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Smart Mining Systems

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ABSTRACT

Advances in mining machines during the past two decades have been dominated by increasing size and unit productivity. However, to a significant degree, the future of mining belongs to the Information Age. Data collection, 'data mining', and data analysis are becoming the new 'efficiency' frontier. Machines today are not only larger but also much smarter, equipped with multiple sensing packages and on-board high speed computers that can measure most aspects of the machines' performance. Advanced wireless technologies are emerging that provide a window into this remote machine data. As more data are made available to mine operators, it must be organised and converted into useful information, resulting in action taken in the field. Expert maintenance, engineering and operating staff, co-located in a centralised area, can monitor mining fleets and also provide valuable guidance to less experienced field personnel. Operator performance can also be assessed in a similar fashion, providing management with an abundance of information that allows efficiency and productivity improvements to be made that can also result in significant cost savings. Ironically, these smart mining systems will greatly help meet the growing challenge of finding qualified field personnel facing the industry today.

This paper will present the Freeport McMoRan Mine Technology Group's vision and advancements in smart mine technology.

HISTORICAL PERSPECTIVE

In metal mining, recent history shows efficiency gains have come from economies of scale. This is particularly evident in the success of some of the largest copper and/or gold operations such as the Grasberg mine in Indonesia and the Chuquicamata mine in Chile. Note the proliferation of larger operations on the bottom half of the world cost curve (Figure 1).

Many of these large operations have achieved the large production divisor through use of ever larger, higher capacity mining equipment. The improved efficiency comes from a reduction of labour, fixed overhead costs and maintenance costs on a unit basis, and reduced energy consumption (Sullivan, 1990). Over the past 20 years, haulage trucks have grown from a capacity of approximately 65 tonnes to trucks capable of carrying more than 300 tonnes today (Caterpillar, 2007; Komatsu, 2007).

In order to load these large trucks efficiently, shovels have grown over the same period from approximately 20 m^3 capacity dippers to shovels with dippers exceeding 66 m^3 (World Gold Council, 2006).

Some researchers have found that this 'economy of scale' has limits and that ever increasing truck payload won't continue to lead to increasingly more efficient operations. Roman and Daneshmend

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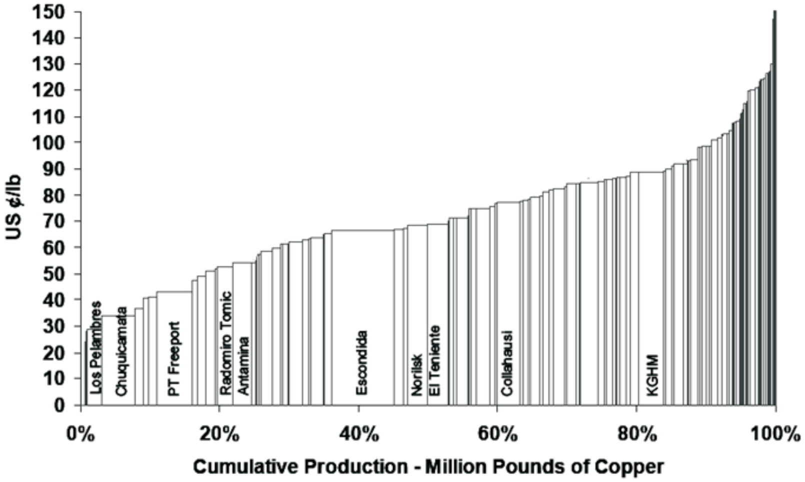


FIG 1 - World cost curve on copper mining (after Brook Hunt and Associates Ltd, 2006).

(2000) have developed models that show higher maintenance costs and lost production in some cases where the equipment is not appropriately matched to the production schedule of the operation.

Additionally, it has become apparent to modern operators that the logistics associated with transporting the operating consumables and maintenance repair parts for these large mining machines have become unwieldy and expensive. Tires are a good example in that, as truck payload capacity grows, so do the tires. Special transportation permits, onsite manufacturing or some other method of ensuring a ready supply must be considered as it will be nearly impossible to transport tires exceeding four meters in height to the mine site under normal circumstances.

