and Community Innovation Program – Applied Research and Development (ARD) Grants support well-defined applied research and development projects undertaken by college researchers with their private-sector partners. Direct project costs are shared by the company partner(s) and NSERC. Projects may range from one year to three years in duration.
- College and Community Innovation Program – Innovation Enhancement (IE) Grants to increase innovation at the community and/or regional level by enabling Canadian colleges to increase their capacity to work with local companies, particularly small and medium-sized enterprises (SMEs). They support applied research and collaborations that facilitate commercialization, as well as technology transfer, adaptation and adoption of new technologies.
- Idea to Innovation (I2I) Grants to accelerate the pre-competitive development of promising technology originating from the university and college sector and promote its transfer to a new or established Canadian company. The I2I Grants provide funding to college and university faculty members to support research and development projects with recognized technology transfer potential.
- The Collaborative Research and Development (CRD) Grants are intended to give companies that operate from a Canadian base access to the unique knowledge, expertise, and educational resources available at Canadian postsecondary institutions and to train students in essential technical skills required by industry.
 - CRD Grants support well-defined projects undertaken by university researchers and their private-sector partners. Direct project costs are shared by the industrial partner(s) and NSERC. Projects may range from one year to five years in duration, but most awards are for two or three years.

- CRD projects can be at any point in the research and development (R&D) spectrum in the domains of the natural sciences and engineering that is consistent with the university's research, training, and technology transfer mandate.

IMII has, on behalf of its industry members and with its university partners, focused on Collaborative Research and Development Grants over its first five years. In 2016 it reached out to NSERC with respect to both Connect and Engage grants. Its members have, independent of the IMII, partnered with NSERC on Industrial Research Chairs and Engage Grants. Our post-secondary partners have extensive experience with several NSERC programs.

Sustainable Development Technology Canada (SDTC)

Partner type and focus: Funding and support for early stage commercialization of clean technologies for Current Operations and Next Generation Mines and Mills.

Sustainable Development Technology Canada funds Canadian cleantech projects. Cleantech refers to technologies that improve business performance while using resources more responsibly, and that reduce or eliminate negative environmental impact.

SDTC has had different funds to support innovative, Canadian cleantech projects through development and demonstration. One, the [SD Tech Fund™](#) supports projects that address climate change, air quality, clean water and clean soil, remains available to the minerals industry. The SD Tech Fund is designed to support the development and pre-commercial demonstration of [cleantech solutions](#) in current priority areas including:

- Responsible natural resource development, including technologies for the sustainable development of mineral resources, including those that increase productivity and reduce energy consumption, and those that minimize land disturbance and waste production.
- Carbon-free power generation and distribution;
- Energy efficiency for industry and communities; and
- Next generation technologies with longer-term benefits for Canada.

STDC has funded mining-related projects in the past (e.g., development of a hybrid underground loader with Mining Technologies International in Ontario, a scalable nickel/copper waste reclamation solution with Minsense Technologies in British Columbia), though none in Saskatchewan. (Sustainable Development Technology Canada, 2016)

Western Economic Diversification Canada (WD)

Partner type and focus: Funding and support for research and early stage commercialization for Current Operations and Next Generation Mines and Mills

In the IMII's first five years, WD provided funding for both an E&T project (Northlands College School of Mines) and R&D project (Mining Materials Research Cluster). Going forward, IMII greater opportunity to partner with WD on RD&D as the organizations share a common commitment to innovation (which they define as the process of transforming knowledge into new products, processes and services which, in turn, generate new economic benefits), and the

importance of an innovation ecosystem. For innovation to succeed, WD believes a complete system must be available that supports the movement of a new idea from initial concept, through research and development, to a ready-for-market product. For WD, a highly developed innovation system, or "cluster", is focused on a specific area of strength and includes:

- Universities, research facilities, industry, government labs, and other "knowledge infrastructure" that develop new technologies and a skilled workforce;
- Early stage venture capital financing to help bring technologies to markets;
- Industry associations and other organizations that link the players in the innovation system (such as the IMII);
- Firms capable of developing and adopting new technologies, and that are connected to local and global market; and
- A business environment that fosters innovation.

WD supports the creation and growth of knowledge-based clusters in new economy sectors that contribute to an increase in knowledge-driven and value-added economic activities. In partnership with other levels of government and other partners, WD can make strategic investments to:

- Support technology commercialization and adoption initiatives;
- Enhance technology skills development;
- Support applied research and development;
- Strengthen knowledge infrastructure;
- Increase community innovation; and
- Create linkages among members of the innovation system.

