Mobile integration - the future of optimized underground mining, resource utilization and logistics
(Congress Theme: Automation/Mine Communication)

BIOGRAPHY

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ABSTRACT

Future mining will use fewer workers for manual jobs and more qualified operator experts for product and process optimization, maintenance planning and environmental control. The operator experts will need to interact with each other to cover the complete value chain. “The central mine control room” would be the target and future solution. It is expected that the operator experts would be able to control perhaps several mines. Sensors and automated systems provide mine operators with real time, essential information for each product and process control. Future mining will require a high degree of integration in product and process optimization, maintenance planning, environmental control, etc. all from the central mine control center. This allows the mine to optimize the utilization of underground mining equipment, increase mine productivity while reducing energy consumption. ABB underground mining offering allows the possibility to integrate real time data from underground equipment of different types and manufacturer’s into ABB’s open Process Control System 800xA. This allows for better visualization and utilization of the equipment fleet, including tracking locations of machines, status of machines, actual operating environments underground, etc. This will allow the operator experts make right decisions to keep production flow as smooth as possible. This paper will show the potential in mobile integration and also provide an existing example where a global vehicle vendor’s machines have been integrated into the ABB Process Control system 800xA.
1. BACKGROUND
Mining companies in general have come to a level of automation where the different sub operations in a mine are often quite automated themselves, but where the integration of the sub operations and the information they are holding are poor or lacking. This has a tendency to drive towards operations where sub optimisation is frequently encountered and where the organization has a heterogeneous perspective of what the process is all about.

The content of this paper is based on experiences gained empirically when implementing automation solutions in different environments over a long period of time. Companies of main impact to our discoveries are Boliden AB (1980-) and LKAB (1990-).

2. STATEMENT OF THE RESEARCH PROBLEM
The situation in mining industry up until today has been such that full control and overview of all of the different operations in the mine has been hard to achieve. There has been a lack of communication infrastructure, wireless as well as wired, in underground environments. Correspondingly, the level of automation and integration of information in the underground mining environment has not been matching the corresponding level when compared to other industries such as oil & gas or pulp & paper. This also results in the mines not having the capabilities to run operations in manners where optimisation of the entire value chain, from mine to mill, many times is more than an illusive desire. At the same time it might be that the mining industry hasn’t, yet, been completely faced with the situation in many other business areas, where cost reduction and optimization of output is maybe more strongly addressed as of today.

The way processes interface to each other, or maybe even more obvious the lack of interfacing, leads to inefficiencies and lost production. The question is how to move into an environment where mining operations are more of a mining factory, where all parts of the different sub operations are supplying relevant data and where on-line analysis applied upon that data is the base for decision support or automated decision making?

3. OBJECTIVES AND SCOPE

3.1 General
The objective of this document is to make a survey of the different data sources possible in the underground mine environment and the order in which to collect, propagate and share the data to make it into useful information for different categories of personnel.

As discussed above the different sub operations in mining have been looked upon as separate production units. Different solutions, different choice of equipment and no demand for unified ways of forwarding data to and from the different sub operations has for many mine operations ended in a total situation, where parts of the operation are more or less isolated islands. Operation, supervision and data storage are not seldom managed locally within the sub operation. Reporting and propagation of data to neighboring and superior systems are limited and often not in real time. Diagnostics functions and maintenance aspects are also catered for locally, which disables the possibility to perform remote diagnostics both by the plant organization and by experts from the outside. If organizations are set to make intelligent decisions about how to make optimal use of their resources and assets in a consistent way, they need data from the different sub operations. However, it will be of limited use if the data propagated is only of a historical character usually found in reports. Instead of presenting data describing what has happened the data must be available for on line use in order to be able to perform on line analysis.

So, the different sub operations should have ways to:
- propagate real time data to neighboring systems
- propagate real time data to superior systems and central control room functions
- enable remote diagnostics
3.2 Different Views Of The Process

When different issues are viewed by different users or user groups, they will in general have a tendency to view the issues from different perspectives. The perspective depends upon many different things such as education and general background. Even cultural heritages may come into place. If the users all have the same perspective the picture painted in their heads might correspond to one another. On the other hand, the situation might be the opposite if the perspective changes.

