Mining Industry Engagement Workshop

Summary Report

December 14, 2017

Canada

NSERC CRSNG

CIFAR CANADIAN INSTITUTE FOR ADVANCED RESEARCH | ICRA L'INSTITUT CANADIEN DE RECHERCHES AVANCÉES

Executive Summary

The National Research Council of Canada (NRC), in collaboration with the Natural Sciences and Engineering Research Council of Canada (NSERC), convened a half-day workshop on December 14, 2017 at the MaRS Discovery District. Goals of the workshop were to provide an overview of quantum technologies to mining industry representatives, strengthen relationships amongst industry and researchers, and to gain insights in order to build on Canada's strengths in quantum science and technology.

Workshop participants from across the mining innovation value chain articulated three broad needs across the mining lifecycle where innovation could fundamentally change the cost curve and/or the way the sector operates:

1. Improve efficiency and effectiveness of exploration and development
2. Optimize operations and reduce environmental footprint
3. Reduce long-term liabilities and closure costs

Quantum researchers explained that quantum technology is a disruptive technology that offers capabilities not currently possessed by conventional technology. During the discussion, members of the quantum research community identified a number of quantum technologies that could potentially be further developed and deployed to address the needs of the mining industry (see Section 3).

These include, for example:

- using quantum gravity sensors to detect underground gravity differences which can provide composition data during exploration;
- using quantum magnetic sensors for driverless vehicles to improve navigation and enable continuous operation; and
- using geophotonics for real time feedback on process minerology, as well as applying multi-purpose distributed optical sensors for monitoring of excavation sites and rock mechanics.

Post-event surveys showed that participants found the workshop to be very useful and expressed a high level of interest in furthering discussions and collaboration in this sector. Through this initial engagement, participants were able to identify a number of areas where quantum technologies may be able to address fundamental mining industry needs. As a direct result of the workshop, several projects have already been initiated to further explore the potential application of quantum technologies to this sector. This underscores the value of bringing together the research community and industry representatives to catalyze this type of collaboration.

Next steps include continuing to develop relationships and collaboration ideas generated during the workshop. The organizers and community will also continue to maximize strategic input in the quantum technology space.

NR16-235/2018E-PDF
ISBN 978-0-660-26970-2 PDF
ISBN 978-0-660-26972-6 PAPER

June 2018
Également disponible en français

1. Workshop Purpose

In April 2017, the Quantum Canada Workshop and Symposium brought together academics, industry and government representatives to explore how Canada can build on its strengths in quantum science. One of the key next steps identified in the discussions was the need for industry-specific workshops. Following up on this key step, the NRC, in collaboration with NSERC, the Canadian Institute for Advanced Research (CIFAR) and the University of Ottawa, held an industry engagement workshop for the mining sector at the MaRS Discovery District in Toronto on December 14, 2017. Thirty-four participants attended the workshop from universities and research organizations, government departments and agencies, and the mining industry.

The objectives of the workshop were to:

- Provide an overview of quantum technologies to relevant mining industry members.
- Further identify and validate key technology challenges for the mining industry.
- Explore 2-3 specific technology applications that address mining industry challenges.
- Build and strengthen the relationship between industry and researchers on quantum technologies.
- Feed into the National Quantum Strategy and advance commitments made at the April Quantum Canada Symposium.

This report provides a succinct synopsis of the mining industry's greatest needs as discussed by participants, as well as potential quantum technology applications to address those needs, and some ideas on how to support and encourage further collaboration.

2. The Mining Industry's Greatest Needs

Workshop participants from across the mining innovation value chain articulated several challenges facing the industry where innovation could fundamentally change the cost curve and/or the way the sector operates. These challenges are presented as three broad needs across the mining lifecycle, with additional detail below.