WD is supporting the growth of technology clusters in several key sectors, including two of interest to the minerals industry:

- Information and Communications Technology – new media, wireless technology, telehealth and geomatics; and
- Other Technologies – synchrotron, environmental technologies, composite materials and micro/nanotechnology.

WD offers two main funding programs relevant to the mineral industry's innovation ecosystem:

- [Western Diversification Program](#) (WDP) – the main program through which WD invests in projects that support strategic outcomes related to innovation, business development, community economic development and policy, advocacy and coordination; and
- [Western Innovation Initiative](#) (WINN) – a \$100 million five-year federal Initiative that offers repayable contributions for small- and medium-sized enterprises (SMEs) with operations in Western Canada to move their new and innovative technologies from the later stages of research and development to the marketplace. (Government of Canada, 2016)

5.2 Accelerators & Incubators

At their core, accelerators and incubators are start-up assistance organizations for business. Both can be broadly characterized as groups of experienced businesspersons who provide nascent firms with advice, business services, financing on occasion and often office space to help them develop and launch their business with greater success than if the start-ups had not received assistance. Their role in an innovation ecosystem is to accelerate innovation by helping to commercialize university and sponsored research, or to help local/regional economic development. As such, they are often programs that help entrepreneurs bring their technologies, ideas, or products into the marketplace and ideally lead entrepreneurs to develop viable businesses. (C.S. Dempwolf, 2014)

IMII's interest in accelerators and incubators is largely from the perspective of wanting to commercialize university and sponsored research. However, it is recognized that local/regional or even national economic development is of strong interest to its provincial and federal funding partners, and other others in the mineral industry's innovation ecosystem.

Dempwolf et al (2014) have identified six types of start-up organizations. They are briefly described here so as to allow for their identification in the Saskatchewan minerals industry innovation ecosystem:

- Incubators – a business support organization (or process) that helps launch start-up and fledgling companies by providing entrepreneurs with an array of needed resources and services, including management guidance, technical assistance and consultation tailored to young, growing companies. Incubators may also give clients access to appropriate rental space and flexible leases, shared basic business services and equipment, technology support services, and assistance in obtaining the financing necessary for company growth;
- Venture development organizations – a more recent model to support regional innovation, either as a public or non-profit organization that contributes to economic development by providing a portfolio of services, including assisting in the creation of high-growth companies, providing expert business assistance to those companies, facilitating or making direct financial investments in companies, and accelerating the commercialization of technology;
- University accelerators – educational non-profits that accelerate the development of student entrepreneurs in the US – note university accelerators in Canada have a broader mandate, including aspects of “proof-of-concept centres”;
- Proof-of-concept centres – accelerate the commercialization of innovations developed by university faculty and staff, and help move these innovations into the marketplace, by offering a collection of services to improve the dissemination and commercialization of new knowledge from universities in order to spur economic development and job growth;
- Corporate accelerators – engage in the provision of seed capital and various combinations of mentoring, technical assistance, networking and facilities to entrepreneurs, inventors and start-up teams to advance certain goals of the corporate or institutional parent; and

- Innovation accelerators – stand-alone, for-profit ventures in the business of: identifying cohorts of promising start-up companies with rapid, high-growth potential; making seed-stage investments in those companies in exchange for equity; engaging in innovation-acceleration activities with these companies to help them obtain next-stage funding; and cashing out for a profit when these companies are acquired or have successful IPOs. (C.S. Dempwolf, 2014)

Using the above working descriptions, business incubators in Saskatchewan include:

- **Ideas Inc.** – a Saskatoon-based business incubator which offers office space, coaching and mentorship. <http://ideasyxe.com/>

Nationally, there is **Futurpreneur Canada**, a non-profit organization that provides financing, mentoring and support tools to aspiring business owners aged 18-39.

