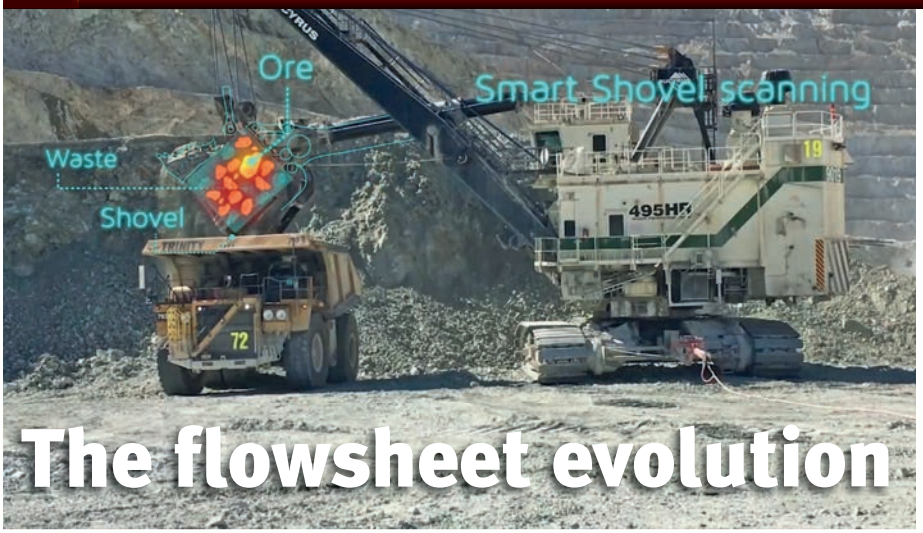


The flowsheet evolution

With the mining industry re-thinking traditional processing methods, a spot in the flowsheet appears to have opened for ore sorting. Dan Gleeson speaks to some of the leading technology providers in this space to find out how they intend to fill this gap

When last year Newcrest Mining announced it intended to acquire 70% of the Red Chris mine, in British Columbia, Canada, the company stated within its deal rationale that leveraging new technologies such as mass sensing and ore sorting could potentially turn the copper-gold operation into a Tier One mine.

While few miners have been as upfront as Newcrest in disclosing how such technology could provide them with a competitive advantage, it is certainly not the only company considering the use of ore sorting.

In addition to numerous diamond, phosphate and tungsten miners using sensor-based ore sorting, the likes of Agnico Eagle Metals, Anglo American, Hecla Mining, Silver Bear Resources and Teck Resources have all come out in support of the technology.

Whether it is bulk sorting, particle sorting or some other way of separating ore from waste, this is quite a turnaround for a group of technologies that have been left out of the process flowsheet for decades.

"It is slowly becoming clear that ore sorting needs to be considered and evaluated as a key potential unit process in the flowsheet," Albert du Preez, Senior Vice President of **TOMRA Sorting Mining**, told *IM*. "You should evaluate it appropriately as you would any other standard mineral processing in the flowsheet."

So, why has this only recently been recognised? The answer is down to a combination of factors.

First off – and a fact that is well documented – miners are suffering from grade declines.

Companies are running to stand still when it comes to retaining their ore grades. What was viewed as an average grade copper discovery 15 years ago is today considered high grade. And typically the lower the grade, the higher the production cost per tonne of material processed.

Water is another factor.

Related to declining grades, processing has become more water intensive. This is a problem in regions where drought conditions are observed. And, even in regions where water is not so scarce, the rise of social and environmental concerns over water use has increased the hurdles companies must jump over to gain access to new water sources.

Energy prices and consumption are another reason for the industry waking up to ore sorting's potential.

Comminution already accounts for close to 3% of the world's electrical energy use so anything miners can do to reduce their power draw by processing only ore, not waste, has a big impact on achieving ambitious global climate change goals. Miners are also addressing their power draw needs in the face of soft prices for some commodities.

Mining's physical industrial footprint is also part of this equation.