1. Improve Efficiency and Effectiveness of Exploration and Development

There is tremendous opportunity to change the way the industry conducts exploration and development, which if realized could reduce land disturbance, costs and timelines. The industry is interested in technologies that enable them to more efficiently find and define deposits. This could include more sensitive and selective sensors, as well as technologies that allow industry to make better decisions about ore bodies from fewer data points. In particular, participants expressed interest in technology applications that enable:

- Improved measurement at greater depths
- Improved sensitivity of measurement
- Real time in situ characterization
- Fewer boreholes to be made, for example by allowing the industry to measure laterally from a borehole or between boreholes, and through improved interpolation

2. Optimize Operations and Reduce Environmental Footprint

During the operational phase, mining companies are interested in technologies that enhance their operational efficiency and reduce their environmental footprint (including use of water, energy and land). This could include technologies that provide real-time characterization and monitoring data, as well as improved computation capabilities to support optimized mine planning, remote monitoring, and automation. More specifically, participants expressed interest in technology applications that enable the industry to:

- Move from batch to continuous processing to optimize operations, reduce environmental impact and better inform decision making, including the following specific applications:
  - Improve dynamic characterization (metal/elemental composition and chemical properties) during processing, and comminution
  - Improve recovery and reduce environmental impacts through continuous operation
  - Continuous core scanning
  - Continuous monitoring of water use to support more water re-use and movement towards closed loop operations
- Optimize mine planning and scheduling through improved computation

3. Reduce Long-term Liabilities and Closure Costs

Closure liabilities and costs are a significant challenge for the mining industry. Technologies that can reduce the volume of tailings (and thereby reduce liabilities associated with long-term monitoring and treatment) and improve reclamation are of significant interest to the industry. Specifically, participants expressed interest in technology applications that can:

- Improve the understanding of mine tailings (e.g. evaporative potential) and provide better real time characterization of ore and constituent elements to reduce the volume of mine tailings and associated treatment and disposal costs
- Provide enhanced characterization of existing tailings, potentially enabling re-processing
- Enable continuous monitoring of wastewater effluents and slope/structural stability
- Improve accuracy of predictive modeling for rehabilitation and reclamation scenarios

Important Considerations

When considering potential uptake of new technologies, the mining sector expressed interest in:

- Technologies that can be applied in a dynamic environment (e.g. ore sorting)
- Sensors that are robust, provide consistency / continuity and are affordable and easily deployable
- Technologies that are proven to be at least as good as the current technology (comparative assessment)
- Tools and sensor data that can inform real-time decisions

3. Potential Applications of Quantum Technologies in the Mining Sector

Quantum technology is a disruptive technology that offers capabilities not currently possessed by conventional technology. It includes technologies that may offer significant value to the mining sector including quantum sensing and quantum computing.

Quantum sensors differ from traditional sensors as they can offer higher sensitivity, selectivity, accuracy and speed of use. Quantum computing, although not as developed as quantum sensing, offers the potential for superior computing power to classical counterparts which may enable complex problems to be solved faster and easier (i.e., optimization problems related to mine planning, machine learning algorithms for process diagnostics, and quantum chemistry).

Quantum technology possesses the ability to help address the three broad needs of the mining industry identified in Section 2 (i.e., improving efficiency and effectiveness of exploration and development; optimizing operations and reducing environmental footprints; and reducing liability and closure costs). A few select examples that illustrate this potential include:

- using quantum gravity sensors to detect underground gravity differences which can provide composition data during exploration;
- using quantum magnetic sensors for driverless vehicles to improve navigation and enable continuous operation; and,
- using geophotonics for real time feedback on process minerology, and using optical methods for monitoring rock and soil stresses.

In addition to and including the examples discussed above, members of the quantum research community identified a number of quantum technologies that could potentially be further developed and deployed to address the identified needs of the mining industry.