Another consideration is the diminishing market for these pieces of mining equipment as they get bigger and bigger; only the largest mines can utilise the massive, plus-300-tonne haulage trucks. While some research continues to go toward developing larger trucks, manufacturers are also putting significant research and development effort into optimising the functionality of their existing product lines. The logical place to begin is to make the equipment ‘smarter.’

Another incentive for OEMs to develop smart machines is that many mine operators have maintenance and repair contracts (MARC) backed by the equipment manufacturer. Under this scenario, it is the holder of the MARC who benefits from a smarter machine. Information that leads to reduced maintenance costs adds directly to the bottom line of the dealer and manufacturer with a fixed-cost contract.

DEVELOPMENT OF SMART MACHINES

Haulage truck manufacturers began to install onboard diagnostic systems in the early 1990s. Examples include the Vital Information Monitoring System (VIMS) on Caterpillar equipment and Vehicle Health Monitoring System (VHMS) on Komatsu equipment. These packages typically included a large number of sensors feeding data to an onboard datalogger. These systems can capture several hundred data tags covering vehicle health parameters such as exhaust manifold temperature, strut pressures, engine temperature and oil pressure, etc. Operating parameters are also captured by these systems. Examples include throttle position, use of the service brake and/or manual retarder, truck speed, engine rpm, transmission gear (or direction selector), etc. They also record any faults that might be generated by the control modules on the truck.

Shovel systems were somewhat slower to be developed, but by the early 2000s, many systems were commercially available. This was facilitated by the development of digital drive controllers, which made a significant amount of data available for capture. Examples of shovel systems include the Centurion System by P&H and various Contel systems in use by Bucyrus International. As with the trucks, data on machine health, including current draw by electric motors, house temperature, switch positions, etc are gathered. Operator performance can also be monitored including boom jacks, swinging the house while the dipper is still engaged in the muck, hitting the travel limits on the sticks, etc. Faults generated by the shovel control system are also usually logged by the system.

These systems did not meet with universal acceptance when they were deployed by the OEMs. There were technical problems with making these complex data-gathering systems work, and when they did, many MARC contracts resulted in most if not all value accruing to the account of the OEM or dealer.

As these issues were addressed, one primary problem remained unsolved until recently. The captured data resided on the machine until it was downloaded by a technician who had to physically mount the machine. This made much of the data inaccessible and resulted in most analyses being 'post mortem' rather than real time.

CURRENT STATUS OF SMART MACHINES

Two key technological advances occurred over the past five years that have caused many mine operators to re-evaluate the value of onboard smart systems. The first was the release of mesh radio networking technology into the commercial sector.

The definition of a wireless mesh network is a network created through the connection of wireless access points installed at each network user's locale. Each network user is also a provider, forwarding data to the next node. The networking infrastructure is decentralised and simplified because each node need only transmit as far as the next node (TechTarget Networking Media, 2007).

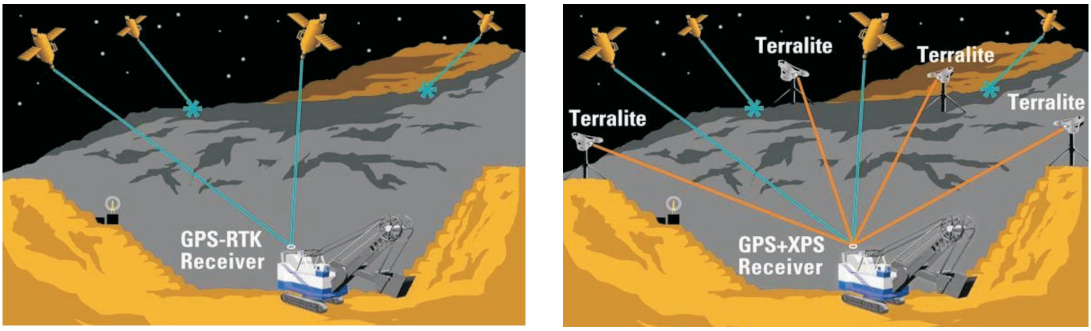
Wireless mesh networking is not a new idea. It was discussed by ham radio operators as early as 1972 (called packet radio Network or PRNET). From the early 1980s through the mid 1990s, the technology was advanced by the US Department of Defense, and the systems were known as Survivable Adaptive Radio Network (SURAN) and Global Mobile Information Network (GLOMOIS). In the mid 1990s, the public sector began looking at mesh networking for public safety/emergency response, and the concept of using IP-based protocols was introduced. The first commercially available mesh network hardware was available in the early 2000s (Das, 2006).