When using this information applied to the mining industry one might argue that if users are predominantly working within a sub operation they will have a different perspective of the process than the users working within another sub operation. This causes problems when it comes to the co-operation. Since the issues will be interpreted differently depending on which user group is handling them, different user groups may have a hard time agreeing upon the nature of the issue. Let alone they will have an even harder time agreeing to solutions to problems that cross the boundaries and needs to be solved. Different users and user groups therefore benefit from looking at the production process in a unified way.

Users from different sub operations in the production chain benefit from sharing a unified view of the process. But also users of different categories benefit from sharing the same unified view of the process. Examples might be how the electrical and instrument group will enhance their co-operation when information regarding equipment of the different disciplines is viewed in a unified way.

Also other categories such as Process development and Maintenance development have the same possibilities of reaching synergies and common perspectives.

Examples of use would be how maintenance related issues will be used as a natural input when taking decisions on changes in the process. Another example would be how maintenance users would be able to view the underlying data when examining the natures of maintenance orders received in the maintenance system.
3.3 Integration – Requirements Of The Data

In order to provide an environment in which different user groups may interact on and make use of the information provided by using the data in the production system, the very first thing to do is to get hold of all the relevant data. There are pitfalls to be aware of along the way! Restrictions regarding availability of data due to “black box”- systems or hard coded communication data sets in turn cause restrictions to the quantity of data available. Even though these types of solutions at an initial phase may provide the data needed, demands for new data are likely to occur. As all parts in the plant over time might be subject for modifications, preparations must be made to provide not only maintenance, but also application modifications and tuning in all of the installed systems. Data initially not taken into consideration might then be cumbersome to provide at a later stage.

The possibility to assess data quality is another crucial issue in these circumstances. The reason why data quality or data blackouts (missing data) are important to the goals aimed for, are that the data is to be used as a basis for building information used for important decision making. When data is converted into information and further refined into process knowledge the lack of data or false data causes the knowledge achieved to drift away from the real mine situation. Since the knowledge is used for decision making this might very well lead to wrong business decisions. To make data available and quality of data assured, there is a need to integrate different equipment and systems, and the data related to them, into one common platform. This must be done in ways that conform to the main objectives described:

- Data availability
- Data quality

3.4 Data Integration

Going from the bottom up, the equipment for various functions in the field is integrated using standardized field buses such as Profinet, Profibus, Fieldbus Foundation or other integration concepts such as IEC61850 for integration of power systems.

Figure 5 – Integration of field devices

Mobile equipment is integrated using standards such as OPC or IREDES.

Figure 6 – Integration of mobile equipment

In the upper part of the system architecture maintenance and business system are integrated using standards such as ECS, ISA-95 and OPC. This means that relevant data from the various equipments are available within the system boundaries by using open and standardized protocols and that data quality can be assessed. Information can be supplied to different users and user groups in a unified way for them to make knowledge off. Data is also available in ways that further analysis, manual or automatic, can be applied to.

This is important since there is no way to go from top to bottom in this matter. If advanced analytics is applied to data where the data itself is either false or incomplete the resulting decisions made based upon the data will be correspondingly false or incomplete. The penalty for wrong decisions in mining is typically severe.
3.5 Handling The Data

The purpose of the data collected is to use it to obtain information regarding the process in order to build knowledge used to take the optimal decisions, short term as well as long term. The way data transforms into knowledge and business decision is not always obvious.

When data is being integrated in the ways described above every conceivable thing can be measured, propagated and presented. New technologies enables more data from a wider range of data providers to be available and human system interfaces such as Smart Phones and PDAs provides ways for interacting with the data in flexible ways wherever the user is situated. A common deception is that making all the data widely available will make users actively choose what they need from it. The often used presumption that all information should be made available to all users ignores the reality that people in different roles and at different levels in the organization have unique information requirements. In short, people don’t have the time to seek out the information relevant to them. They need information regarding the types of decisions they are set to make served at the top of their fingers. Providing vast amounts of undifferentiated information (not user role-specific) backfires and carries a large opportunity cost and is counterproductive.