<http://www.futurpreneur.ca/en/about/>

Venture development corporations include:

- **Economic Development Regina Inc. (EDR)** – EDR is the lead economic development agency for the City of Regina and region. EDR provides leadership to the community with specific accountability for the following core functions: support industry growth and diversification through retention, development and attraction of industry and tourism; and find innovative ways to promote sustainable growth while effectively addressing the challenges associated with it. EDR identifies the mining supply chain as one of their key industry sectors. <http://www.economicdevelopmentregina.com/key-industry-sectors/sector-strategy/mining-supply-chain>
- **Saskatoon and Region Economic Development Authority (SREDA)** – SREDA's role is to help grow the local economy by providing programs and services in the areas of business attraction, retention and expansion; entrepreneurship support; regional planning; economic forecasting and analysis; and marketing the Saskatoon Region. <http://sreda.com/about-sreda/goals-and-strategy/>
- **Women Entrepreneurs of Saskatchewan Inc.** – a non-profit membership organization which works with women who are considering starting a business, purchasing a business, or operating an existing business. The priority is to help women throughout Saskatchewan achieve their entrepreneurial goals. It offers programs and services including business advisory and support services, start-up and expansion lending, networking and mentoring opportunities, and business development seminars which focus on entrepreneurial skill development. <https://www.womenentrepreneurs.sk.ca/>

University accelerators include:

- **Industry Liaison Office** at the University of Saskatchewan – The Industry Liaison Office is responsible for the commercialization of research and knowledge developed by the University's researchers, faculty, staff and graduate students. Its focus is to foster and develop collaborative work environments among researchers, industry partners and funding agencies. <http://research.usask.ca/research-process/commercialization.php>

The University of Regina has a research office (<http://www.uregina.ca/research/research-office.html>) which provides comprehensive services for researchers and research partners but does not fit the working definition of an accelerator.

IMI was unable to identify any formal corporate or innovation accelerators in the province, and particularly none that are oriented to the minerals industry, and this suggests a gap exists in the industry's innovation ecosystem that needs to be addressed.

The Wilson Centre at the University of Saskatchewan has identified a combination incubator/accelerator program available through **Next 36**. The Next 36 is a program that accelerates the growth of Canada's most talented young entrepreneurs by providing mentorship, capital, and unparalleled founder development. For eight months, selected young entrepreneurs are mentored by successful Canadian entrepreneurs and business leaders, taught by some of the world's top faculty, and seek funding from top investors to build their venture. <https://www.nextcanada.com/next-36#what-we-do>

There is a venture-capital organization in the province – the **Saskatchewan Capital Network**. The Saskatchewan Capital Network is a member-based, non-profit organization of Saskatchewan angel investors. They have investor members interested in seeing good investment opportunities in startup and growth-focused entrepreneurial companies, particularly those based in Saskatchewan. Through presentation and networking events, Saskatchewan Capital Network facilitates the introduction of investment-ready entrepreneurial companies to potential investors. Events are held in Saskatoon and Regina based on deal flow – typically every two to three months.

Saskatchewan Capital Network investor members are interested in technology-based companies with a proprietary product or service, as well as companies in other industries with high growth potential. <http://www.saskcapitalnetwork.com/>

While neither an accelerator or incubator, **Innovation Place** is one of North America's most successful university related technology parks, with facilities in Saskatoon, Regina and Prince Albert. Innovation Place is focused on assisting new technology companies, facilitating growth of existing technology companies and contributing to the technology sector community. The campuses provide a unique physical, technical, social and business environment that supports the needs of the technology sector and encourages innovation, collaboration and entrepreneurship. Innovation Place also offers co-working space on their Saskatoon campus. <http://innovationplace.com/about.php>

There are also several support organizations, such as Innovation Saskatchewan and local Chambers of Commerce, that technology developers and entrepreneurs may approach as a starting point for exploring sources of advice and/or funding. Federal funding agencies, such as NRC-IRAP and WD, can also be considered support organizations for the minerals industry innovation ecosystem.

6. Path to Commercialization

To support the development of the minerals industry's innovation ecosystem, IMII has presented a path to commercialization to its potential partners. This path begins with the generation of ideas and concludes with innovations being put into use:

