



A Summary Report of the Impacts of Disruptive Technologies in the Yukon Territory Mining Sector

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About this Project

This report is part of *Remote controlled: The impacts of disruptive technologies in the Canadian mining sector*, which was designed to understand the impacts of disruptive technology adoption, including the scope of technologies that could disrupt traditional production practices and the future of work. For more information, please visit [our project website](#).

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Executive Summary

The mining sector in Canada is in an “age of disruption” (Stuart et al., 2015) where technology has the potential to reshape the future for workers and communities. Remote Controlled is a national research project that aims to understand the adoption of emerging technologies in the Canadian mining sector and the impacts on mining communities in rural and northern communities (Hall et al., 2025) in four case study regions, including the Yukon Territory. In the Yukon, the study involved a comprehensive data collection process, including 14 interviews with 15 interviewees across different sectors of the mining industry, conducted over a two-year period from August 2022 to July 2024. These interviews provided key insights into the adoption of technologies in a region where mining operations are influenced by both local and global dynamics.

Technology in the Yukon Territory Mining Sector

Top Technologies

- The most frequently cited technologies were drones, electric-powered equipment and vehicles, software, and sensors.
- These technologies are primarily used to reduce costs, improve safety, increase operational efficiency, and enhance environmental performance.
- Technology adoption was particularly strong in exploration and remediation stages of the mining lifecycle.

Drivers of Technology Development and Adoption

- Key drivers included reducing environmental impacts, improving operational efficiency, generating better data for mine planning and decision-making, and responding to market and regulatory pressures.
- Economic pressures (e.g., fuel and energy costs) and ESG imperatives were often interconnected in adoption decisions.
- First Nations leadership and partnerships are actively shaping innovation in Yukon’s mining sector.

Barriers to Technology Development and Adoption

- Interviewees cited the complexity of Yukon’s regulatory environment, high capital costs, workforce shortages, and infrastructure limitations as major barriers.
- Cultural attitudes toward risk and legacy permitting systems were noted as constraints on experimentation and innovation.

Employment Impacts & Required Skills

- Interviewees described both job loss (e.g., reduction in low-skilled labour due to automation) and job creation (e.g., demand for high-skilled technical roles).
- Training needs span technical, environmental, and community engagement skill sets, with adaptability cited as a universal requirement.

- Labour shortages and challenges in attracting/retaining skilled workers were seen as critical bottlenecks.

Regional Development Impacts and Responses

- Technology was linked to broader regional issues such as broadband access, energy infrastructure, and housing shortages.
- Interviewees highlighted promising regional responses, including new minerals legislation, Yukon University's Centre for Northern Innovation in Mining, and First Nations-led environmental and energy initiatives.
- Smaller operators and remote communities face particular challenges in benefiting from technology-driven opportunities.

General Influences on Mining Technology, Adoption, and Innovation

- Yukon's distinctive regulatory landscape, strong Indigenous governance, and the Territory's self-reliant mining culture shape how innovation is understood and implemented.
- Federal and territorial investments in digital transformation, sustainability, and workforce development were seen as enabling—but not yet sufficient—conditions for broad-based innovation.

Future Considerations

- Interviewees expect a shift toward increased automation, remote operations, and electrification.
- Future technology adoption will depend on site-specific realities, evolving regulatory requirements, and the integration of Indigenous knowledge systems.
- Ensuring that Yukon communities benefit socially and economically from mining innovation will require coordinated, inclusive, and forward-looking policy and investment strategies.

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1 Introduction and Context

The mining sector in Canada has entered an “age of disruption” (Stuart et al. 2015), where advances in technology are fundamentally reshaping the future of work and economic development. Globally, increased automation and digitalization in the mining sector are becoming a growing reality. For example, in Australia Rio Tinto’s Mine of the Future™ features autonomous (driverless) haul trucks that operate 24/7 from a control centre located over 1,500 kilometres away (Rio Tinto, 2022). Growing alongside these trends is a rich body of international research examining how emerging technologies are transforming mining operations and redefining the relationship between mines and the people and communities where they operate (McNab and Garcia-Vasquez 2011).

However, comparatively little is known about these technological shifts and the adoption of emerging technologies in the Canadian mining sector, particularly the community and regional level impacts and responses. [Remote Controlled](#) is a national research project exploring technology adoption in the Canadian mineral mining industry and the future of work and economic development in four case study regions: Newfoundland and Labrador; Northern Ontario; British Columbia; and the Yukon.

1.1 Overarching Research Objectives and Methods

The key objectives of the research are to:

- (1) Determine the nature and extent of emerging technologies in the Canadian mining sector;
- (2) Examine how these technologies are reshaping the sector;
- (3) Identify what is driving the adoption of emerging technologies in the Canadian mining sector; and
- (4) Explore the impacts on mining communities/regions and the related responses by companies, organizations, governments etc.

To better understand technology adoption, impacts, and responses, we conducted:

- A **systematic scoping review** of articles in the *Canadian Mining Journal* to assess the main drivers, barriers, and opportunities for technology adoption in the Canadian mining sector between 2016 and 2024 (see Crabbe et al. 2025);
- A **survey** of Canadian mining representatives exploring the drivers, enablers and barriers to technology adaption in the mineral mining sector (see [Crabbe, 2023](#));
- **Interviews** in the case study regions with a range of Yukon Mining Industry Experts, Yukon Mining Company Representatives, Yukon Mining-Related Technology Company Representatives, and local and regional support organizations;
- The **creation of a novel dataset** of Canadian mining technology organizations to explore the national MineTech landscape (see Huneke et al., forthcoming); and
- A series of **MineTech case studies** exploring specific technologies and their potential

impacts on the future of work and economic development (see Zhou, Huneke, and Hall et al., 2026a; 2026b; 2026c; Huneke and Hall et al., 2026).

1.2 Yukon Data Collection and Analysis

To achieve the research objectives, semi-structured interviews were conducted with various stakeholders and key informants across the Yukon mining sector. In total we conducted 14 interviews with 15 interviewees over a two-year period from August 2022 to July 2024. Given the distance and cost of travel to the Yukon, the majority (11) of these interviews were conducted virtually, on Zoom, with 3 interviews conducted in person during a visit to the Yukon in May 2024. Interviewees represented a mix of the Yukon mining sector including industry organizations, Yukon Mining-Related Technology companies, and mining companies. Given the industry focus on mineral exploration in the Yukon, most interviewees highlighted technologies related to exploration and remediation stages of the mineral lifecycle. Table 1 provides a brief overview of the interviewees and their relationship with the mining sector in the Yukon.

Table 1: Key Informants¹

Interviewee Category		# of Interviews	# of Interviewees
Mining Industry Experts	Researcher, Yukon Mining-Related organization	5	6
	Governance representative (regulatory body, licensing official, etc.)	5	5
Mining-Related Technology Company Representatives		3	3
Mining Company Representatives		1	1
Total		14	15

Source: Created by authors

Given the size of the Yukon and the smaller-scale nature of the mining industry relative to the scale of mining operations across the other sub-regions of the larger study, results presented in this study are drawn mostly from the perspectives of Yukon Mining Industry Experts and governance representatives. While there was a concerted effort to recruit more mining related technology companies and Yukon Mining Company Representatives, the reality of the region is that there are a very limited number of mining related technology companies, and existing mining companies faced time constraints which prevented participation in the study. The focus on policy and regulatory perspectives is significant for the Yukon case-study region as recent research suggests that the introduction of Yukon-specific legislation in the early 21st century reshaped technology innovation in Northern mining operations (Rowles, 2021). Current Yukon

¹ This research received ethics approval and a Territorial Research License as part of the process. While the interviewees spoke about First Nations involvement in the mining sector, none of the participants were members of a First Nation.

mining assessment and regulatory processes include caveats on technology. However, the Government of Yukon is developing new mineral legislation that may evolve assessment and regulatory processes to address new or changing technologies, as the Yukon seeks to balance industry viability, environmental protection, Indigenous rights, and community sustainability (Howarth, 2024).

To supplement stakeholder interviews, several grey literature sources provide critical insights into the Yukon mining industry. The *Yukon Mineral Development Strategy and Recommendations* (Yukon Mineral Development Strategy Panel, 2021) outlines a comprehensive framework for modernizing the Yukon's mineral resource management, emphasizing collaboration with First Nations and sustainable development practices. Complementing this, the *What We Heard* report (Government of Yukon, 2024b) encapsulates feedback from diverse stakeholders, highlighting the need for regulatory clarity and enhanced community engagement. Addressing operational challenges, PricewaterhouseCoopers (2020) conducted a review identifying redundancies in Yukon's mining regulations, proposing actionable solutions to streamline assessment and permitting processes. Furthermore, the Yukon Chamber of Mines (2022) published the *Yukon Mining and the Green Economy* report, discussing the sector's role in the global transition to sustainable energy and the importance of critical minerals. Collectively, these documents offer valuable perspectives on policy development, industry practices, and strategic planning within Yukon's mining landscape.