Business measures are what ultimately drive an organization to achieve its goals. To be effective, the system that delivers those measures must direct information to the users, or user groups, who need it in business related ways as a basis for their decision making. The design and implementation of systems, including the selection and direction of information to drive business performance, is a critical source of competitive advantage.

Knowing what to measure, the purpose of key performance indicators and how to act on those metrics is as basic to mining as it is to any other business. The key questions arise:

- What information is crucial to the business output?
- What information is critical to what user group?

The first question should be addressed by referring to the business value chain, the sequence of activities in a business that progressively adds value to the saleable product of the business. The generic mining industry value chain illustrates the structure of mining operations and how value is gained and lost along the chain of activities from the mine to the market from an economic perspective. Key performance indicators typically set the focus on:

- Efficient use of input resources
- Effectiveness of each link in the chain
- Opportunities to minimize waste output

![Figure 7 – A mining value chain](image)

Therefore the different sub operations should contribute with complementary data to these measurements.
For performance enhancements there are mainly a number of different uses for performance information.

- **Planning/Keeping score**
  What happened? Are we doing well or not? The information typically houses scorekeeping of accumulated and dissected performance data to answer these questions, such as totals and averages during different periods.

- **Directing Attention**
  Which are the current problems to direct attention to? Variances in content of management reports directs attention to quality issues, operating problems and waste.

- **Solving Problems**
  What can be done about the problems? What action would be the best? This information is most often used for long term planning such as budgeting and future projects.

Other usual cost related KPIs expected to be found are output measures of resources and activities, such as tonnage, man hours, meters drilled, meters trammed and so on. These cost indicators are basic measures of effectiveness, but can also be used to estimate resource requirements for maintenance and supply purposes.

For example, materials used in mine development can be factored on the basis of meters of development. Every meter will have a standard bill of material associated with it, a recipe. For example, every 10 meters of advance will consume:

- nn kg of drill steel
- nn ltrs of water
- nn kg of explosives

Likewise, every 1,000 tons of ore milled will consume:

- nn kg of grinding kWs
- nn % of lining wearage
- nn kg of froth chemicals

The indicators bearing cost in this example are meters and tons, and they can be applied to the actual meters and tons measured each period to estimate all the supplies and maintenance required for the ongoing support of the operation for that period. If this is done for every step in the value chain, there is substantial potential for reducing working capital through better coordination of supply and demand.

### 3.6 Mobile integration

When communication infrastructure is established underground and the mobile equipment fleet is increasingly computerized openings to exchange data with the production machines can be found. Drill plans, loading sequences etc. for the production machines shall be delivered to the machines and the results of the actions are reported back. The integration with the production control systems for mobile equipment has several purposes:

- Deliver the results of the initial steps of the mining process; Geology, Ore calculations, Mine survey, Mine design and the Production planning, to the mobile equipment systems in a useful format.
- Retrieve the results reported by the mobile equipment and feed them back to the relevant users: Reports and follow up, analyses and statistics.
- Retrieve execution statistics and maintenance data from the on-board system Information is partly used by the process control system, some (mainly the maintenance information) shall be transferred to /collected by the other systems (maintenance system).
- Online status of mobile equipment in the process control environment including localization information

The interfaces to the production control system are based on the interfaces provided by the production control system products. The interface towards the open ABB Process Control System is OPC (DA, A/E, HDA). Data sets and naming of items are configured to conform to the IREDES standard.
Localization information of the mobile equipment is obtained through the use of information originating in the WLAN infrastructure. The localization information together with the information obtained from the mobile equipments is aggregated, consolidated and available for viewing in the open ABB Process Control system.

The combined information from the mobile equipment and the localization system is the basis in order to provide an accurate and online status of the ongoing activities and the mining progress in the process. Output of the analysis are used to provide further optimization in different areas

- The ventilation is not only on demand; it is even further adapted to meet the actual needs derived from the mobile equipment status.
- Availability of the mobile equipment is increased when asset monitors combine data from the machines and data regarding the process environment to provide accurate maintenance at accurate intervals.
- The way the mobile equipment adhere to the activity planning can be updated online and deviances used as input for recalculating the activities.