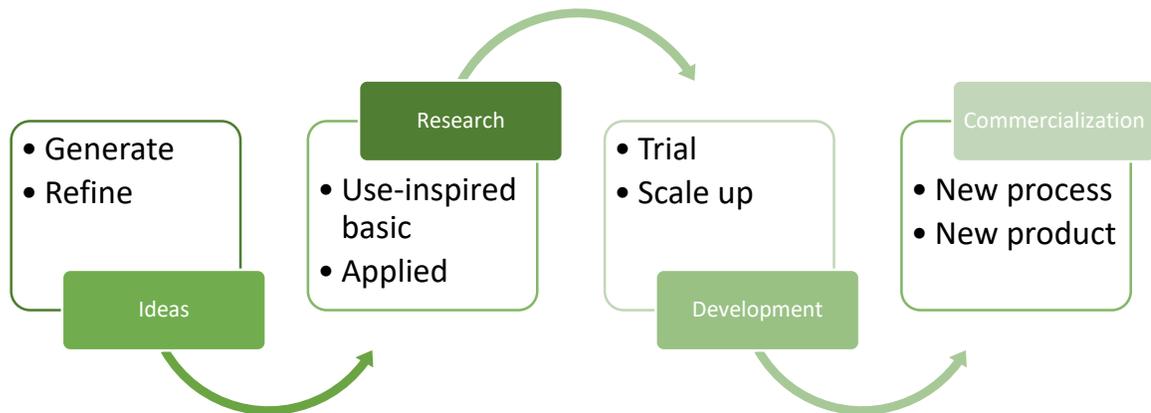


Figure 6: Path to Commercialization

Partners in idea generation include:

- Mining companies (as creators of demand for innovation);
- Service & technology suppliers;
- Post-secondary institutions;
- Research organizations; and
- Funders.

At this initial stage, problems are discovered and potential paths to solutions are identified.

Partners at the research stage include:

- Mining companies (for oversight and/or funding);
- Universities;
- Saskatchewan Polytechnic;
- Research organizations; and
- Research funding agencies.

In this stage, experimentation helps to set the path and talent is developed in support.

Partners at the development stage include:

- Mining companies (for input/testing);
- Saskatchewan Polytechnic;
- Saskatchewan Research Council;
- Service & technology suppliers;

- Business advisors; and
- Development funding agencies.

Product development (e.g., prototype) takes hold in this stage and the business model for commercialization is also developed.

Partners in commercialization include:

- Incubators and accelerators;
- Angel investors and venture capitalists;
- Other funders;
- Service & technology suppliers; and
- Mining companies (as adopters/purchasers).

Product validation occurs (e.g., pilot testing and launch) and business, revenue and distribution models are defined and validated. With the path to commercialization complete, innovations developed by the innovation ecosystem can be put to use by IMII member companies.

For 2017 to 2019, IMII has re-aligned its project funding to support the path to commercialization with three models:

- Exploring Innovations for idea generation – seeding research into potentially transformative solutions to longer-term needs of future mines;
- Developing Innovations for research & development – applied research & development into emerging innovations or adaption of innovations from other industries for next generation mines & mills; and
- Operationalizing Innovations for early state commercialization – demonstration & deployment of innovations focused on existing operations.

The above generally aligns with the development phases used in the mining industry:

- Use-inspired basic research/concept development/lab work;
- Applied research/first prototype/pilot; and
- Demonstrations and first of its kind deployment.

Funding for full-scale commercialization is outside of IMII's mandate. However, as some funding partners are interested in the use of technology readiness levels (TRLs) as the basis for their participation in the minerals sector's innovation ecosystem, IMII has adapted TRLs and mapped them to its three funding models. Further details and definitions as they may be applied to the minerals sector can be found in Appendix 4.

7. Conclusions

IMII, on behalf of its members, aims to develop and nurture an innovation ecosystem for the minerals industry in Saskatchewan by helping research & development results to become innovations bringing economic, environmental or social benefits to the province. The minerals industry is at the centre of this effort as it both creates the demand for innovations and provides the venue for their adoption and use.

The minerals industry is also at the centre of the innovation ecosystem because it is important to improving innovation performance to organize such ecosystems around competitive advantage. Natural competitive advantage leverages resource endowments and heritage, such as potash and uranium extraction in Saskatchewan. (Grant, 2015)

This document is a “next step” in developing an innovation ecosystem for Saskatchewan’s minerals industry. The first several steps have already been taken over the course of the past 50 years as Saskatchewan’s world-class potash and uranium resources were explored, developed and brought into production with innovations large and small. Innovations have allowed these resources to be extracted – from the development of the combination of ground freezing with the layering of “Blairmore Rings” to create water-tight shafts for underground potash mines in the 1960s, to the deployment of the jet boring mining system to produce uranium from the Cigar Lake uranium deposit starting in 2014, and the industry will continue to require innovations in order to be sustainable.