2 A Brief Overview of Mining in the Yukon

The Yukon provides a fascinating jurisdiction to study mining and mining technology, as the extraction of valuable ore is deeply embedded in the Territory's history and its peoples' way of life. The history and evolution of mining and technology innovation in the Yukon begins far before the Klondike gold rush with evidence showing Indigenous communities collecting nuggets of copper in riverbeds aided by caribou and moose antlers (Cooper, 2012). These traditional extractive practices were then disrupted in the late 19th century by the arrival of settlers² during the Klondike gold rush in the 1890s. Initial advances in technology around placer gold in the Yukon stemmed from increased efficiency and safety. For example, around the turn of the 20th century miners would "fire-thaw" mine shafts down to the bedrock which resulted in the deaths of many miners due to smoke inhalation until the advent of "steam-thawing" which proved more efficient and safer (Gilbert, 1989).

The 20th century saw fluctuations in the colonial extractive industries and world wars and gold prices dictated activity in the Yukon. However, Gilbert (1989) affirms that as technology advanced and gold prices skyrocketed in 1934, extraction in the Yukon boomed until the Second World War. Post-war extraction in the Yukon similarly dipped but rose again paralleled by increasing gold prices in the 1970s and 80s. In terms of technological disruption and innovation, Alcantara et al. (2012) and Rowles (2021) point toward political devolution and

² Settlers in this context refers to prospectors, miners, and entrepreneurs from the United States, other parts of Canada, and Europe who migrated to the Yukon in search of gold.

transformative mining legislation as key turning points for the mining sector (and others) in the Yukon. Now over two decades since these major shifts, this study considers the importance of technological innovation and disruption in the Yukon mining industry with considerations for future directions in education, workforce development, and employment in the sector.

The Yukon mining sector is characterized by both hard rock (quartz) and placer mining, with gold, silver, and copper being the primary exports (Mining Association of Canada, 2024; Government of Yukon, 2009; 2023). As of 2021, approximately 400 individuals were employed in the combined sectors of mining, quarrying, and oil and gas extraction in Yukon, reflecting a decrease from previous years (Government of Canada, 2025). Placer mining, Yukon's original mining industry, remains robust, employing nearly 500 people annually, with just under 40% being Yukon residents (Yukon Minerals Advisory Board, 2022).

The mining landscape is ever changing in the North and this is clearly illustrated in the Yukon. For example, at the start of the primary data collection for this project in 2022-2024, the Yukon hosted three major hard rock operations: Eagle Gold, Keno Hill, and Minto mines (North of 60 Mining News, 2023). However, over the life of the project the Yukon has seen the Minto and the Eagle Gold mines close in May 2023 and May 2024 respectively (Roan, 2024; Russel, 2024). Keno Hill currently remains the only operating hard rock mine in the Yukon, with recent acquisition by mining giant Hecla Mining Company in 2022. Placer gold mining remains robust, with 2021 output totaling over 77,000 crude ounces valued at approximately C\$139 million (North of 60 Mining News, 2023). Despite its substantial economic contribution, Yukon's mining sector employs relatively few local residents, relying on out-of-Territory labour to meet nearly half of its staffing needs (Conference Board of Canada, 2025).

Mining takes place within the traditional territories of several First Nations. Eleven of the fourteen Yukon First Nations have signed Final Agreements that define rights related to land, self-governance, economic development, and resource management (Government of Yukon, 2025a). Socio-economic cooperation agreements between mining companies and Indigenous governments are now common, focusing on employment, training, and business opportunities (Yukon Mineral Engagement, n.d.).

Another central actor in the mining process is the Yukon Environmental and Socio-economic Assessment Board (YESAB), an independent body established under the *Yukon Environmental and Socio-economic Assessment Act* as part of the Umbrella Final Agreement with Yukon First Nations. YESAB is responsible for conducting assessments of proposed projects—including mining developments—to evaluate their potential environmental and socio-economic impacts before they can proceed (YESAB, n.d.). Through a public and evidence-based process, YESAB provides recommendations to decision bodies, ensuring that projects align with sustainable development principles and First Nations rights. Additionally, the Yukon Chamber of Mines (2022) produced a report on *Yukon Mining and the Green Economy*, which explores the industry's role in the energy transition and positions the Yukon as a future leader in critical minerals and low-impact technologies. Collectively, these documents provide a valuable

evidence base for understanding policy development, technology integration, and governance structures in the Yukon’s mining landscape.

The sector is seeing growing interest in autonomous technologies, environmental monitoring tools, and data-mapping platforms such as GeoYukon, which enhance planning and safety (Government of Yukon, 2024a). However, challenges persist. Financial constraints, regulatory uncertainty, and a shortage of skilled labor continue to act as barriers to growth (Future Skills Centre, 2025). In response, a new Minerals Act is under development to modernize Yukon’s legislative framework in ways that respect Indigenous rights, safeguard the environment, and support sustainable development (Government of Yukon, 2024b, 2025b). Looking ahead, energy transition, digital innovation, and Indigenous partnership models are expected to shape the future of the sector (Stewart, 2024).

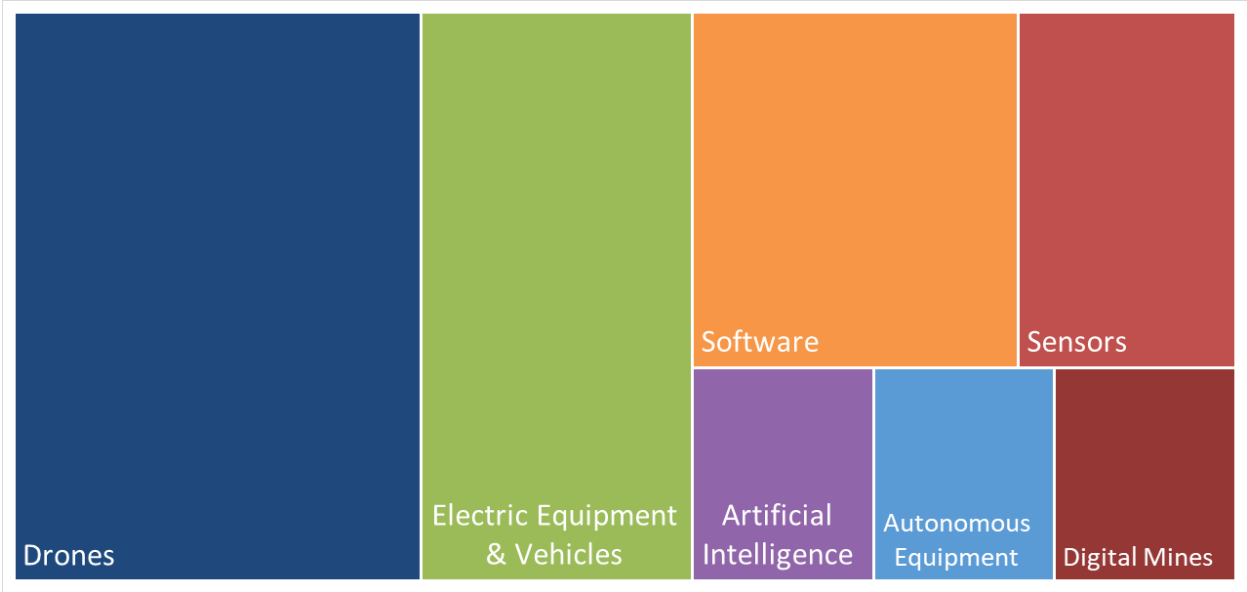
3 Technology Adoption in the Yukon Mining Sector

3.1 Identified Technologies

We asked our Yukon Mining Industry Experts and mining technology companies about the top three technologies being adopted over the last five years in the Yukon mining sector. We categorized their responses into the supporting technologies identified in our quantitative analysis (see Table 2 for a detailed description). More specifically, the top technologies cited by our industry experts include drones, electric-powered equipment and vehicles, software, and sensors.

Current Technologies: The identified technologies that the sector has adopted over the past five years are found in Figure 1.

Figure 1: Technologies Adopted over the Past Five Years



Source: Created by authors

Drones were cited as the top technology adopted over the past five years. Interviewees described how drones help to enhance mapping, surveying, and monitoring capabilities that may support mine exploration, planning, and assessment activities. As described by Yukon Mining Industry Expert 4:

I think from a positive perspective, the mapping has improved significantly. So we've got a lot of operators that are flying with drones, their own site with their own machines, which is great. We have a lot of operators that are having a lot of drone survey work done in advanced exploration, which is really positive. That's a sort of a big, that's a big one in the last five or ten years.