Whether it is tailings storage facilities, mineral processing plants or open-pit mines, the need to reduce mining's footprint is constantly made clear by NGOs at every AGM major mining companies convene. The ability to produce more metal within the same footprint is of significant benefit when up against such pressure.

And, of course, the technology associated with ore sorting has improved. With the advent of new and more powerful sensors and analytical tools, the accuracy, speed of ore detection and number of minerals that can be 'sensed' has substantially increased.

MineSense's ShovelSense XRF solution has been proven at Teck's Highland Valley Copper operation in British Columbia, Canada, where the miner now has three systems up and running in the pit (Credit: Teck Resources)

Re-think tank

Traditionally when existing operations are set to come to the end of their economic lives, an expansion plan is tabled to increase throughput, go underground, or mine a different orebody.

This normally involves a plant or fleet expansion and, depending on the size of operation, tens to hundreds of millions of dollars of investment.

It is this scenario where ore sorting could provide a much cheaper and efficient alternative, according to Chris Beal, CEO of **NextOre.** Pursuing such a solution can require a shift in mindset from mining teams and engineers, however.

"In conventional mining, once it's on a truck or in a bucket, the difference between one tonne of ore in terms of its grade and the next tonne is immaterial as, without a bulk sorting system, there is no way to practically make any benefit out of that," he said.

Without a tool to accurately measure the grade variation in ore following blasting and primary crushing, miners have been left to assume the rocks they feed through to the process plant are homogenous. If metal production from the plant happens to vary from week to week, they often conclude that something must have gone wrong downstream – an assumption often taken into mine reconciliation meetings.

Beal, a mine engineer himself, said: "There has not been a really reliable and accurate source of the grade of material as it comes out of the mine."

Bulk samples and geological and grade control work can be done at the face and in the pit, but something that "covers 100% of the material and is accurate to 0.01-0.02% is so outside of business-as-usual for mining people that it is not something they would consider in terms of value", Beal says.

In published data from Newcrest Mining's Ridgeway block cave mine (currently on care and maintenance) – where ore was fed by a whole grid of drawpoints to two different crushers, through the crushers onto a single conveyor belt – NextOre's magnetic resonance (MR) technology was able to show there was a considerable amount of variability in the grade of the material as it flowed past the on-belt magnetic resonance analyser (MRA), according to Beal (see diagram, right).

"For people to be able to watch in real time as ore comes out of the mine and see the statistically significant amounts of waste that are being processed as ore as a result of the fact that

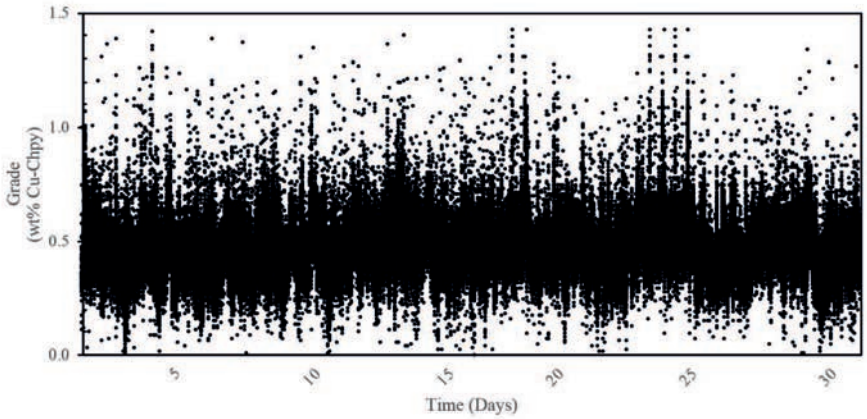
NextOre's on-belt Magnetic Resonance Analysers can operate at mining rates of as much as 5,000 t/h per conveyor belt with no material preparation requirement, according to the company (Credit: NextOre)

mining is a large-scale process is a big deal," he told ***IM***. "That new information could change people's way of thinking about ore sorting."