As such, more work is required to ensure that each component documented in this report works in an integrative way, that research and development can contribute to business innovation, and that funding and support agencies do their best to help bring innovations to market, and particularly those being pulled out of the ecosystem by industry need.

Work will also be required to fill in the gaps that exist in the province – such as the apparent shortage of relevant accelerators and incubators (and possibly venture capital and angel investors as well). Expertise gaps may also exist within the province’s post-secondary institutions or other research organizations to meet industry’s needs, and as such the innovation ecosystem may well have to be extended nationally or even internationally, given the multi-national enterprises that make up IMII’s industry members.

An innovation ecosystem describes, among things, a cluster – a geographical concentration of a group of suppliers and customers and skilled people and specialists, that provides a centre or environment for innovation. IMII will support and welcome those already in the minerals industry innovation ecosystem, and those who could help close the gaps, through collaboration, and by coordinating and managing mechanisms to achieve innovations that matter to mining.

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9. Appendices

9.1 Appendix 1 – List of IMII Members (December 2016)

IMII Membership List

Current membership consists of six companies in Category A and one company in Category C.

*Indicates members of the IMII Board of Directors.

Industry – “Company A” Category

- Agrium*
- BHP Billiton*
- Cameco Corporation*
- K+S Potash Canada GP*
- Mosaic Potash*
- Potash Corp*

Industry – “Company B” Category

No members at this time

Industry – “Company C” Category

- North Rim Exploration Ltd.*

Government of Saskatchewan

- Innovation Saskatchewan*
- Ministry of Advanced Education*

Post-Secondary Educational Institutions, Research Providers, Associations, and Others

- Canadian Light Source
- Carlton Trail College
- Cumberland College
- First Nations University of Canada
- Genome Prairie
- North West Regional College
- Northlands College
- Parkland College*
- Prairie Agricultural Machinery Institute
- Saskatchewan Indian Institute of Technologies
- Saskatchewan Mining Association*
- Saskatchewan Polytechnic*
- Saskatchewan Research Council
- University of Regina*
- University of Saskatchewan*

Associates

- Saskatchewan Industrial & Mining Suppliers Association Inc.
- Saskatoon Regional Economic Development Authority

9.2 Appendix 2 – Mapping of Saskatchewan Polytechnic Programs to Selected Mining Industry Occupations – 2016



CREDIT PROGRAM MATRIX

<i>PRODUCTION OCCUPATIONS</i>	<i>SASK POLYTECH PROGRAMS</i>	<i>LOCATION OFFERED</i>
Underground production & development miners	Underground Mining Core (C), Underground Mining Raise Boring (C), Underground Mining Shaft Operations (C)	Northlands College, TBD
Transport truck drivers		
Heavy equipment operators (except crane)	Heavy Equipment Operator (AC)	Subject to needs assessment
Heavy-duty equipment mechanics	Agriculture Equipment Technician (C)	Saskatoon
	Heavy Equipment & Truck & Transport Technician (C)	Saskatoon
	Heavy Equipment & Truck & Transport (AC)	Subject to needs assessment
	Multi-Mechanical Trades (C)	Subject to needs assessment
	Tri-Trades Heavy Equipment, Truck & Transport, Agricultural Machinery Technician (AC)	Subject to needs assessment
	Tri-Trades Heavy Equipment, Truck & Transport, Automotive Service Technician (AC)	Subject to needs assessment
Mine labourers	Underground Mining Core (C), Underground Mining Raise Boring (C), Underground Mining Shaft Operations (C)	Northlands College, TBD
Material handlers	Underground Mining (C)	Northlands College
	Mining Engineering Technology (D)	Saskatoon
Construction trades helpers & labourers	Carpentry (C)	Moose Jaw, Prince Albert
	Electrician (AC)	Moose Jaw, Prince Albert, Saskatoon
Underground mine service & support workers	Underground Mining, Raise Bore, Shaft Operations, Radiation Technician (C)	Northlands College, TBD
Machine operators, mineral & metal processing	Machinists (C)	Regina, Saskatoon
Central control & process operators, mineral & metal processing	Instrumentation Engineering Technology (D),	Moose Jaw
	Chemical Technology	Saskatoon
Labourers in mineral & metal processing	Underground Mining (C),	Northlands
	Mining Engineering Technology (D)	Saskatoon