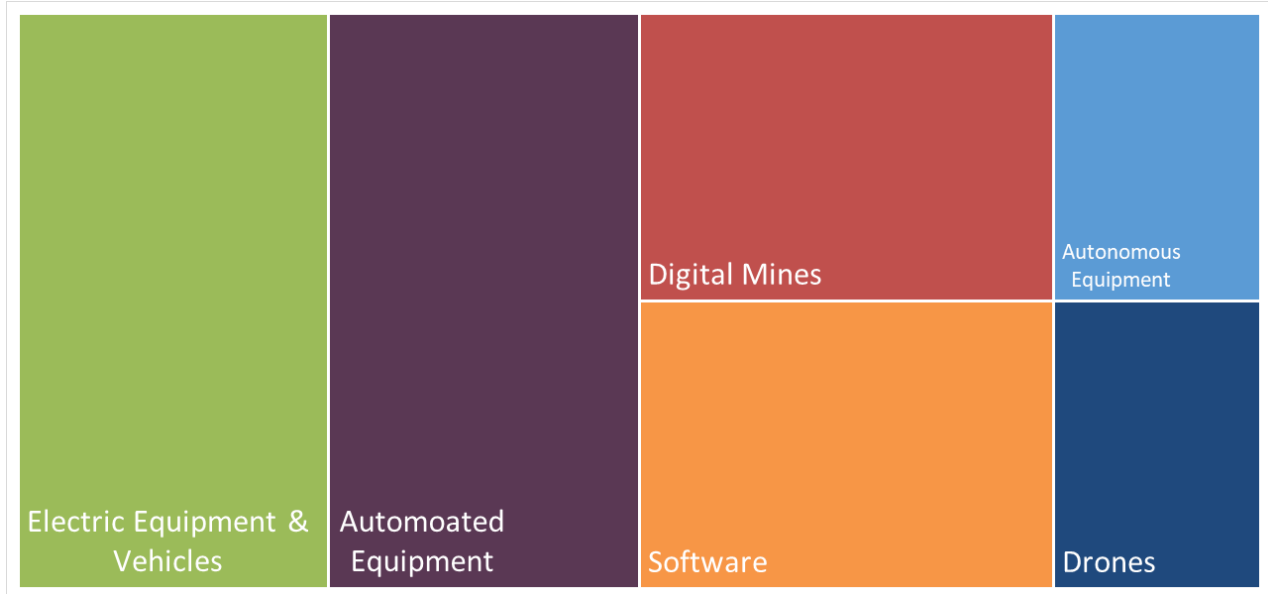
Table 2: Description of Supporting Technologies

Technology	Description
Drones	Remote-controlled (unmanned) aircraft
Electric Equipment & Vehicles	Electric-powered or battery-electric powered equipment and vehicles
Software	Data visualization; 3D modeling; mine operations management software
Sensors	Standalone sensors or embedded sensors
Artificial Intelligence (AI)	Artificial intelligence models
Autonomous Equipment	Autonomous equipment and machinery; automated control systems
Digital Mines	Digital transformation solutions
Internet of Things (IoT)	Network-connected devices, equipment, and objects; wearable and handheld devices

Source: Created by authors

Future Technologies: Technologies identified as those the Yukon mining sector will adopt in the next five years are found in Figure 2.

Figure 2: Top Identified Future Technologies



Source: Created by authors

Electric equipment and vehicles and automated equipment were prominent future technology categories cited by interviewees. These technologies were often discussed in relation to energy transitions expected to occur across the Yukon mining sector in the next five years. As described by Yukon Mining Industry Expert 1:

Nobody knows where things are going to go. Are they going to go hydrogen? Are they going to go electric? The only known to date is that it's going to change. And you know the batteries will change. And so, if they go electric, you're going to have fewer gears, and you're going to have a fundamental shift in mechanics. If they go hydrogen, maybe not as much. And so, we're at the point where we're watching it. We haven't changed a huge part of what we do, because right now we still are basing everything on basic diesel or gasoline.

3.2 Drivers for Technology Adoption

There are a number of factors driving technology adoption in the Yukon mining sector. Some of the top responses cited by interviewees were economic drivers, improving mine planning and management through enhanced data and insights, and making mining more environmentally and socially sustainable. According to interviewees, many mining operators in the Yukon seek technology to help meet requirements in each of these three areas simultaneously. As Yukon Mining Industry Expert 7 explained:

Innovations [that] reduce environmental impact and improve cost efficiency and provide real time data for live decision-making are the ones [that] are going to

add the most value in these investment attractiveness in our sector, or, as I would like to paraphrase, be able to, you know, meet that value proposition as part of the Yukon First Nations.

3.2.1 Economic Related Drivers

All 15 interviews discussed how adopting specific technologies are largely related to economic issues like increasing productivity and efficiency, reducing costs of mining operations in remote locations in the Yukon, and responding to broader market demands and industry development forces. As Yukon Mining Industry Expert 1 explained, an individual technology may have been adopted to solve a specific problem, but “...the other motivation is it cut down on time, it cut down on cost.”

For example, a majority of Yukon Mining Industry Experts and mining technology companies explained that fluctuating fuel costs drive adoption of a wide range of electric-powered technology in the Yukon mining sector. Mining operations and mine planning in the Yukon are heavily influenced by global markets, particularly their regional impact on fuel prices. As Yukon Mining-Related Technology Company Representative 2 explained: “a lot of [technology adoption] comes down to gold price and fuel price. If the gold price is high and the fuel price is low, then that opens up property that may not have been economical before but is now.”

With declining electricity costs and advancements in battery technology, Yukon mining operations are increasingly replacing traditional diesel-powered machinery, heavy equipment, and vehicles with electric alternatives. Yukon Mining Company Representative 1 described the economic benefits of transitioning to electric-powered machines: “... if you've got cheap power, it's cheaper to run your car or your truck off of electricity than it is off of any sort of carbon-based fuel.” Likewise Yukon Mining Industry Expert 4 explained that “...in the last 10 years, we've seen a significant growth of the use of conveyors in our industry and that significantly cuts down on diesel. So, people are using conveyors over dozers or rock trucks.”

Transitioning to electric-powered equipment and vehicles can also trigger the adoption of other mining technologies. More specifically, electric-powered mining operations require different infrastructure, systems, and workflows compared to traditional diesel-powered mining operations. This system-wide shift creates opportunities for additional and complementary cost reduction scenarios through related technology implementation. For example, investment in electric-powered machines equipped with sensors and connectivity may enable remote operations. When mining operators create long-term electrification plans for their mines and assess potential technology impacts, they may also be required to submit their project plans for review to Yukon mining authorities. As Yukon Mining Industry Expert 8 explained:

...going from a diesel operated underground fleet to something that's electric, you know, electric vehicles or remotely operated vehicles... we know that we can do it this way, but we are also thinking that this [other related technology] will

become available to us during the life of the project and so you assess both of those at the same time.

Most interviewees (9 out of 15 total) also explained that drone technology adoption was driven by the high costs and time involved with executing land and geographic surveys that have been traditionally conducted from airplanes with human crews. As Yukon Mining-Related Technology Company Representative 3 described, traditional airplane surveys require “...mobilizing up with fuel, and all these things [are] high, high cost.” However, by using drone technology to reduce operating costs, they continued: “we can dock this in with [a] prospecting mapping program... and we get the same large area collect[ed], as you know, what would have been a pretty big and rigorous undertaking.” For the Yukon mining sector in particular, drone surveys help reduce the cost and time of surveying large areas, difficult terrain, and remote locations. As Yukon Mining Industry Expert 7 explained: “[drones are] an absolute game changer for everybody. They'll collect the same data [as traditional aircraft survey approaches] using light gear in rural, remote areas.”

Similarly, some Yukon Mining Industry Experts (3 out of 11 who discussed sensors) explained that lightweight, digital sensor technologies have been adopted in the Yukon to reduce high costs associated with transporting and operating heavy equipment in remote locations. For example, Yukon Mining Industry Expert 7 described “bedrock interface sampling rig...” that is “...light, agile, top hammer rig, mounted on low ground pressure tracks operated with wireless remote” and has “replaced the need for an invasive excavator trenching.” Because the probe uses a low-impact sampling method, it has created a new approach that:

does not have to fly an excavator out to a remote exploration site. Just come in, pound a three-inch hole, no reclamation. Again, significant investment in methodology, tripled productivity by using the tool and replacing trenching and operate at a third of the cost of the traditional method.

3.2.2 Mine Planning and Management

As older mines are retired and fewer new sites are available for potential mining projects in the Yukon, mining operators are seeking better information and insights to plan mines more precisely and manage existing projects more efficiently. In particular, Yukon mining operators have adopted technologies that enhance the discovery, development, and assessment of mines. This often includes technology for improved collection, management, and utilization of detailed and high-resolution data, as well as tools to share data for enhanced collaboration and decision making. As Yukon Mining-Related Technology Company Representative 2 explained:

I think one of the big things that's pushing [technology adoption] is the fact that the resources that are left are becoming less and less economical. So, in order to survive they have to find new ways to be more efficient. All of the very lucrative mining grounds have been mined. So, we're kind of picking at scraps. And in order to make that economic[al], we have to adapt the way to do it and that kind

of comes down to yeah, adopting new technologies, [...] getting better data and using better equipment.

Nearly half of the Yukon Mining Industry Experts (5 out of 11 who discussed data) and mining technology companies explained how better data can help in the discovery of underground minerals and resources. For example, Yukon Mining Industry Expert 3 explained how LiDAR and other sensor technologies allow for data collection “...to understand, the architecture, the regional geologic architecture. And within that there may be porphyries and faults and other features that are important, for whatever reason, whether it's for rip wrap or geothermal energy or mining.”

