Mining, as producers of raw material for our wellbeing, is an important industry for the development of the world. The sector is global and is often a strategic commercial area for regions. There are around 10,000 underground mines and ABB’s primary focus is on the metals market which includes commodities such as iron, copper, nickel, gold, silver, zinc and lead.

Mining, the community
The mining industry is currently facing dramatic price drops of commodities and many new or recently started mining projects have been postponed or closed. Typically the price drops have been between 30 to 50 percent and even more for iron. The industry is being driven by high growth in emerging countries and at the same time new exploration is being done in more remote locations and moving underground or deeper underground with up to 50 percent lower mineral content for some commodities. As a result, producing the same value requires much more ore to be extracted from increasingly difficult locations.

The mining industries priorities are:
- Safety
- Efficient production
- Environmental impact
- Workforce recruitment and retention

Typical mining operation characteristics are:
- Harsh environment and high risk areas
- Long distance and limited space
- High degree of unplanned activities
- High degree of human and mobile machines involved
- Utilization of mobile machines can be as low as 20 to 25 percent
- Utilization of open faces, can be as low as 20 to 30 percent
- Limited visibility of ongoing operation in real time

Mining and ABB
ABB has a portfolio of solutions for long term sustainable business on the global mining market. The portfolio is for growth, both with technology and the market needs. Mining 2.0 was the starting point for developing the ABB business for mine automation.

The concept includes some unique solutions for the market, as stated by AngloAmerican: “We have not seen any similar. You have something unique in your concept” or by RioTinto “if we had have this solution, we would increase our production with 10 to 20 percent.”

Producing the same value requires much more ore to be extracted from increasingly difficult locations.

Challenges to meet
One challenge for the project in the early years was to clearly understand and communicate the problems and eventual solutions. The mining industry understood that they had problems and new
challenges but struggled to express their findings, on the other hand ABB as a supplier found it difficult to present solutions in an understandable way.

The focus until today has been on increasing the productivity and capacity of the machines to build larger and more mechanically efficient machines, but that solution is close to its limits. As Garvin Yates BHP Billiton says: “We cannot continue to build larger and larger machines, we need to think in a new way of doing mining”. Over time the areas of interest were defined as: 1–2:

- **New mining operation methods** – to move to more continuous mining.
- **Autonomous machines** – using more time for production. A lot of time is consumed by nonproduction activities such as, shift changes, breaks and ventilating the mine after blasting.
- **Machine maintenance** – more preventive maintenance of machines has the potential to improve the utilization of them and reduce unplanned stops in the mine.
- **Remote and centralized control** – A centralized control with an operator supervising all scheduled activities for efficient coordination and acting on disturbances in real time. Doing this remotely means less people need to be on site and several mines can be managed from the same control center. A large mine can have some hundreds of machines in operation and some thousands of events happen every shift.
- **Efficient ore transport** – Stable transport process avoiding disturbances as running silos ore passes empty, efficient filling of trucks, trains and mine hoist. Running machines efficiently, and only running them to their limit when really necessary 3.

### Technology and methods

The developments in Mining 2.0 have included several research areas in CR, such as: communication, user experience, software, sensors and control. The development has been vision based and user driven. Several demonstrations have been developed for displaying and testing scenarios and ideas. Where possible solutions have been evaluated by on site tests.

The technologies used and developed in Mining 2.0 have been:

- **Field studies** – A field study is a team of 2 to 4 people visiting a mine site to observe and conducting interviews to gather information and work flow. This creates the base for further developments:
- **Domain models and architects** – as reference. Describing current and future mining operations.
- **Persona and scenarios** – description of people involved and a workflow for developing user centric automation solutions.
- **Visualization** – different concepts have been developed for different solutions and scenarios ➔ 4.
- **Wireless communication** – has been tested to understand the limitations and how to install in an underground mine. It has also been used to test existing localization ➔ 5 based on wireless communication technologies.
- **Control methods** – has been a key component in mine ventilation, water control, scheduling optimization and material control and tracking.
- **Optimization and statistical methods** – for criticality based optimization of maintenance strategy.

**Solutions and products**
The vision of an “ore factory” was about introducing process control into a discrete process, just as mining is. Key components have been vertical and horizontal integration, centralized control, single source data and real time access to machine data. The missing piece was the integration of mobile machines enabled through an installed wireless communication network. Solutions developed have been:

- **Maintenance strategy optimization**
  - CRiticality-analysis-based Maintenance (CRIM) optimization tool solves the customer’s problem of finding an optimum mixture of predictive, preventive and run-to-failure maintenance strategies for their plants. The developed CRIM optimization process and tools offer one solution to the problem in several steps. Starting with criticality assessment and ending up with life cycle cost analysis (LCCA), the tools help mining customers to analyze and choose the most cost efficient maintenance strategy for the entire plant.