CREDIT PROGRAM MATRIX

Drillers & blasters – surface mining, quarrying & construction	Underground Mining (C) Mining Engineering Technology (D)	Northlands Saskatoon
Other trades helpers & labourers	Plumbing, Welding, Carpentry, Electrical, Industrial Mechanics, Machinists	Various locations within Sask Polytech
DESIGNATED TRADES	SASK POLYTECH PROGRAMS	LOCATION OFFERED
Carpenters	Carpentry (C) (AC)	Moose Jaw, Prince Albert
Plumbers	Plumbing & Pipefitting (AC)	Saskatoon
Crane operators		
Steamfitters, pipefitters & sprinkler system installers	Plumbing and Pipefitting (AC)	Saskatoon
Power engineers & power systems operators	Power Engineering Technician (C) Power Engineering Technology (D)	Saskatoon Saskatoon
Construction millwrights and industrial mechanics	Industrial Mechanics (AC)	Prince Albert, Saskatoon
Industrial electricians	Electrical (C)	Moose Jaw, Prince Albert
Welders & related machine operators	Fabricator – Welder (C) Production Line Welding (AC) Welding (AC) (C) Machinists (C)	Saskatoon, Prince Albert, Regina, Moose Jaw Saskatoon, Moose Jaw Moose Jaw, Prince Albert, Saskatoon, Regina Regina, Saskatoon
	SASK POLYTECH PROGRAMS	LOCATION OFFERED
Mechanical engineers		
Electrical & electronics engineers		
Mining engineers		
Biologists & related scientists		
Civil engineers		
Other professional engineers, n.e.c.		
Geological engineers		



CREDIT PROGRAM MATRIX

Chemical engineers		
Metallurgical & materials engineers		
Industrial & manufacturing engineers		
Environmental engineers		
Other professional occupations in physical sciences		
Chemists		
HUMAN RESOURCES & FINANCIAL OCCUPATIONS	SASK POLYTECH PROGRAMS	LOCATION OFFERED
Financial auditors & accountants	Accounting (C)	Regina, Saskatoon & distance
	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
Human resources managers	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Human Resources Management (C)	Distance
Financial & investment analysts	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
Financial managers	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
Human resources professionals	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Human Resources Management (C)	Distance
SUPPORT WORKERS	SASK POLYTECH PROGRAMS	LOCATION OFFERED
Inspector in public & environmental health & occupational health & safety	Occupational Health and Safety (D)	Saskatoon
Administrative assistants	Office Administration (C)	Moose Jaw, Prince Albert, Regina, Distance
Non-destructive testers & inspection technicians		
Cooks	Culinary Arts (D)	Saskatoon
	Food Service Cook (AC)	Moose Jaw, Prince Albert
	Institutional Cooking (AC)	Prince Albert



CREDIT PROGRAM MATRIX

	Professional Cooking (C)	Moose Jaw, Prince Albert
General office support workers	Office Administration (C)	Moose Jaw, Prince Albert, Regina, Distance
Dispatchers	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Human Resources Management (C)	Distance
Production logistics coordinator		
Inspectors & testers, mineral & metal processing		
Engineering inspectors & regulatory officers		
Transportation route & crew schedulers	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Human Resources Management (C)	Distance
	Commercial Pilot (D)	Saskatoon
Construction estimators	Applied Project Management (AC)	Distance learning
	Architectural Technologies (D)	Moose Jaw
TECHNICAL OCCUPATIONS	SASK POLYTECH PROGRAMS	LOCATION
Drafting technologists & technicians	Architectural Technologies (D)	Moose Jaw
	Engineering Design & Drafting Technology (D)	Moose Jaw
	Mechanical Engineering Technology (D)	Saskatoon
Civil engineering technologists & technicians	Civil Engineering Technology (D)	Moose Jaw
	Environmental Engineering Technology (D)	Moose Jaw
	Civil Technician (C)	Moose Jaw
Geological & mineral technologists & technicians	Mining Engineering Technology (D)	Saskatoon
Electrical & electronics engineering technologists & technicians	Computer Engineering Technology (D)	Moose Jaw
	Electrical Engineering Technology (D)	Moose Jaw
	Electronic Systems Engineering Technology (D)	Saskatoon