While sensor technologies help enhance data collection, software and connected platforms help mining operators manage and analyze data for insights that can help decision making and planning. As Yukon Mining-Related Technology Company Representative 3 explained, mining operators have adopted sensors, software, and platforms in an effort to consider “*what other data sets can really complement and help us up the odds of exploration and give us a better fighting chance in the industry.*” Likewise, Yukon Mining-Related Technology Company Representative 2 described how “*it's a bit of a battle, but it's becoming even more essential to have this good data and to have a very [...] efficient mining plan. Whereas in the past, there was a lot of really good ground and people could afford to suck up some bad ground. So drilling wasn't as essential because they kind of rode out the highs, highs and lows, whereas these days it's pretty - there's not a lot of room for error.*”

Technology adoption is also driven by the increasing need to share data and communicate insights for enhanced collaboration and decision making. For example, 3D modeling and data visualization software applications can help communicate mining plans and management approaches before actual groundwork is implemented. Yukon Mining Industry Expert 3 described data visualization software as “*just a way of showing people without spending any money, really.*” They went on to explain:

if I have a potential clientele that want a certain type of wash plant, well, I can go back through old drawings and be like, OK, here's something I've built in the past and I can send them a 3D model of it, and then they can sort of get their head around what it might look like if I haven't got actual pictures of what it looks like or I can do up a quick model and then send that to them and say, this is what you might want.

A few interviewees (3 out of 15 total) explained that streamlining collaboration and planning with data visualization and modeling software ultimately reduces time and costs of discovery, development, and assessment of mines. For example, Yukon Mining-Related Technology Company Representative 1 explained how “*...we use SolidWorks and like SpaceClaim [...] and different drafting, because what's happening, what's the best way to build things now is to have it completely drafted and completely modelled.*” Although the acquisition cost of these software

tools can be prohibitive, Yukon Mining-Related Technology Company Representative 1 explained that for many operations in the Yukon:

it ends up paying for itself in the end because you're just more or less putting Lego together at the end, you know? Yeah, there's some welding and some bolting and whatever, but it's just. Yeah. The product goes up really easy and there's no issues because you've already built it digitally on the computer.

3.2.3 Making Mining More Sustainable

Increased focus globally on environmental and social impacts of mining have driven technology adoption in the Yukon mining sector. Experts have called for the Yukon mining sector to reduce mining emissions by 45% by 2030, however the lack of access to hydro-powered electricity via grid connections means that most mines must continue to rely on diesel, gasoline, or natural gas to power operations (Rifkin, 2021).

Yukon Mining Industry Expert 6 described how “greenhouse gases and either the technology that creates them or reduces them has suddenly become a big issue, I mean I'm sure it's across the country. Mining generates a huge amount of greenhouse gas emissions, whether it's the actual exploration or mine, or closure of remediation, and that people are starting to pay a lot of attention to it.” Likewise, Yukon Mining Industry Expert 7 explained that technology discussions in the Yukon mining sector have increasingly been connected to:

...understanding more about what exists in the Yukon for geological makeup and opportunities to be able to contribute towards a low-carbon future and a greening-type industry. So, the transition, when we talk about the transition, really Yukon should play a significant role in that.

According to Yukon Mining Company Representative 1, across all types and sizes of operations in Yukon, technology adoption is “being driven much more now by greenhouse gas considerations.”

According to interviewees, Yukon First Nations are leading the focus on environmental and social factors in the Territory’s mining sector. Although we did not speak directly to Yukon First Nations, we heard from Yukon Mining Industry Expert 7 who explained that “[Yukon First Nations] are telling us that they don't view, you know, mining as necessarily the be all end all to economic opportunities and traditional territory. So how do we approach that?” They continued to describe how technology and innovation play a significant role in questions such as:

How are you going to reduce the impacts? How are you going to ensure that you respect the land that we have fished, you know, fished from or hunted on or, you know, settled on or lived on, or transient on for millennia? You're just here for, you know, a particular mine cycle, a life cycle of a mine. We're going to be here generationally.

Likewise, Yukon Mining Industry Expert 9 explained:

In the end, we do want people to, you know respect the environment and not destroy everything and be able to reclaim it, and that is, I think, a big objective, especially with Yukon First Nations. They're very keen on that. And that we don't leave like huge, contaminated waste sites that are just contaminating the environment for years and years to come and nothing can be done about it. So that's definitely the priority in the minds of all Yukoners, you know, government and the public. So, we're definitely working towards that. So, any type of innovation and technology that can help, support and reduce contaminated sites after a mine has ended its life, or even during those phases is something that I think people are open to here.

Environmental considerations are a key driver for adoption of electric-powered machinery, equipment, and vehicles. As Yukon Mining Industry Expert 3 explained, transitioning to electric vehicles achieves greenhouse gas emission reductions while helping to shape public perception about the mining sector: “...what I'm seeing with industry is a big drive towards greenhouse gas reductions, you know, for social license and also I think some companies really do care.” Electric vehicles and other technologies can also be particularly effective in environmental remediation of mines. For example, Yukon Mining Industry Expert 6 described how the “abandoned mine at the Central Yukon” has led to a:

huge fuss over the amount of greenhouse gases that will be released while cleaning it up. So you sort of get into this weird thing about, well, we have to clean it up, but we're gonna cause more pollution through greenhouse gases and there's been some discussion on how technological fixes could perhaps reduce those emissions. Electric bulldozers, things like that.

Beyond greenhouse gas emissions, technology adoption is driven by the need to reduce the potential land, habitat, and biodiversity impacts of mining operations. For example, Yukon Mining Industry Expert 7 described how unmanned aerial vehicles (UAVs) and drones are helping the mining sector by “moving away from invasive on the ground, chopping down trees, you know, trenching with large excavators... moving away from investment on the ground technologies or approaches, I should say, to drones from the air that create, like... I'll just lift stuff straight up.” Interviewees also suggested that technology adoption is driven by the need to monitor compliance with environmental and social regulations or requirements. As Yukon Mining Industry Expert 9 explained:

that's a priority, and then compliance monitoring and inspections providing that organization with more tools to have enforcement as the Yukon is very remote, trying to hit up all of these mines is very difficult. You won't see an inspector there all the time. So new innovative ways to visit, bringing in drones, things like that to enhance compliance, monitoring, and inspections.

3.2.4 Worker Safety

Two interviewees also cited worker safety and public safety as key drivers for technology adoption. For example, with remote operations enabled by sensors and connected devices, workers conduct activities further away from hazardous situations or heavy machinery where proximity could otherwise pose a risk to human safety. Yukon Mining Industry Expert 1 explained: *“They're making it so that if they're doing blasting, people don't need to be underground, and so I'd say it's improving safety. It's not necessarily having an enormous impact on production.”* Public health and safety of communities also drives technology considerations. For example, Yukon Mining Industry Expert 9 described how:

a lot of the times we have surface water as the main drinking water source or used in mining operations and therefore they have other treatment objectives that we need to meet with the Canadian drinking water guidelines. If they're using it for potable water, so we're looking at filtration and UV light and regular bacteriological sampling schedules that we have associated with that.

3.3 Factors Influencing Technology Adoption

Yukon Mining Industry Experts and mining technology companies also discussed a number of factors that influence adoption of technologies in the Yukon mining sector. These included Canada's increased focus on digital transformation and rural economic development in the North, the Yukon's movement toward energy transition, Yukon First Nations involvement in the mining sector, and the unique history and culture of mining specific to the Yukon.

Some Yukon Mining Industry Experts (2 out of 11) cited Canada's increased focus on digital transformation and economic development in rural and Northern regions as a key enabler for adoption of technologies in the Yukon mining industry. For example, Yukon Mining Industry Expert 1 explained that *“I think it's deliberate on the part of Canada. It's bringing people into the digital economy, but it's also on the part of the North, making it far more accessible to resource development.”* They continued to describe how this impacts the Yukon mining industry:

I mean, it's, however communities will look at it, on the good side people have better access to Internet and hopefully if everything goes through, the permitting, and there's a decision and a will and a desire to mine in a specific region, probably with the availability of Internet. It's also a greener enterprise. And hopefully that would sit better because right now you'd have to fly or drive trucks in. And with that you're holding a lot more fuel. You're holding a lot more different potential contaminants on site than you ever would if you had a far more automated environment.

Some Yukon Mining Industry Experts (2 out of 11) noted how the regional movement toward consideration of energy transition pathways was an important factor for adoption of technologies in the Yukon mining industry. For example, Yukon Mining Industry Expert 1 explained:

...with the backdrop of energy and the real desire on the part of government to invest in trying different energy options, cleaner energy options. They're saying to industry that actually, diesel is not going to be an option. So, I think that's where the economic development agencies are playing a role to say, okay, we know that you don't have cash to try this out, but we might be able to float this to see if this is a viable option. And again, we're still at the point where the technologies that they're buying aren't necessarily leading edge. But give us two years, and I think we'll see a really big shift because we'll actually have the companies that understand and have the capacity to be able to operate those technologies. What we have, are sort of burdened with here, is that there's a lot of different technologies but if we don't have the capacity, collective capacity, to use them, it breaks, and then people can't afford to fix it.