The powerful sensor-based ore sorting solutions that NextOre and others provide are built to exploit the natural heterogeneity that comes with large-scale mining and, through a separation method, reduce the amount of waste currently processed as ore.

Contrary to initial industry belief, this does not necessarily lead to lower metal production.

"With ore sorting, you can create ore from the



NextOre MR analysis of measured chalcopyrite content of crushed ore produced by the Ridgeway mine for one month. Every measured 20 s point is displayed with an instrumental resolution of 0.05 wt.% Cu-as-chalcopyrite (credit: Consequences of fractal grade distribution for bulk sorting of a copper porphyry deposit, Peter Coghill, David Miljak, Elizabeth Williams)

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IMA Engineering's Ilpo Auranen says ore sorting sensors work best just after primary crushing as that is where the ore and waste can still be effectively separated

waste," Ilpo Auranen, Chairman of **IMA Engineering**, a firm that specialises in testing and installing ore sorting systems, says. "At a typical open-pit mine, the mining cost (factoring in ore and waste) is $10/t of ore. With ore sorting it is less than $1/t, which means that the cutoff rate for the whole operation can be reduced significantly."

This is why it should be factored into the mine expansion debate with plant and fleet upgrades as the presence of an effective ore sorting system can lead to higher metal production using the same plant inputs.

Beal said: "If they can feed all of the ore they would have sent to an expanded plant to a bulk ore sorter, they can deliver a substantial amount of metal out of that in a much reduced amount of tonnage.

"You have effectively bumped that metal production back up without having to spend that capital (associated with a plant expansion), expand the tailings pond and start using twice as much water and electricity, as well."

More than profit

As Beal indicates and du Preez confirms, the reasons for employing ore sorting at mine sites are multifaceted and depend on the commodity, operation and environment in question.

"In general, I believe reducing water, energy and reagent consumption, is one of the major ones," du Preez said in answer to a question about the main reasons mining companies employ ore sorting.

"In turn, this reduces the environmental impact of processing ore, and consequently leads to significantly less time spent on environmental permitting."

As explained earlier, with water scarcity concerns rising, obtaining permission to either expand wet tailings ponds or increase water uptake from local sources has become increasingly complex. This has seen ore sorting being included alongside the use of dry stack tailings in economic studies for either brownfield expansions or greenfield assets.

The footprint dynamic is also on the list of reasons.

"Removing waste from ore prior to final processing reduces the size, cost and often complexity of the downstream processes," du Preez said.

Auranen said existing waste stockpiles can be reprocessed and recovered too, freeing up land for other activities that may strengthen a company's social licence to operate.

And, in some instances, ore sorting can lead to a change in mining method from selective mining to bulk mining, according to Auranen.

"When we talk about automation and robotisation of mining machinery, this bulk mining makes it all much simpler," he said. "You wouldn't need to separate ore and waste in the mining process – the ore sorters would effectively do that."

When it comes to greenfield projects, employing ore sorting can lead to mining companies being able to more accurately size their processing plant from the off.

Beal explains: "The larger value proposition (both in terms of straight economics but also for reductions in electricity/water consumption and reductions in tailings generation) is the application of this technology to projects where a processing plant has not yet been built, and being able to build a significantly smaller plant while maintaining planned product output."

It's hard to find examples of this, such is the dearth of greenfield projects moving forward, but NextOre has aligned itself with one in Australia.

The Magnetite Mines-owned Razorback Iron project, in South Australia, is the asset in question, with a recent report from the two companies demonstrating that the natural heterogeneity of the Razorback and Iron Peak resources would potentially allow for significant upgrading from ore sorting.

"For example, at a 50% rejection level (corresponding to a cutoff grade of approximately 16% Fe at Iron Peak and 14% Fe at Razorback), the grade of the accepted material would be increased by a factor of about 1.4," Magnetite Mines said.

Were this to be implemented as part of the project's development – by increasing mining rates, and pre-concentrating the plant feed – the throughput of a given plant capacity could be increased by some 40%, the company said. This would translate to significant savings in capital and operating costs per tonne of concentrate product.