CREDIT PROGRAM MATRIX

Land surveyors	Geomatics & Surveying Engineering Technology (D)	Moose Jaw
	GIS Technician (C)	Prince Albert
Industrial instrument technicians & mechanics	Instrumentation Engineering Technology (D)	Moose Jaw
Chemical technologists & technicians	Chemical Technology (D)	Saskatoon
Land survey technologists & technicians	Geomatics & Surveying Engineering Technology (D)	Moose Jaw
	Civil Technician (C)	Moose Jaw
Mechanical engineering technologists & technicians	CAD/CAM Engineering Technology (D)	Saskatoon
	Mechanical Engineering Technology (D)	Saskatoon
Information systems analysts & consultants	Business Information Systems (D)	Moose Jaw
	Computer Engineering Technology (D)	Moose Jaw
	Computer Networking Technician (C)	Regina
	Computer Systems Technology (D)	Saskatoon, distance
Industrial engineering & manufacturing technologists & technicians	Instrumentation Engineering Technology (D)	Moose Jaw
	Innovative Manufacturing (D)	Regina
Technical occupations in geomatics & meteorology	Geomatics & Surveying Engineering Technology (D)	Moose Jaw
	GIS Technician (C)	Prince Albert
Biological technologists & technicians	Bio Science Technology (D)	Saskatoon
	Integrated Resource Management (D)	Prince Albert
<i>SUPERVISORS, COORDINATORS & FOREMEN</i>	SASK POLYTECH PROGRAMS	LOCATION
Supervisors, mining & quarrying	Leadership Skills (AC)	Distance
	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Human Resources Management (C)	Distance
	Mining Engineering Technology (D)	Saskatoon



CREDIT PROGRAM MATRIX

	Business Management (PGC)	Moose Jaw
Managers in natural resources production	Resource and Environmental Law (D)	Prince Albert
	Integrated Resource Management (D)	Prince Albert
	Leadership Skills (AC)	Distance
	Human Resources Management (C)	Distance
	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
Construction managers	Business Management (PGC)	Moose Jaw
	Carpentry (C) (AC)	Moose Jaw, Prince Albert
	Leadership Skills (AC)	Distance
	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Human Resources Management (C)	Distance
	Environmental Engineering Technology (D)	Moose Jaw
	Geomatics & Surveying Engineering Technology (D)	Moose Jaw
Contractors & supervisors, pipefitting trades	Business Management (PGC)	Moose Jaw
	Human Resources Management (C)	Distance
	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Leadership Skills (AC)	Distance
Engineering managers	Mining Engineering Technology (D)	Saskatoon
	Human Resources Management (C)	Distance
	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Leadership Skills (AC)	Distance
	Business Management (PGC)	Moose Jaw



CREDIT PROGRAM MATRIX

Supervisors, mineral & metal processing	Mining Engineering Technology (D)	Saskatoon
	Business Management (PGC)	Moose Jaw
	Human Resources Management (C)	Distance
	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Leadership Skills (AC)	Distance
Contractors & supervisors, mechanic trades	Business Management (PGC)	Moose Jaw
	Business (D) (C)	Saskatoon, Moose Jaw, Prince Albert & distance
	Human Resources Management (C)	Distance
	Leadership Skills (AC)	Distance

* Subject to needs assessment - Many of these courses will be delivered by Sask Polytech through the regional colleges.

Credit Program Credentials

Credential	Credit Units (minimum) 15 hours instruction = 1 credit unit	Length
(AC) Applied Certificate	16 to 40	240 to 600 hours
(C) Certificate	44 to 72	660 to 1080 hours
(D) Diploma	100 to 135	1500 to 2025 hours
(BD) Bachelor Degree	120 to 130	Typically 8 semesters or 4 years
(PGC) Post Graduate Degree (with a Bachelor Degree)	30 to 45	450 to 675 hours

In keeping with Sask Polytech’s approved Academic Model and policy for a creation of credentials, a certificate, diploma and degree are established and defined by the credit number and program hour length as identified above.