Another key factor for technology adoption cited by most Yukon Mining Industry Experts (7 out of 11) was the deep involvement of First Nations in the Yukon mining sector. Collaboration and oversight from Yukon First Nations are generally perceived as an innovative and unique part of the Yukon mining context that drives positive change for evolution of the mining industry as well as for social and environmental outcomes. Yukon Mining Industry Expert 7 described how:

Innovation doesn't necessarily have to be limited to technology. It can be ways of doing things in ways of being, and ways of, you know, approaching business. And I think without question then if that were the case, I would put, you know, engagement with First Nations at the top of that innovation numerical sphere, right, because that is the absolute key.

They continued to explain that: “[Yukon First Nations] have developed their own, some of them have developed their own mining policies, their own mining legislation, the way that they approach and view and review and permit that mining in partnership.”

These innovative approaches resulting from First Nations involvement can help facilitate technology adoption. For example, Yukon Mining Industry Expert 3 described how:

one of our more innovative companies have an exploration project in a very remote area last summer and they partnered with a First Nation and the First Nation purchased and installed a big solar array in the camp and then sold them the power. So, it's just an exploration project at this point. But they had three drills turning. So, they had a core shock with, you know, electric rock saws cutting core and they had a kitchen tent, I think 20 odd people in camp. So, you know, it's

an insular little isolated community that was entirely solar powered except for the drills.

Similarly, Yukon Mining Industry Expert 1 described how First Nations involvement resulted in an innovative environmental monitoring program for mining in the Yukon:

We designed that in cooperation with a number of Yukon First Nation communities, and it really was at the request of the mining sector, and we also involved some of them. Obviously, we needed to be able to provide the necessary skills so that the mining or exploration companies could hire our [Yukon] graduates. But what we found is that that area has been an area that has really taken off. That program continues to be full, and one hundred percent of our students are from communities, and we also made a commitment to not base that in Whitehorse. And so, we have a number of condensed modules or courses that we offer on the land, and there's an element of technology in that. Not a ton. But it's an area where we see a real coming together of community industry and young people. It just, again, it continues to be something that we're watching.

Finally, a majority of interviewees (10 out of 15) noted a key factor related to the unique history and culture of mining specific to the Yukon. Yukon Mining Industry Expert 4 explained how this translates to Yukon mining industry actors' independent attitudes, self-reliance, and ingenuity to adopt, maintain, and repair technologies:

It's that if we have drones, we can do this ourselves. We still understand everything ourselves. We can fix it ourselves. We know what's going on ourselves. The more they depend on outside resources, the less confidence they have. It's a huge driver. It's their independence, their ability to do things themselves. It's one of the reasons why we have so much old equipment that is still running is because they can fix it.

Yukon Mining Industry Expert 2 similarly explained how the Yukon's independent and self-reliant cultural perspective is embedded into the Territory's resource management approach:

So, we in the Yukon, we devolved in 2003, NWT did so, quite a bit later 2010 or something, and Nunavut, I'm not sure actually. So, it means we control our own resources here and the feds don't have a whole lot to do with resource management here in the Yukon. With the exception, of course of federal acts like the Fisheries Act and some NRCan Explosives Act, that kind of thing. But generally we manage our resources ourselves.

3.4 Barriers for Technology Adoption

Interviewees discussed a number of barriers to adopting technologies including the Yukon regulatory environment; uncertainty and risk perceptions; labour and skills; costs; mining culture and attitudes; and technology and infrastructure constraints.

3.4.1 Regulatory Environment Barriers

Most interviewees (14 out of 15) cited the complexity of the Yukon's regulatory environment as a barrier to technology adoption in the mining sector. Depending on the type of mine, a mining operation may be required to provide detailed evaluations and impact assessments of any proposed technologies in order to secure permits, licensing, and/or approvals from multiple governance organizations. Some interviewees noted that the complexity of the Yukon regulatory environment stems from a heightened sense of responsibility and scrutiny within the Territory after mining governance authority was transferred from the Canadian federal government in the early 2000s to the Yukon Environmental and Socio-economic Assessment Board (YESAB) and other territorial organizations. For example, Yukon Mining Industry Expert 1 explained that:

Yukon, and something like YESAB, is feeling the weight of that responsibility. So, they're very reluctant to recommend projects. There's a lot of things that are getting bunged up, and in part, not even necessarily the quality of a proposal coming forward. It's this collective anxiety about, if we make a decision, and the decision is wrong, we are now on the hook, and we could actually affect the future and sustainability of the Territory, so that that's something that I know people are getting caught into, and the way they're dancing through that is with the legalese.

The heightened responsibility of mining governance may also be a result of the Yukon's deep history of mining and the lasting environmental impacts of previous, less-regulated operations in the Territory. As Yukon Mining Industry Expert 6 noted: *"The Yukon has been scarred by a lot of mines that have not been operating it very ethically in the sense of they didn't provide enough security and then they're abandoned."*

Other interviewees noted challenges related to the Yukon's current permitting process and long backlogs for approvals. For example, Yukon Mining Industry Expert 8 discussed how *"So it's a complicated process. So, we have independent assessments. We have [a] government agency that issues one license and then we have an independent board that issues another license for the one project."* They went on to explain that this complexity can be especially difficult for smaller mining companies:

We just heard from a company, they kind of bank on 8 years to get from assessment to having a license. If you can weather that then it's fine. Probably small single asset companies maybe have a harder time of getting through that

and being able to fund that kind of process. But the bigger companies [have]no problem, I don't think.

Yukon Mining-Related Technology Company Representative 1 noted how increasing regulatory complexity has reduced the number of active permits for mines:

Five years ago there was 350 active water licences and now there's 150. So it's moving into Territory where only bigger companies and there's a couple of them, there's not many of them, but there's, you know might be four or five guys who have 20 plus workers, right. And it's getting to the point now where it's only the guys with the real money [...] and the real like, you know stake in the game that can afford to fight [...] those organisations to get the licensing and stuff, you know. So the smaller guys just [...] say, Oh well, I'll go do something else.

Similarly, Yukon Mining Industry Expert 7 discussed how permitting complexity has compelled some mining companies to relocate operations elsewhere:

And I think a majority of the companies are, and they're understanding that, and there have been some, I would consider to be colossal policy regulatory permitting failures that companies have experienced either directly through government or through the courts even, over the course of the last 10 years that are really giving the industry, especially those operating here, pause for thought, knowing as to how they would operate here, but how they're going to operate globally and those that are already operating globally are attuned to what is happening here and are either engaging in it, or retracting and engaging in other countries with less emphasis on ESG.

In addition to regulatory complexity, some interviewees (3 out of 14 who mentioned regulatory challenges) pointed out that Yukon assessment systems may not be designed to promote innovation or adoption of new technology. For example, Yukon Mining Industry Expert 2 noted that:

I think our system, our assessment and licensing system is not only, it's not set up to promote innovation or use of new technology, and in fact I think it doesn't even really facilitate it. It certainly doesn't promote it. But I think it mostly gets in the way. I think it's because our system, our assessment and licensing system and even the enforcement system is really set up to highlight negative impacts and risks, and this is probably true of most jurisdictions, but I think particularly true here.

Yukon Mining Company Representative 1 similarly discussed how new technology is difficult to justify within the permitting process:

Building a new mine and [...] going to get a lot of public scrutiny, as it should, bringing in a new technology for those that are against the project is just an easy target, right? Right. And its like "Oh well, you know prove to me that this is going to work" and you're like "Oh, well... its new." Right? And here's all the studies. And then it's like, OK, well, that was done in the lab. And, you know, this is in the real world and it gets very difficult to justify these new technologies through, a new technology through a permitting process.

Some interviewees (3 out of 14 who mentioned regulatory challenges) also discussed how the anticipation of new mining legislation that is currently under development in the Yukon adds to the complex situation for mining technology adoption. For example, Yukon Mining-Related Technology Company Representative 1 explained that:

Right now they're going through a big legislation change. Because a lot of the mining legislation in regards to the placer industry or even the hard rock industry hasn't changed in 100 years [...] since they were mining up here with, you know, gold pans[...] so a lot of that's changing a lot of the environmental stuff's changing. So, you know what are licenses and that sort of thing, there's a lot [...] more pushback you know.

Similarly, Yukon Mining Industry Expert 8 discussed how shorter-term political initiatives drive a continually evolving regulatory environment for the mining sector:

I mean, regulators move the bar around because politicians get elected, and they're elected on platforms of greenness or employment that or whatever. So, when they follow through on their political commitments, it leads to, you know, revision of standards or new legislation or updates of regulations and so [...] the public, through government, drives it to some extent.