Wireless mesh is important because it provides a conduit for getting all the data being captured by the vehicle health monitoring systems on the equipment into the hands of experts in nearly real time. With the help of sophisticated software, these experts can identify single and multi-sensor trends that indicate pending component failures. By monitoring production fleets in nearly real time, many developing problems can be identified and mitigated before becoming catastrophic failures.

Another important outcome of nearly real-time monitoring is that individual operator performance can be accurately evaluated. When critical operating issues are identified, action can be taken immediately to correct improper techniques. Additionally, operator performance can be evaluated over longer periods of time, and peer group comparisons can be made. This can identify specific training needs by individuals or by the entire peer group.

The second key technological advance was the development of a ground-based system to augment GPS coverage. This allows a mine operator to know where the equipment is at all times. A commercial product called the Terralite XPS System has been developed by a company named Novariant. This system consists of a base reference station, multiple Terralite transmitters and as many GPS + XPS receivers as needed to outfit the fleet.

The Terralite concept is simple; with GPS-only systems in a deep or congested pit, highwall shadows and multipath reflections from large pieces of mining equipment and the pit highwalls precludes a GPS-only receiver from achieving a high precision RTK solution. When the ground-based XPS transmitters are added to the mix, multipath problems are eliminated by the strong primary signal and by careful placement of the Terralites so that most are visible to the equipment in the pit, and an RTK solution can be achieved at all times.

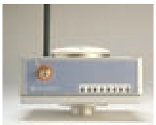


Traditional GPS Setup

Novariant Terralite Setup

Terralite Transmitter

Terralite Receiver



Terralite Base Station

FIG 2 - Comparison of traditional GPS and Terralite XPS System and products (Novariant, 2007).

MAKING IT WORK – DISCUSSION AND CONCLUSIONS

The key to success when embarking on a data-gathering exercise is to remember what the primary object is: to effect change in the field. Without converting the data into information, and then using that information to take action, the effort to gather the data is wasted.

Maintenance and operating subject matter experts must memorialise their knowledge and findings so that it can be used by the organisation. This involves many hours of dedicated work upfront to begin to turn the data into useful information. This work must be ongoing as new data becomes available.

The onboard smart systems, full-time accurate location system and the mesh radio infrastructure must work in concert to deliver the data to a central location where it can be evaluated by these subject matter experts. This implies the use of a complex, integrated software package capable of handling time-series as well as sequential data. These data must be displayed in a multitude of different formats, and the system must be flexible enough to 'learn' new relationships between sensor readings and equipment failures as the subject matter experts discover these relationships. Finally, the system must be capable of communicating with operations personnel to assist them in understanding and managing the mining equipment fleet.

Co-location of the tactical operations personnel in a 'room of truth' where they can study the information generated by the system and actually guide maintenance and operations from the start of the process to the end is necessary to optimise the effective use of the information. This room of truth has all verified information available in a real-time environment where the subject matter experts can study the data and assist with tactical decisions about the operation and provide guidance to less skilled employees in the field. In this environment, peer to peer communication, cross pollination of ideas and a shared operational awareness will result in additional significant efficiency gains for the organisation. By institutionalising the knowledge of the experts and making it available, less skilled personnel in the field can use that knowledge to better troubleshoot problems with the equipment, leaving the more highly skilled experts to continue to evaluate the data and assist with issues that are extraordinary.

Figure 3 shows a conceptual view of 'room of truth'. Individual work stations can be seen where subject matter experts and tactical operations personnel are located. A large display wall is shown in the front, capable of displaying images and information from any of the workstations. Breakout rooms and work areas for support staff surround this area to provide strategic assistance to the personnel in the room when needed. We believe this is the mine control room of the future.

FIG 3 - 'Room of truth' conceptual view.

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