9.3 Appendix 3 – SIMSA Regular Members List

SIMSA Members - as of November 21
3Twenty Modular
Aggreko
AkzoNobel Coatings Ltd. (Canada)
AGI Envirotank
A.H. McElroy Sales and Service - Associate
Air Unlimited Inc.
AJ Machine & Manufacturing Ltd. - Founding Member
Allan Construction
Almita Piling Saskatoon
Andritz Separation
Applied Industrial Technologies
Armour Steel Fabricators
ATS Traffic
Bit Service Company Ltd.
Black and McDonald
Brandt Engineered Products Ltd. - Founding Member (memberships now due)
Business Development Bank of Canada - Associate
Canada North Environmental Services
Cherry Insurance - Associate
Commercial Sandblasting & Painting
Continental Mine & Industrial Supply Ltd. - Founding Member (membership now due)
Croatia Industries Ltd. - Founding Member
CSA Group - Associate
CWA Engineers Inc. - Associate
Deca Industries - Founding Member
Double Diamond Industrial Structures
DynaIndustrial
Engcomp Engineering & Computing Professionals Inc.
Flodraulic Controls Ltd.
Fortis Mining Engineering & Manufacturing
Flyer Electric LP
GMR Electric Motors Ltd. - Founding Member
Goodman Steel LTd.
Graham
Green Earth Environmental Solutions - Founding Member
Howatt Consulting Ltd.
Industrial Machine & Mfg. Inc. - Founding Member
Inproheat Industries
IWL Steel Fabricators
JNE Welding - Founding Member
Kelly Panteluk Construction Ltd.

Kristian Electric Ltd.
Lynco Eagle LP
MINETEC
National Bank of Canada - Associate
North Fringe Industrial
Northern Resource Trucking LP
Northwest Polymers, Inc
Orbis Engineering
PAMI - Associate
Park Derochie Coatings (Saskatchewan) Ltd.
PFM Capital Inc. - Associate
PME Inc.
Points Athabasca Contracting Limited Partnership
Prairie Crane
Projectline Solutions Inc.
Precision Electro-Mechanical Ltd.
Procon Group of Companies
RAM Industries
Redhead Equipment
RobWel Constructors Limited Partnership
Rockford Engineering Works Ltd
Ross Machine Shop Ltd.
Safety Association of Saskatchewan Manufacturers - Associate
SaskAlta Safety Corp.
Saskatchewan Ministry of the Economy - Associate
Saskatoon Metal Mfg.
Sherwin Williams Paints - Associate
Skyhigh
Saskatchewan Research Council (SRC) - Associate
Supreme Steel
Syl's Mechanical Company Ltd.
The Store Anything Fast & Easy Co.
Venables Machine Works Limited
Wainbee - Associate
Weldfab Steel Fabricators
Westlund
Whitecap
Wolseley Industrial Canada Inc.
Xtended Hydraulics & Machine Inc.
Xylem Water Solutions

9.4 Appendix 4 – Technology Readiness Levels and IMII RD&D Project Funding

Exploring Innovations

Level 0: **Use-inspired/Oriented basic research.** Work carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognized or expected current or future problems or possibilities.

Developing Innovations

Level 1: **Basic principles of concept are observed and reported.** At this level scientific research begins to translated into applied research and development. Activities might include paper studies of a technology's basic properties.

Level 2: **Technology concept and/or application formulated.** At this level invention begins. Once the basic principles are observed, practical applications can be invented. Activities are limited to analytical studies.

Level 3: **Analytical and experimental critical function.** At this level active research and development is initiated. Activities might include components that are not yet integrated or representative.

Level 4: **Component and/or validation in a laboratory environment.** At this level basic technological components are integrated to establish that they will work together. Activities include integration of "ad hoc" hardware in the laboratory.

Level 5: **Component and/or validation in a simulated environment.** At this level the basic technological components are integrated for testing in a simulated environment. Activities include laboratory integration of components.

Level 6: **System/subsystem model or prototype demonstration in a simulated environment.** At this level a model or prototype is developed that represents a near desired configuration. Activities include testing in a simulated operational environment or laboratory. Proof of concept demonstrated.

Operationalizing Innovations

Level 7: **Prototype ready for demonstration in an appropriate operational environment.** At this level the prototype should be at planned operational level and is ready for demonstration of an actual prototype in an operational environment. Activities include prototype field testing.

Level 8: **Actual technology completed and qualified through tests and demonstrations.** At this level the technology has been proven to work in its final form and under expected conditions. Activities include developmental testing and evaluation of whether it will meet operational requirements.

Level 9: **Actual technology proven through successful deployment in an operational setting.** At this level there is actual application of the technology in its final form and under real-life conditions, such as those encountered in operational test and evaluations. Activities include using the innovation under operational conditions.



“Innovations that Matter to Mining”

International Minerals Innovation Institute
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