Due diligence

Not all sensor-based ore sorters will be able to produce results such as these.

du Preez explained: "People are gradually becoming more aware of the potential value that sensor-based sorting can add to their business. It needs to be evaluated as a potential key processing step in the flowsheet development of the project."

NextOre's Beal is upfront about this fact, explaining that his company's MR technology, originally developed by CSIRO, is currently configured for around three dozen minerals at this stage – copper, iron ore and gold among them.

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A TOMRA XRT ore sorting project at Minsur's San Rafael mine in Peru has both increased plant capacity and improved overall recoveries at the tin operation

"If you don't have an orebody that has the applicable minerals then MR is not going to be terribly helpful," Beal said. "Yet, it offers incredibly precise measurements when it is applicable."

It does this using a conveyor belt-mounted MRA, which uses a form of radio frequency spectroscopy for the quantitative measurement of target ore minerals.

Beal provides an example: "MR's sensitivity comes from the fact the system is 100% blind to everything except the tuned target mineral. If we tune it to chalcopyrite, for example, that's all it will ever see, but it's able to sense this incredibly quickly because nothing else is producing a signal at exactly that radio frequency."

It is this technology that enables NextOre's on-belt analysers to operate at mining rates of as much as 5,000 t/h per conveyor belt with no material preparation requirement, according to the company. Even operating at these rates, it can provide grade readings in seconds enabling customised diverter gates to react in real time to this information.

This makes it a bulk sorting solution, hence the reason why copper and iron ores have been configured as target minerals.

Within this same bulk sorting category is **MineSense**'s ShovelSense in-pit solution.

This product uses X-ray Fluorescence technology (XRF) to analyse the ore that comes in contact with shovels. The ShovelSense platform uses a combination of powerful XRF sensors, software and proprietary algorithms to provide real-time grade control and ore routing decisions at the point of extraction.

This solution has been proven at Teck's Highland Valley Copper (HVC) operation in British Columbia, Canada, where the miner now has three systems up and running in the pit.

MineSense CEO, Jeff More, said Teck is moving 120,000 t/d using these ShovelSense-equipped shovels as part of a commercial installation. In trials at HVC, the miner said it had seen a net "measurable increase in the amount of ore (and the associated head grade)".

While trials in Chile (copper), Peru (copper-zinc), Alaska (zinc-lead) and Sudbury (nickel) have all proven valuable to the miners in question, More stated the application of the platform was currently focused on these commodities as well as iron ore.

The cutoff points for the likes of TOMRA's sensor-based ore sorting solutions are a little harder to ascertain as its sensor options include Colour, Near-Infrared, X-ray Transmission (XRT), Electromagnetic and Laser.

This combination has seen the company's technology prove decisive at tin, gold, rare earth, diamond, coal, quartz, tungsten and phosphate operations.

With this experience and the company launching its COM XRT 2.0 units in 2018 (able to analyse up to 400 t/h per unit with the conveyor belt running at up to 3.5 m/s), du Preez thinks TOMRA's ore sorting solutions could compete with bulk sorting products like the ones NextOre and MineSense are delivering from a scale perspective.

"With time – and we're almost there – the sorting technology will be so good that it will be more economically feasible – and significantly more accurate – to sort ore that was previously done via bulk sorting with sensor-based sorting," he said.

With all these technologies, there is the potential for effective ore sorting outside of the 'primary' target minerals depending on the mineralogy of the deposit at hand. "Where there is

Snow Lake Resources is one of the latest companies to eye up ore sorting to reduce costs and increase productivity, with the exploration company asking DRA Global to collaborate with **Steinert** and come up with an effective strategy for its Thompson Brothers lithium project, in Manitoba, Canada.

The engineering firm will examine the best laser or X-ray method to help separate out waste material from the spodumene pegmatite at Thompson Brothers, Snow Lake said.

Over the other side of the world Steinert is involved in a sorting project for a rare earth asset.