Further along the line there are possibilities to close the loop and provide different methods of automatic redirection/replanning of mobile equipment when needed. Already the mere fact that information regarding the surroundings (traffic situation, status of production equipment etc) can be compiled and made available for mobile machine operators will increase their possibilities of making intelligent decisions when things turn out to differ from original plans. And in mines they often do!

### 3.7 Multi facet Ways Of Using The Data

Different user categories and the main purpose of the integration of information for different user groups are:

- **Operations**
  - Online visualization of production status for responsibility area
  - Sufficient view into neighboring areas

- **Maintenance**
  - Online fault reporting into maintenance environment created by operators and automatically generated by system.
  - Possibility to view data related to maintenance orders such as historical trends, alarm and events.
  - Remote diagnostics of all equipment

- **Engineering**
  - Remote configuration
  - Remote calibration
  - Remote fault tracing

- **Process development**
  - KPI related to process status (throughput/h etc)

- **Maintenance development**
  - KPI related to maintenance status (wearage/ton etc)

- **Business development**
  - KPI related to business figures (cost/ton etc)

- **Management**
  - KPI on overall performance
When the different user categories has access to all data needed and the views have been adapted to the different needs each discipline has the tools to work their own tasks. But in the same way as operators in different sub operations must co-operate with at least the neighboring sub processes the different disciplines must also co-operate. Operators and others must generate work orders to maintenance in ways:

- Consistent
- Clear
- Rich with background information

Maintenance must co-operate with engineers to make the control of the equipment, not only in productive ways, but also in ways that causes as little maintenance as possible. Engineers must interact with process engineers to feed back knowledge about less useful process design. Maintenance development engineers must co-operate with process development engineers in order to make up a process design where maintenance aspects are taken into consideration. Business development need to co-operate with process development in order to make changes to the process reflecting the current business situation and management does what management do.

These are merely examples. Of course there is a multifold of interactions between the different users in operations going on all the time.

So, different experts need to interact with each other both within their own disciplines and on inter-disciplinary basis. A trend arising is to consolidate the operator environment into one, or fewer, control rooms. This does not only mean that all data and information is harnessed into one location. It also means that the experts of running the online operation, the operators, are brought together. Around this hub of operations there should be space prepared in order for the other experts; maintenance, engineers and process developers, to gather, interact and make useful business decisions with the help from experts from the outside. This is prone to lead to operations which are integrated and where silo mentality and interaction problems in interfaces are greatly reduced.

5. SUMMARY AND DISCUSSION

This paper is about integration. It’s about integration of data from different equipment and operations.

It’s about integrating the different operations and their operators with each other. Last but not
least it’s also about integrating the different disciplines, the different experts. All integration efforts serve the purpose of bringing it all together. To view and run operations in an integrated manner.

6. CONCLUSION AND RECOMMENDATIONS
The future will lend the mining industry fewer hands for manual work to run operations.

These will be covered for by fewer, but more qualified, experts. The experts, locally or remotely situated, will have to have access to all relevant data regarding the operations and they will have a need for presenting the data in meaningful ways adapted to their needs. It’s also crucial that the data are both complete and true since the usage will be to analyze the data and make intelligent business decisions using this analysis. Efforts therefore must be made to integrate the data in ways that ensures that this is the case.

Boundaries in between different sub operations and different functional disciplines must be set so that they overlap in order to keep the value chain of the entire process intact and in focus.

Figure 14 – Keeping the (value) chain intact

“One control room” is the target and future solution. The control room receives online processed information from the rock, from personnel and from the machinery and equipment that makes it possible to control and fine-tune the complete operation from resource characterization to the final product.

The experts working with the control room as the hub will become more competent dealing with perhaps several mines. Due to the progress of communication technology, the overall control centre can theoretically be located anywhere in the world enabling expertise to cooperate. The co-operation of the experts is also enabled when providing a common platform for integration where all experts can co-exist and share ideas and thoughts. Once an organization is brought into this level of integration there is a platform established from where the operation is not only monitored and run in ways serving the entire value-chain. There is also a situation where the operation is constantly undergoing real time analysis leading the way to intelligent business decisions.

This overall operational awareness will greatly enhance efficiency within the organization and further develop the mining process.

References
Extensive automation projects at sites of:

- Boliden AB (1988-)
- LKAB (1993-)