In an underground mine, technology is a key enabler. Mine-wide wireless communication allows real time connection to the mobile machines.
Key components have been vertical and horizontal integration, centralized control, single source data and real time access to machine data.

- **Localization** – of personnel (via their mobile phones) and machines. Via a tagging system machines and personnel can be tracked and visualized in a 3D map of the mine. Geofences for safety zones can be built into the system. Productization is done in cooperation with Mobilaris. A product is available on the market named, ABB Mine Location Intelligence.
- The greatest value to the customer is safety but to also make the underground mine more transparent. Everyone knows where everything is.
- **Scheduling optimizer and dispatch** – short term scheduling of all underground activities and online distribution of created work orders to operators. Feedback on progress can be reported back online. Due to the closed loop and optimizer, short term scheduling can be automated. It is a product named MineInsight. The dispatch system is on the market and scheduling should be ready by the end of 2016.
- Customer value is that when unplanned events happen, the time required for unavoidable re-planning is reduced from hours to seconds. As a result a tighter schedule can be done leading to an increase of the production (tests have shown 10 to 20 percent) and thereby improved resource utilization. It will always have the current status in real time and it will be possible to predict future production.
- **Ore flow control** – is still under development because it has had a lower priority for the market. Material tracking framework is developed and together with visualization concepts it will be part of MineInsight. Customer value is online visualization of ore production, prediction of future production and events, mass balancing through the value chain and an efficient production with minimized disturbances.

The fifth solution developed has been:
- **Mine Ventilation control** – is part of the product ABB Smart ventilation and is ready for the market. All fans and regulators can be controlled via feedback control from sensors.
- Customer value is a robust ventilation system which can easily adapt to new conditions. Fan energy consumption has the potential to decrease up to 50 percent. More efficient use of existing mine ventilation infrastructure (i.e., shafts) postponing investments if desired and mine expansion.

**The journey of Mining 2.0 – some facts**

Mining 2.0 started as pre-study in September 2009. At that time Rio Tinto had stated their concept “Mine of the Future”
with an ore project called “A pit”. There they would remote control a full mine from a remote operation center (Perth) located 1500 km from the mine (Pilbara region in north west of Australia). Mining 2.0 was the ABB response to the initiative from Rio Tinto with the task: “Mine of the future – what does it mean for ABB?”

During spring 2010 there were two events that were significant for continuation. ABB had started to explore collaboration possibilities with Atlas Copco. The optimized mine was presented in April 2010. Central was the integration of mobile machines and material tracking describing process flow. The second event was a meeting with Vattenfall AG in Germany. Vattenfall AG stated: “We have automated our machines as much as we can, our focus is on process optimization where all share information from the same single source”. Vattenfall AG also preferred demand control rather than push control which is the normal condition for mine operations and continuous mining.

**Summer 2011 – ABB put the vision of an ore factory in place for customer presentations.**
The first LTE installed in an underground mine in the world is in Boliden, Sweden. It will be used for the testing of future 5G communications and solutions.

End of 2011 – ABB presented the first solution concepts for an ore factory. The first outputs were the CRIM optimization tool and method for a cost efficient maintenance strategy had been successfully tested on site and was also presented at the end of the year.

2012 – The concept demonstration is ready, presenting production control through scheduling, material tracking visualization and ventilation. The mine ventilation control was also proved on site with successful results. In 2012 ABB’s Mining business unit started to develop the dispatch order system; an essential part of automated scheduling.

2013 – Dispatch systems were developed and a first prototype was installed. CR started to test scheduling algorithms on real data. The algorithms were tested on site by the end of the year.

2014 – MineInsight and Smart ventilation are introduced to the market. The first products, as part of the two concepts, to be sold have been the dispatch system and mine ventilation on demand.

2015 – ABB scheduler is introduced to specific customers and is planned for product release by the end of 2016.

Continuing Mining 2.0
Mining 2.0 has paid attention to the mining market and several relationships have been established with the market. This has been used by other initiatives using mining as their primary target market. Unman the site is one example, developing an industrial mobile manipulation platform and remote control platform. It has resulted in a robot system for the charging process. The results are currently being developed into a deliverable solution.

Remote service including new services such as analytics and service robots, are currently being given attention as a new start-up. Specifically, mine ventilation and power analytics are under development together with conveyor inspection.

The first Long-Term Evolution (LTE) network is currently installed in an underground mine in Boliden, Sweden. The project is called PIMM funded by Vinnova and run in a consortium. It will be the first LTE installed in an underground mine in the world. It will be used for the testing of future 5G communications and solutions.

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