Recently Northern Minerals capped off its ore sorting project enhancement initiatives at the Browns Range rare earths project, in northern Western Australia, with the selection of a Steinert ore sorter for use at its heavy rare earth pilot plant.

Northern Minerals said it expected the system to be installed by the middle of the year.

The company said: "The findings from initial test work and studies indicate that the inclusion of ore sorting at Browns Range has the potential to double the mill feed grade potentially leading to an increased production rate of heavy rare earth carbonate and a potential lowering of operating costs."

XRT ore sorting is also being evaluated at North Arrow Minerals' 100% owned Naujaat diamond project in Nunavut, Canada.

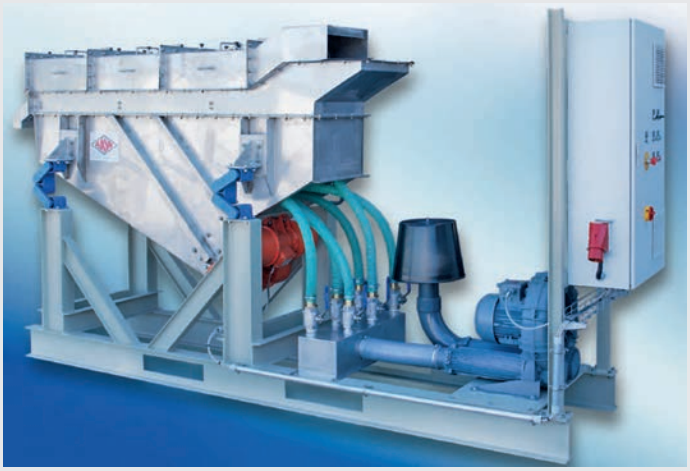
In May 2019, the Toronto-listed company confirmed it had engaged **Imilingo Mineral Processing** of Pretoria, South Africa, TOMRA, and Microlithics Laboratories of Thunder Bay, Ontario, to investigate modular diamond recovery design options incorporating TOMRA's XRT sorting technology at the project.

The engagement is with a view to recovering diamonds greater than 3 mm (nominally >0.5 ct) in size from a diamond recovery plant, it said.

North Arrow is currently planning for collection of a 10,000 t bulk sample from the Q1-4 deposit at Naujaat and, as part of this work, has initiated an engineering design and costing study of a small-scale mobile diamond recovery plant.

Imilingo's iPlant packages combine XRT solutions from the likes of TOMRA to sort and deliver feed material in a clean and well classified state, Managing Director, Jaco Prinsloo, told ***IM*** last year. Microlithics Laboratories, meanwhile, provides several diamond-specific services to clients in North America.

It may not be sensor-based ore sorting, but **allmineral**'s alljig® units have gained recognition across the industry for their ability to separate high-value ore from waste in primary and secondary raw materials such as coal, ore, gravel, sand and slag.



The AKA-FLOW functions on a combination of an air fluidised bed with a specially developed sifter

The company, in November, announced that Yunnan Hualian Zinc and Iridium Co Ltd had awarded the Dusseldorf-based company with a contract for the supply of three advanced alljig units to the world's largest "multi-mineral plant".

The order included two F/R type, single cut, side pulsed alljig units with an enhanced shaft system and one M(UB) type 2 cut, under pulsed alljig unit incorporating allmineral's poppet valve system to significantly reduce air consumption. The latter unit will also be fitted with the allscan® chamber monitoring system for enhanced operation, it said.

alljig units fluidise feed material using pulsating water to form layers of grains according to their density, which subsequently separates the heavy material from the stratified material bed. Electronic sensors are used to automatically monitor and control the discharge of heavy particles contained in the feed, with the jigging machines creating a physically stable and individually adjustable optimal jigging stroke at minimal energy consumption by means of air-pulsed water, according to allmineral. These machines provide capacities ranging from 5 t/h up to 700 t/h, with separation and cleaning of feed material applicable in grain sizes from 150 mm down to less than 1 mm.