3.4.2 Uncertainty and Risk Perceptions

The majority of interviewees (12 out of 15) also noted uncertainty and risk perceptions as a main barrier to technology adoption in the Yukon mining sector. As Yukon Mining Industry Expert 1 explained: *"part of where that comes from is a total misuse of new technologies in the past."* Some interviewees (3 out of 12) described how the perception of risk has influenced the review of technologies during the assessment and permitting processes for mining companies. For example, Yukon Mining Industry Expert 2 described how *"... if you're proposing something that isn't proven or there is some uncertainty with it, you're going to get held up in the assessment process and asked for more information as a means of managing the uncertainty."* They continued by raising the question: *"how do you convince the shareholders and that community of people that, you know, it's worthwhile?"*

Other interviewees described how different types of technology may generate different levels of uncertainty about risk. For example, Yukon Mining Industry Expert 8 explained that:

So, it would entirely depend on what kind of innovation it is. So YESAB has what are called assessable triggers. So if we got an application and said OK, we said we were going to do a mine, you know, underground mining using this mining fleet. But now, we actually want to do it remotely. And here's what we have proposed. We would go and look to see does it create an environmental effect that wasn't already assessed? [...] are you required to have a bigger footprint, you know, are there things that you need to do to implement that technology that we didn't previously consider in an assessment, so going from a diesel operated [...] underground fleet to something that's [...] electric [...] or remotely operated vehicles that wouldn't necessarily trigger one unless there was like, with that, came a bigger power plant and that changes the megawatts that are required and that has to go through an assessment because you need more fuel on site that wasn't considered, or you need more, you know, more infrastructure that wasn't considered, that might happen.

Uncertainty about new technologies and their perceived risks may also limit the potential financial support for technologies from government organizations, investors, or lenders. Most interviewees (9 out of 12 who discussed uncertainty and risk perceptions) described how uncertainty about technology can prevent mining companies from accessing the needed funding to explore, trial, or test new technologies. As Yukon Mining Industry Expert 11 explained: *Because if there is no support from the government in terms of capital or funds available for people to, you know, make wise use of technology or able to explore the usage of technology I think these are going to be some of the barriers.”*

Some interviewees (3 out of 12 who discussed uncertainty and risk perceptions) noted that technology validation or evidence-based assessments may help address barriers related to uncertainty or risk perception. However, achieving validation or even finding the qualified personnel to assess technologies in the Yukon can be difficult. As Yukon Mining Industry Expert 7 explained:

But a technical advisor will evaluate any new technologies. We also require the elements of anything new is fine. People are for that. But there has to be something to substantiate it. There has to be some kind of verifications, whether it's from a professional engineer licensed to practice in the Yukon to do a secondary review and comment. So those kinds of things once they've been endorsed by professional opinion the board is satisfied with those type of things. From what I have seen. But they want things substantiated. You know, they want evidence-based stuff before they say yay or nay.

3.4.3 Lack of Labour and Skills

Another key barrier to technology adoption discussed by interviewees is the lack of skilled labour needed for operating, managing, and maintaining new technologies. As Yukon Mining-

Related Technology Company Representative 3 described, it can be difficult for mining companies to find and hire workers with the required skills who are also willing to work in the remote and harsh weather conditions of mining sites in the Yukon:

It's good that you have a technical aptitude. But now you're gonna go to a basic bush camp. And oh, it's gonna be rainy and windier like, do you like this? Because that's what like [you are going to have to do for] many thousands of line kilometers? And you're gonna be out there in these elements, remote area and things like that. So it's a interesting little balance of aptitude [and] appetite to actually want to, or do you want to be in a remote spot. Do you want to have these types of challenges where rarely anything works?

Interviewees discussed how skilled labour must often be sourced from outside the Yukon. For example, in terms of finding a technician who could operate the needed water analysis digital technologies, Yukon Mining Industry Expert 9 explained that “when it's more complex you know, you're going to have someone that requires a higher level of certification and it's unlikely they're going to come from the Territory.” Some interviewees expressed concern about the Yukon mining sector’s reliance on skilled labour coming to the Yukon from elsewhere. For example, Yukon Mining Industry Expert 1 described:

And you know again, we also have a really mobile workforce. And so, although there's a real desire to have a significant number of people who are from Yukon working in the mines, there just aren't enough people. There are forty thousand people total in the Territory and not everybody wants to be a miner. So we're bringing in people from other jurisdictions and I think increasingly, there's an expectation on that side, too, for if you're working in a mine down in BC and you come up here and you're asked to go underground.

3.4.4 High Costs and Inadequate Funding to Support Technology Adoption

Some interviewees (4 out of 15) cited the high costs of technology and the inadequate funding available to support technology adoption as key barriers to adoption. Because many mining companies in the Yukon are smaller “junior” organizations, the high costs associated with purchasing and maintaining emerging technologies may be prohibitive. As Yukon Mining Industry Expert 1 explained: “And so, I'd say with Yukon, we're kind of on the cusp in that. Right now, you still have junior companies, or companies with not deep pockets, and so they can't afford the new technology.”

Despite this barrier, some interviewees noted that Yukon mining companies would be eager to adopt cleaner or greener technologies if they were available at a competitive cost to existing approaches. As Yukon Mining Industry Expert 4 described:

So, reliance on diesel, for example, is, you know, we keep getting asked what can we do to support you in getting less reliant on diesel? There isn't a good answer. If there was a way for an operator to mine cheaper, they're going to do it tomorrow. They'll do it this second. Because they're completely self-funded. There's no public businesses. There's, you know, it's their, it's them. So if they can save money and you know, burn less fuel to make better power, great. But there's just no technology available yet.

Interviewees also noted that funding or incentive programs from government or other sources would help to accelerate technology adoption in the mining sector. For example, Yukon Mining Industry Expert 4 explained:

I think funding from the government would really help. I don't know what it is, but if we want to incentivize innovation and technology and evolution of mining and reduction of environmental impacts, whether they be to water or, you know, greenhouse gas emissions, the government has to incentivize that. And in some way like here, we'll pay. Pay part of your security payment or we'll take that on. Like, you know, Government of Yukon, don't worry about this cost, we the Government of Canada are good for it you know in like security insurance type of arrangement in order to facilitate this company trying some new technologies.

3.4.5 Mining Culture and Attitudes

Another barrier discussed by some interviewees (6 out of 15) was how the unique culture of mining in the Yukon may influence technology adoption. Despite Yukon University's regional effort to drive innovation and new technologies in the mining sector, interviewees noted that mining companies may be skeptical of new technologies that could require changes to mining operations and processes. Yukon Mining Industry Expert 9 described the Yukon University's efforts:

Yukon University has a whole programming, a whole course in regards to innovation and mining technology. So there there's clearly a drive for that and a push for that to bring in new technologies and be innovative and how we can do things because Yukon is very supportive of mining. It is essentially a main contributor to our economy. So therefore, how we can do things in a cleaner way and making smaller footprints is always going to be endorsed.

However, other interviewees noted that some mining companies may be slower to consider new technologies or skeptical of evolving their existing mining practices. For example, Yukon Mining Industry Expert 7 explained that some organizations may believe that “*from a company perspective, well, ‘we've always done it this way.’ So it takes time for adoption. It takes time for a ship to turn direction.*”

As interviewees highlighted, the perceptions of new technologies may be influenced by the specific type of mining operations as well. For example, many placer operators in the Yukon come from multi-generational lines of family members who have passed down tacit knowledge and mining skills specific to their mine site. New technology may not easily utilize or adapt to these site-specific processes or approaches honed by families over time. As Yukon Mining Industry Expert 4 explained:

So with the Yukon placer operators, 90% of our mines are families. So it's very similar to agriculture in that respect. It's multi-generational. On average, there's 2 1/2 generations of family per mine and the impacts of mining is relatively short scope compared to hard rock operations." They went on to say that "the industry is full of people who love DIY. Right. So that's why they do it. It's a huge part of who they are, yeah.

3.4.6 Technology Barriers and Infrastructure Constraints

Interviewees noted a number of technology-specific barriers and infrastructure constraints that may limit adoption of new technologies in the Yukon mining sector. For example, Yukon Mining Industry Expert 1 explained: *"How come we're not in a more automated environment? Partially, it's related to the availability of Internet and our bandwidth capability and people to be able to access Internet remotely. That's still a challenge that over the next couple of years is going to be resolved. There's a lot of work here as far as connecting communities and different sites, locations"* Similarly, some interviewees (3 out of 6 who discussed technology barriers and infrastructure constraints) noted that the power grid infrastructure is a limiting factor for technology adoption. Yukon Mining Industry Expert 3 described how:

Many of our mineral deposits are not on our power grid and our power grid doesn't have the capacity to [...] supply power to any given mine. I mean connecting it would be prohibitively expensive and there's probably not enough megawatts for all operations to draw on our power so setting emissions targets that would be crippling to an industry may not be the wisest thing. Yukon is looking at connecting to the BC grid which would really open up opportunities for us because it would give us, and right now it's an entirely insular grid, mostly hydro based, and that's kind of the limiting factor for many companies, if they want to be on a grid.