Table 1: Examples of quantum technology applications that could address the mining industry's needs

Need	Sensor/Computing Application
Finding/Defining Deposits To improve efficiency and effectiveness of exploration and development 	› Gravity/magnetic quantum sensors could be used to find underground deposits without the use of surface penetration/drilling › Quantum technology could be incorporated into wire-line, including: - Magnetic field sensors: valuable for rock type determination - Electric field sensors: can be used at a higher frequency with quantum when looking for rock type - Ultra sound: can provide throat size - Gravity sensing: these sensors are now compatible with wire line - Magnetic resonance method: can provide information on the fluid type, mobility, rock type and hydrocarbon ratio - Quantum sensors have been successfully applied in oil and gas exploration, including to: • Determine fluid type and pore size to differentiate between oil and water in pores • Draw fluid in wire line down the hole and monitor the fluid being produced • Enable accurate well logging over a range of classical parameters (quantum control method for well logging) - Seismic atomic clocks: enable precise time stamps for sensors which can enable more accurate underwater exploration
Real Time Processing To optimize operations, reduce environmental footprint, and/or reduce long-term liabilities and closure costs  	› Magnetic sensing: can image geological samples on micron level scales › Quantum technology can be used to take existing sensors and read them out with higher accuracy › Quantum sensing via satellite: can be used to monitor methane and potentially other emissions › On board quantum magnetic field sensors: can be used for driverless vehicles to improve navigation and automate mines and processing plants › Fibre Bragg gratings for sensing for structural health monitoring of tailings ponds › Geophotonics: opportunities include imaging cyanide/carbonaceous materials in preg-robbing gold ore, imaging arsenopyrite to prevent arsenic leaching into tailings, imaging surface morphology during froth flotation, imaging kimberlite/carbonates during diamond mining, imaging agglomerates/clay fines/asphaltenes during bitumen processing, enhancing recovery from old tailings, real time feedback on process minerology, rapid in situ analytics for ore blending and tracking methane › Quantum computing: can optimize plant operations (e.g. energy/water use/distribution), solve advanced problems/simulations such as complex chemistry simulations, machine learning/automation, and defend against cyber threats

4. What is Needed to Support Collaboration

This workshop was the first step at convening members of the quantum and mining communities.

Workshop participants were invited to identify what is needed to support collaboration between the mining sector and quantum researchers, taking into consideration additional information, resources, programs and incentives, and relationships. A sub-set of participants provided input on this question, and their input is summarized in Table 2. These ideas can be used as a starting point for encouraging further collaboration and generating new ideas.

Table 2: What is needed to support collaboration between the quantum research community and the mining industry?

Information	Resources
› More information on quantum technologies › List of potential applications for quantum technology accompanied with a direct comparison to other 'competing' technologies › Data library available to validate technology demonstration findings › Work to help define the national strategy and frame the discussion › Identification and definition of Canadian areas that are likely to have early success	› Easy access to funding as an enabler for university/industry teams to work on projects to develop early generation prototypes › Leading experts inside the organizations who can explore the power of quantum computers when applied to industry-specific problems › Assistance in coordinating with the Federal government (e.g. UK showcase) › More workshops similar to this one
Programs and Incentives	**Relationships**
› NSERC funding for academia/industry collaboration › National level activities › Program to imbed a subject matter expert inside organizations to identify potential opportunities in a more proactive manner; government funds could be used to pay for these resources › Continue work from Canada First Research Excellence Fund (CFREF) program	› Continue holding small meetings and encouraging follow up › Build international relationships (UK/EU) › Innovation labs › Work with partners to encourage knowledge transfer › Find topics for joint research › Conduct small academia/industry focus groups › Share findings of industry engagement workshops with other industry sectors to facilitate cross-sectoral communication and learning › Work together to get quantum technology on the industry roadmap

5. Conclusion and Next Steps

Participants found this workshop to be very useful and expressed a high level of interest in furthering discussions and collaboration in this sector. Through this initial engagement, participants were able to identify a number of areas where quantum technologies may be able to address fundamental mining industry needs. As a direct result of the workshop, several opportunities have been followed up on and initiatives have already been created to further explore the potential application of quantum technologies to this sector. This underscores the value of bringing together the research community and industry representatives to catalyze this type of collaboration.

Next steps include continuing to develop relationships and collaboration ideas generated during the workshop. The organizers and community will also continue to maximize strategic input in the Quantum technology space.

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