Density separation is also the focus for **AKW Equipment + Process Design** and its AKA-FLOW product.

As a dry operation gravimetric sorting device used for preliminary separation and enrichment of materials of different densities, AKA-FLOW is often used as a pre-treatment process ahead of wet mechanical separation.

The company says limited availability of water in arid areas has led to the need for additions and amendments to wet mechanical processing technology. "Dry gravity separation ensures, among other advantages, eco-friendly processing, low energy consumption as well as potential cost reductions due to obviating process water circuits and product and tailings dewatering and drying processes," it said.

The AKA-FLOW functions on a combination of an air fluidised bed with a specially developed sifter, with studies looking at different raw materials showing "outstanding performance" both in terms of throughput and classifying, the company said. The optimum grain size ranges from 30 µm to 2 mm, with throughput ranges, depending on the material, of 3-6 t/h based on units of 400 mm width of the fluidised bed, and 9-18 t/h with units of 1,200 mm width of the fluidised bed.

According to the company, product purity and output can be influenced by five adjustable parameters:

- The feed mass flow: controlled via a vibro channel, this allows an equal distribution of the feed material over the screening surface;
- The split preparation, which has influence on the amount of the intermediates;
- The number of strokes controlled via the rpm of the unbalanced drives. The higher the frequency, the faster the material transport via the screening surface;
- The amplitude, which can be changed through the adjustment of the weights; and
- Airflow, which is produced by a fan and passes from below through the screening surface. This generates the fluidised bed.

To achieve and ensure optimum sorting results, each material has to be tested in accordance with the process and machine parameters above.

In its technical laboratory in Hirschau, Germany, AKW can perform a variety of tests for customers with all relevant processing equipment for classifying, sorting, solid/liquid separation, gravimetric preparation/dry separation, thickening, dewatering and magnetic separation, it said.

The laboratory is equipped with a small, as well as large, AKA-FLOW test device, allowing for pilot tests to be carried out.

And, for the dry separation machines, control for the regulation of the solid concentration of the heavy fraction output has been successfully developed, it says.

no direct detection, then a proxy is often used," Beal said, explaining this is exactly the case for NextOre's MRA gold detection process.

Regardless of which technology is chosen over the other, what is undisputable is the fact that these sensors all work better at the front end of the process flowsheet where ore is more heterogeneous.

Auranen concluded: "We have conducted several studies analysing the ore distribution – typically after primary crushing. Why after primary crushing? That is where the ore and waste can still be effectively separated. When the material goes to an intermediate stockpile and to further crushing and grinding, it gets homogenised."

New developments

The industry might still be in the process of assessing how it can best use the current crop of ore sorting technology on the market, but those companies leading this change are already preparing to launch new solutions to widen their sensing and sorting scope.

NextOre, which has an MR analyser currently installed on a 4,000 t/h conveyor at Newcrest Mining's Cadia East block cave copper-gold mine in Australia and has two units ready for shipment to Southeast Asia copper operations, has plans to expand its mineral analysis capabilities through the addition of new sensors, Beal said.

He explained: "The tendency for finer particles within a copper sulphide orebody – in particular, porphyries – to carry a disproportionate amount of the metal within the orebody means that if you can simultaneously track the particle size of what is going across the belt and its precise grade, then you can start making decisions based on these two characteristics (particle size and grade)."

He said that the company has already incorporated such a design into its new generation of process flow diagrams for bulk sorting.

Beal added: "You could get to the point where there is almost this designer mill feed and the metallurgist in charge of the plant on any specific day could plan for what is going to be fed through, making sure the variation coming in is eliminated before it goes into the process plant."

On top of this, Australia-based NextOre recently received a A$1.07 million ($720,995) grant from the New South Wales Office of the Chief Scientist & Engineer, through the Physical Sciences Fund, to adapt its existing on-conveyor MRA to in-pit mobile mining machinery.

With another A$500,000 raised through a private placement to support the development and the help of "a leading global supplier of heavy mining equipment and service support", it is confident of delivering an integrated system that is "highly adaptable and efficient", it said.