Other interviewees noted that the smaller size of the Yukon mining sector relative to other regions may limit the advancement and investment in infrastructure. Yukon Mining Industry Expert 5 explained:

That's actually a good point is that some of these technologies, you need a threshold before they're effective and the Yukon is such a small jurisdiction and a standalone jurisdiction as an individual grid, could some of these be applicable? Take the drones thing. If only one company is using drones, is it worth [it] to have

a drone repair company? Probably not. But if 10 companies have 10 separate drones and they need servicing, you know every couple of months or whatever that might make sense. But just to reach that threshold to create local work skills, knowledge, whatever, we might not be there.

3.5 Impacts on Regional Development

As part of the technology discussions, interviewees identified impacts on employment, skills and training, and regional development. With regards to employment, we asked whether adopting specific technologies had changed the number of jobs, the type of work available in the mining sector, and the skills and training requirements of these jobs. In addition, we inquired about the business development impacts, including opportunities for procurement or servicing. Similarly, we were also interested in identifying regional development impacts, such as infrastructure needs.

3.5.1 Employment, Skills, and Training

Interviewees highlighted several concerns about employment, skills, and training related to mining technology adoption. Two industry experts identified how drone technology can result in a decrease of the number of jobs, as a single high-tech drone operator typically replaces a group of low-tech drill rig assistants. For example, Yukon Mining Industry Expert 5 explained:

OK, so basically people in the late teens, early 20s, right. You're basically drill rig assistants. It's a tough job, but it pays well and your academic credentials, you don't have to have any, you know? But I mean, you're just helping out. You're a labourer essentially. So that form of employment is quite important, especially in the summer in some of what we call the 'Communities,' the areas outside of Whitehorse. Drone operators require a lot of technical skills and training. So there might be a bit of that at play in that these high-tech jobs get rid of low-tech jobs and that then is a negative to the Yukon. We're bringing in outsiders to fly drones. Meanwhile, people who used to have drilling rig jobs, what do they do?

However, Yukon Mining-Related Technology Company Representative 3 described how technology advancement has resulted in growth of high-skilled jobs within specific departments of their business. But recruiting and hiring for these job openings is often difficult. They explained:

The number of geologists employed by the company. Okay, well, that's higher. We're growing that division. So that's another pool of you know, staffing that that we like, we need to source. And I like, I don't know. It's just say, it's more challenging remote field-based work overtime, just demographically like people like working from home more often. People like a lot more comforts and things like that. As we go, we're really proud to be this lean and mean, you know, remotest place on the planet, we go and like, we're still trying to maintain that.

But yeah. So I guess yeah, back to the employment piece there, like, okay, we're needing more people with university degrees to satisfy the [...] component of geological mapping. And you know, geologists say 'add a drill rig running technical instrumentation' and things like that. So that's a bigger piece.

Other interviews described how new technologies and the current conditions of low unemployment in the Yukon create demand for skills and expertise that may only be sourced from outside the Territory. For example, Yukon Mining Company Representative 1 explained:

The challenge of the Yukon in particular is there's just, I mean, the low unemployment, I mean. We have a tough [time] finding people that want to, become conventional, you know, underground miners, pit miners. So, you know, just by ramping up the technology part of it, it just makes it even more challenging, you know. Really, it's about attracting people into the industry from a, you know, a country-wide, if not global perspective, that really drives that. I mean, and so, you know, again, for these, you know, mines being remote, there's always, I mean, you know being a good company, being a good operator in any jurisdiction is to try to employ as many local people as possible. I mean, this is sort of just again being a good corporate citizen 101. So the training is a big part of that.

Bringing non-local technology specialists into the Yukon can create other challenges, for example with housing. Yukon Mining Industry Expert 6 explained:

There's that criteria to hire Yukoners first. One of the things that I've noted with that is because of housing. So to be able to bring people even to move them to live here, to be able to work that technology is difficult in itself. If you're going to go like a little bit wider it's being able to house them. Because housing's a massive issue up here"

Even when the right technology specialists are hired, additional on-the-job training is typically required to prepare them for the unique demands of the Yukon mining sector. A Yukon Mining-Related Technology Company Representative 3 explained that their firm uses a mentor-based approach to training, where new hires are guided through multiple jobs under supervision to ensure they meet internal standards. This hands-on system is tailored to their operating environment and is seen as more effective than formal education alone. As the representative noted, there is currently “no university degree” that fully prepares workers for the practical, dynamic scenarios encountered on the job.

3.5.2 Regional Development

Interviewees also discussed some broader regional development implications related to adopting technology. For example, Yukon Mining Industry Expert 1 highlighted links between

mining technology, improved broadband internet access in remote areas, and the potential to make mining more sustainable:

So, you know, on that part, and I think it's deliberate on the part of Canada. It's bringing people into the digital economy, but it's also on the part of the North, making it far more accessible to resource development. I mean, it's, however communities will look at it, on the good side people have better access to Internet and hopefully if everything goes through, the permitting, and there's a decision and a will and a desire to mine in a specific region, probably with the availability of Internet. It's also a greener enterprise. And hopefully that would sit better because right now you'd have to fly or drive trucks in. And with that you're holding a lot more fuel. You're holding a lot more different potential contaminants on site than you ever would if you had a far more automated environment.

Some interviewees also noted that improvements to the Yukon's power generation and grid infrastructure would facilitate adoption of mining technologies and result in more sustainable operations. For example, Yukon Mining Industry Expert 8 explained:

Just looking at how to reduce emissions at mines in the north and, you know, more efficient equipment [...] a lot of our operations are diesel operated generators. They're not connected to the grid. [...] I think there's going to be a push to different technologies, or whether it's operations like different kind of equipment fleets, different processing technologies that use less energy. I could see those coming in as the Yukon establishes the, you know, net zero by 2050 or 30% reduction by 2035. That those kinds of targets I could see us getting applications and requests along those lines.

Yukon Mining Industry Expert 6 explained that current infrastructure limitations make it difficult to rely on technology. They described how grid infrastructure improvements would be critical to open the possibility for adoption of new power generation technologies, as well as mining-specific technologies:

But I'm just saying that like when you're looking at infrastructure, when it comes to being able to do stuff, for example, our Internet went down from a fire that happened 950 kilometers away from us... Infrastructure is not necessarily the most robust to be able to, say, bring in a small modular reactor and be able to upkeep it and be able to ensure that it is safely operated.

3.6 Innovative Programs and Responses to Impacts

We asked interviewees to provide information on any organizations, initiatives, or programs that respond to the impacts identified above. As seen in Table 3, interviewees discussed a range

of stakeholders involved including the private sector, all levels of government, post-secondary institutions and industry associations.

Table 3: Organizations, Initiatives, or Programs that Respond to Impacts

Program	Lead Organization	Scale	Description
New Minerals Legislation	Government of Yukon	Territorial (Yukon)	Replaces outdated Quartz and Placer Mining Acts. Aims to modernize mineral resource management by incorporating Indigenous rights, environmental protection, and economic viability.
Centre for Northern Innovation in Mining (CNIM)	Yukon University	Territorial (Yukon)	Offers flexible, northern-focused mining education and research. Connects students and industry through hands-on training, mobile classrooms, and simulators. Supports innovation and workforce development.
Yukon Chamber of Mines	Yukon Chamber of Mines	Territorial (Yukon)	Industry association advocating for responsible mining. Represents 650+ members and supports industry partnerships with governments and First Nations.
Yukon First Nations Mineral Engagement & Consultation Tool	Yukon Chamber of Mines & Yukon First Nations	Territorial (Yukon)	A digital and print resource developed collaboratively with all 14 Yukon First Nations. Informs industry on consultation practices and Indigenous governance in mining.
Yukon Mining Alliance (YMA)	Yukon Mining Alliance	Territorial (Yukon), with National/International Outreach	Alliance of Yukon-based mining companies promoting Yukon's investment appeal through international conferences and marketing initiatives.

Source: Created by authors

3.7 COVID-19 & Mining Technology Adoption

Given that this project was funded during the height of the COVID-19 global pandemic, we were also interested to learn if the pandemic had an impact on mining technology adoption. Interviewees noted a number of shifts, including an increased interest in technology; a greater comfort with digital tools like online meeting tools while also reducing the need for in-person meetings; and an increased awareness of challenges related to global markets and the Yukon mining industry's regional economic impacts.

For example, Yukon Mining Company Representative 1 described how the Yukon mining sector increasingly considered technology in order to maintain operations during the COVID-19 global pandemic:

I mean, I think, you know if it did anything [...] it actually, sort of, maybe led to an increase in some of the technology discussions... The mining industry in Canada

was considered a critical industry during COVID, so it didn't stop, and, you know [...] they had to use technology. They had to be sort of nimble in terms of making sure that they didn't end up without breaks and this that and the other thing.