Beal said the company has also received interest for a sensor to measure the grade of material carried in trucks.

"We are working with both manufacturers and customers on surface and underground configurations at the moment," he said, adding that both will be initially developed for copper detection and expanded to other commodities.

Similarly, the MineSense team is involved in both sensor and application developments.

More told *IM* that the company was currently working on a commercial installation of its ShovelSense on the bucket of underground loaders. This would build on the trials and commercial ShovelSense installations on excavators above ground.

"For underground, we think adapting the core technology will be relatively straightforward and very applicable to what we have designed for surface shovels, but one of the things we need to study is how the sensor deals with, for example, the top of the bucket coming into contact with the roof of the mine," he said. "It's that physical contact we need to work on."

The company already has a trial ongoing at an integrated nickel operation in Sudbury, which it is hoping will be converted to a commercial installation before the year is out.

The MineSense R&D pipeline also includes the testing of additional sensors on top of its existing XRF solution.

These would either be standalone sensor types or a combination of sensors, according to More, who said he was expecting R&D testing to take place this year before two new sensor-based solutions become commercially available, possibly by the end of 2021.

"These will both extend the metals we can look at – beyond our current range of copper, nickel, zinc and iron ore – and also create other value adds within those four core segments," he explained.

While he was not ready to give any information away on what types of sensors might be included in a future ShovelSense or BeltSense (MineSense's on-belt ore sorting solution) platform, he did admit retaining the company's speed of analysis is of utmost importance in this process.

"Our XRF systems are right now extremely fast – faster than any other sensor on the market from what we see. We see that as one of our core strengths," he said. "We will introduce other sensor types under that objective, looking to maintain the vast speed of our XRF with these new sensor types."

TOMRA is also not standing still.

Having built up a stellar reputation in the diamond space that has seen many miners leverage its XRT technology to recover massive rough diamonds, du Preez said the company is working on a final recovery solution for this sector where a TOMRA unit can handle various diamond streams in a very compact sorter down to 2 mm in size.

Future adopters

Even with these product enhancements, there will be no 'one-size fits all' approach to ore sorting.

Each solution will be tailored to specific ore mineralogy, the existing plant in place and the outcomes a company wants to achieve.

For these solutions to gain great market adoption, these leaders will need to get engineering companies on side.

Beal says NextOre is already receiving enquiries from engineering firms and consultants bidding on miners' feasibility work.

du Preez says that TOMRA is an independent OEM equipment provider that will assist all its customers (EPCM, EPC, consultants and mining companies) in flowsheet development and value optimisation for their respective projects. "It is really important for us to build strong customer relationships, in which we are trusted to add value to the projects with which we are involved in."

MineSense's More said the company is also looking to expand its dialogue with engineering firms in the next couple of years after initially demonstrating its technology to miners.

IMA Engineering, meanwhile, is working on ore sorting projects in South America and Africa.

If these ore sorting focused companies can establish such a connection, it appears to be only a matter of time before the OEMs and mineral processing firms try to strike up some sort of co-operation agreement or build their own solutions.

As mentioned, NextOre is already working with an OEM on its in-pit MRA solution and More says MineSense has informal agreements in place with shovel manufacturers looking at aspects of the technology such as application design.

Metso's SVP for Mining Technology, Olivier Guyot, meanwhile, confirmed in this same report last year that the company was "developing breakthrough proprietary technology to address the demand of high throughput accurate sorting".

All this interaction bodes well for the future of ore sorting technologies in mining, with flowsheets increasingly being constructed to best leverage their abilities.

The 'designer mill feed' Beal talks about could then become a reality for every mine site, eradicating the heated debates that regularly take place between mining teams and processing teams.

"Obviously the system that can do that involves programmable feed systems and that is a much more sophisticated material handling system than what is currently employed at most sites," Beal said.

"We'll get there eventually, but it requires the first implementation of bulk ore sorting and sensors more broadly across the industry." IM