Similarly, Yukon Mining Industry Expert 7 explained how technology and innovation was necessary for Yukon mining companies to continue operations and meet ESG requirements:

And I saw innovation actually play a role in ensuring that Yukon had a viable and operating mining industry even during COVID. So, you know, Yukon companies were able to implement all of these, unbelievable... ESG principles and being global conglomerates, it has its advantages because best practices were employed here immediately... And these companies stepped up and were able to implement testing and procedures and protocols better than government had been able to roll out. And so when they did that and were able to demonstrate to not only to Yukon government but to First Nation governments, they were going to be able to keep their communities safe with the continued importation and deportation of people from mine sites through rigorous testing and isolation procedures. They were able to keep operating even during COVID.

Most interviewees (9 out of 15) highlighted how the pandemic increased the industry's comfort with online digital meeting tools and remote collaboration compared to relying exclusively on in-person meetings. As Yukon Mining Industry Expert 1 explained:

It used to be that they have had far more engagement on site, and so I don't know what that means to their communication, or how they communicated. But we know something different happened in that period, because I talked to a number of people who said they couldn't come into the Yukon, for [a] two-year window. And yet their mines continued to grow. They continued to advance some of their permitting, you know, depending on how big their property was. They might be trying to permit multiple projects at the same time.

This was echoed by Yukon Mining-Related Technology Company Representative 2 who noted:

We didn't Zoom before. It sort of showed that you can work remotely. I think we, you know, there was the initial hit, the surprise, the realization that this isn't going to be just two weeks long. As everybody adapted, we came back in Yukon, Yukon Government folks came back well before the Federal government did. I mean, I think right now there's a fair number of federal employees who still are just migrating back on a part time basis. But yeah, I mean, I think Zoom was or Zoom-like platforms were huge in sustaining our ability to function and then zoom became one of these exhausting things that everyone was Zoomed out and just craved in-person contact.

Finally, one interviewee described how the COVID-19 global pandemic increased awareness of challenges and opportunities related to global markets, labour, and the Yukon mining industry's regional economic impacts. For example, interviewees described how mining exploration and certain types of mining field work decreased during the pandemic, leading to a reduction of jobs in those specific areas. For example, Yukon Mining Industry Expert 6 described how

I had heard that exploration really dropped because [...] they couldn't raise money for the exploration [...] and then just trying to get workers [...] to come into the Yukon during COVID. It was a hassle and then they're in the field and then they can't really socialize in the towns, you know, because of COVID restrictions. So exploration really did drop off.

However, increasing gold prices during the pandemic resulted in shifts to additional capacity and budget toward innovative projects. As Yukon Mining-Related Technology Company Representative 2 noted:

Early 2020 was when COVID kind of came along and a lot of the environmental and geotechnical work dried up, mostly due to its government contract based and they weren't sending people out to the field. So we had extra capacity during that time and at the same time with all that going on, gold prices went up. So increased gold prices meant that these companies had a little bit more of a budget to play with. They're willing to try things and we had the time to do it. That kind of led to a few people taking a chance on what we were doing and typically like the cost of sonic drilling, is probably three to four times the cost of the other methods.

Similarly, Yukon Mining-Related Technology Company Representative 1 explained how "...gold was still going up. So there was a lot more people coming into mining... So sort of gold mining [...] the work that I do sort of was picking up more and more because of one they didn't shut the industry down and a lot of people, even down South, knew the industry wasn't shut down so that they were coming up and like because they couldn't do other work down South."

A number of interviewees noted that placer mining, in particular, helped to sustain the broader Yukon economy during the pandemic. For example, as Yukon Mining Industry Expert 4 explained:

And I have all kinds of businesses that said, if it wasn't for placer miners, we wouldn't have made it. So, I think that that's an interesting offshoot, is that we're, you know, almost 50% of the employment rates in Dawson, in Dawson based businesses like grocery stores, hotels, things like that are directly related to the placer industry. And then we're about 80% of the revenue.

With a long history of placer mining in the Dawson City region, respondents described the importance of the industry for all local businesses, including during the COVID-19 pandemic.

The local economy in the region is driven by the mining industry and its related services companies and required amenities such as food, recreation, accommodation, etc. for those employed in the sector.

4 Future Considerations

Finally, we asked Yukon Mining Industry Experts and mining technology companies about future Yukon Mining-Related technologies and their potential impacts on rural development. The majority of interviewees (9 out of 15) discussed an expected increase in automation, remote operations, and electrification. For example, Yukon Mining Industry Expert 7 described what increased automation might look like in the Yukon mining industry:

But my opinion is, five years from now, I'm going to do a quick snapshot. You know, I'm prospecting - I'm using online staking. I'm doing exploration - I'm using, you know, drones and low impact technology, and non-core samples anymore, right? Like I'm getting everything digitized. It's all real time on computer screens, right? So just taking the human elements pretty much out of it all together. And then for operating mines - it's automation, automation, automation, right. It's everything that's already occurring everywhere else. It's automation, it's electric, it's low carbon, it's transitioning away from high energy inputs and outputs to solar, to, you know, green energy, to passive energy, to passive reclamation... It's a lot more computer screens, remote controls, and staying out of those environmentally sensitive areas as much as possible will garner, or help garner support for any future mines to be open in the Yukon.

Similarly, Yukon Mining Industry Expert 1 described a future mining industry where technology might enable increased remote operations, with “people being able to use computers in a way to engage with equipment and processes on the mine site without having to be physically on the mine site.” However, they continued to explain that the implications of this shift in work location and labour would need to be carefully considered:

Where the danger is for Yukon, is not physically in the Yukon, and so where do the jobs go, and that comes into the impact benefit agreements. And really, do people want the jobs? Maybe they don't. But what sort of economic benefit will there be to a community, economic and social benefit? And those are really hard questions.

Some interviewees who discussed software and other digital technologies (2 out of 9) spoke specifically about how the Yukon mining industry might embrace these technologies that have been adopted in other regional mining sectors. For example, Yukon Mining Industry Expert 7 described how online staking, a software technology currently used in Newfoundland, would benefit the unique requirements of the Yukon mining industry:

This is not new technology, but another game changer when it comes to improving relations with Yukon First Nations and reducing impacts on the land. Something that's been in existence for decades in other jurisdictions. We still don't have yet, and really the red line for the industry when I was involved was around the concept of what is called Free Entry in the act. Free entry is an absolute lightning rod when it comes to First Nation relations and uh, the industry's role in, you know, being on the land.

Some interviewees (2 out of 9) expressed an expectation that technologies based on alternative or renewable energy would be increasingly adopted in the Yukon mining industry. For example, Yukon Mining Industry Expert 1 explained:

What we see, and we're told by industry, and it's all industry, is that yes, we will see changes in technology. Nobody knows where things are going to go. Are they going to go hydrogen? Are they going to go electric? The only known to date is that it's going to change. And you know the batteries will change. And so, if they go electric, you're going to have fewer gears, and you're going to have a fundamental shift in mechanics. If they go hydrogen, maybe not as much. And so, we're at the point where we're watching it. We haven't changed a huge part of what we do, because right now we still are basing everything on basic diesel or gasoline.

However, some interviewees noted that any large-scale shift in the Yukon mining industry's energy sources could likely only be driven by future legislation. For example, Yukon Mining Industry Expert 6 explained: *"But it has to be legislated. I don't know if you follow Yukon politics, but legislation, well, it's a brutal sport up here. Yeah, it will take you know, could take five years to get that through the [legislature]."*

5 Conclusion

This study has shed light on the multifaceted nature of technology adoption in the Yukon's mining sector—a region marked by its geographic remoteness, cultural richness, and socio-political distinctiveness. As mining enters a new era of automation, electrification, and digital innovation, our findings underscore that technology uptake in the Yukon is not solely driven by economic imperatives. Instead, it is shaped by a convergence of factors: the regulatory environment, energy and infrastructure constraints, Indigenous governance and stewardship, labour dynamics, environmental values, and the unique history and culture of mining in the North.

Emerging technologies—from drones and sensors to electric vehicles and digital mine planning software—offer clear opportunities for improving efficiency, reducing environmental impacts, and enhancing data-driven decision-making. However, the path to adoption is uneven and deeply contextual. Barriers such as regulatory uncertainty, funding limitations, skills shortages,

and legacy systems persist, particularly for junior miners and smaller operators. First Nations play an essential and often innovative role in shaping responsible mining practices and pushing for technologies that align with land stewardship, community priorities and community well-being.

The Yukon is at a critical juncture. The development of new minerals legislation, investments in training through Yukon University, and the activities of organizations like the Yukon Chamber of Mines signal efforts to modernize and future-proof the sector. However, meaningful progress will require coordinated and inclusive approaches that center Indigenous voices, anticipate workforce transitions, and provide targeted supports for technology validation and deployment.

Looking ahead, policy frameworks and research agendas must grapple with the socio-economic implications of remote operations and increased automation, particularly their potential to displace local employment and shift economic benefits outside of the Yukon. As such, strategies to strengthen regional infrastructure, build local capacity, and ensure community participation in innovation ecosystems will be key. Ultimately, ensuring a socially equitable, economically viable, and environmentally responsible future for Yukon mining will depend not just on what technologies are adopted, but on how, by whom, and to what end.

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