

## TOTAL OPEN PIT MINING SYSTEMS: A DREAM OR A REALITY?

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### ABSTRACT

The paper reviews the current status of surface mine automation. It then proceeds to discuss the recent technological advances related to mining applications of advanced computer, communications, GPS and other technologies. Following this the recent philosophies guiding the development of Total Surface Mining System concept are outlined and the current status of these systems is reviewed.

### 1. INTRODUCTION

Over the last twenty years a number of attempts were made to automate and robotize mining operations. Automated longwall operations were tried in Britain, in Poland and in the former USSR. Autonomous equipment operation in surface mines was introduced and is used in a Japanese quarry. While these systems worked for periods of time the applications failed to prove their economic or technical viability, or both. Some of the main problems encountered was the lack of and unreliability of suitable sensors used in the harsh mining environment, the lack of sufficient data transmission and processing power, and lack of full understanding of how various parts of the system interact.

Recent advances in computer, communications and GPS technology have spurred renewed effort to develop a "Total Surface Mining System", a system that provides real time control and management of a mining operation with the objective to optimize the mine performance. The present efforts are lead by two surface mining equipment manufacturers, Caterpillar Inc. and Komatsu Mining Systems and as such are limited to surface mining operations. Development of similar systems for underground mining operations is hampered by the lack of Caterpillar-size underground equipment

manufacturers and significant reductions in government sponsored mining research worldwide.

### 2. RECENT OPEN PIT MINE DEVELOPMENTS

Over the past decade the cyclical surface mining has been developing and changing rapidly. The stimulus for this development was provided by consolidation of the equipment manufacturing capacity and heated competition between the remaining manufacturers. Relatively mobile, large hydraulic shovels have become available, able to develop huge digging forces, mine selectively and move fast between mining faces. Similarly, several families of large wheel loaders have been developed able to significantly lower the cost of excavation in many mines. However, the most spectacular developments have been related to off-highway truck developments. These are briefly discussed below (Golosinski, 1999).

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#### 2.1. Truck size

Facilitated by the development of new diesel engines, new types of truck tires and drive transmission trains, the size of mining trucks has been increasing continuously. While in the early 1980's the largest truck was designed to carry 170 st (short tons) of material, some 150 trucks with capacity of 320 st

are in operation early in 1999, the number expected to reach 400 units within the next year. Most recently 360 st trucks have become available from at least two manufacturers. Doubling of the truck payload, therefore doubling of its productivity, has lowered the unit cost of truck transport by up to 50%. Moreover, trucks with payloads in excess 400st are on the drawing boards at present.

## 2.2. Efficiency of drive trains

In their desire to outperform competition the suppliers of both the electrical and mechanical drive trucks have improved significantly the efficiency of the truck drives and speeds at which the trucks move. Powered by efficient AC electric drive the 320 st truck moves faster than the 170 st truck of early 1980's. It is also able to stop at a much shorter distance due to characteristic features of AC retarding system, thus able to travel faster while going downhill. Comparison of the corresponding truck rimpull charts indicates that today's truck speeds are up to 30% higher, and especially so on uphill and downhill ramps. This allows for significant reduction in truck cycle time. The related productivity increase is in the range of at least 20%. Even the same model trucks perform significantly better, a result of incremental improvements of design, manufacture, drive train efficiency, more efficient controls and the like. As an example the Caterpillar Model 777D truck manufactured in 1999 has twice the productivity of the 777 model manufactures in early 1980's (Golosinski, 1999).

Wider introduction of trolley assist systems, pioneered in South Africa in early 1980's, offers the potential to further increase the truck speed and its productivity.

## 2.3. Availability and reliability

In early 1980's the typical availability of truck fleets was in the range of 70%, and sometimes less. Improvements in truck design and manufacture, reduced maintenance requirements and better maintenance procedures, and easier truck operation have led to significant increase of availability. Truck purchase or lease agreements are being signed today which guarantee truck availability in excess of 90%, with 85% to 90% availability commonly achievable

by well run fleets. This high availability translates directly into lower unit cost of mining.

Following improvements in truck availability, their reliability have improved as well. Many mines work towards and are close to achieving the target of eliminating any truck failures between the consecutive PM (preventive maintenance) service. The industry standard for MTBR (mean time between repairs) stands currently at 125 operating hours.

## 2.4. Fleet management, dispatch and control

The computerized fleet management and dispatch systems are a common feature in most mines today. These allow for optimization of truck assignments and fulfillment of production objectives at significantly lower overall cost. Mines reported productivity increases of over 20% after introduction of those systems.

## 2.5. The results

As the result of all above developments the unit cost of cyclical mining has decreased significantly. In well run, modern surface mines using the new generation of the cyclical mining equipment the unit cost is often less than one-third of that in early 1980's. This lead to significant change in mine preferences, with the cyclical systems preferred under most circumstances over the continuous mining.

# 3. CURRENT ADVANCES IN MINE CONTROL

## 3.1. Background

More recently a number of new technologies became available that are applicable to open pit mining operations. These include not only advanced digital computing equipment but also such technologies as reliable and accurate GPS (Global Positioning Systems), high-speed, high-band, bi-directional wireless data communication, flat panel displays and the like.

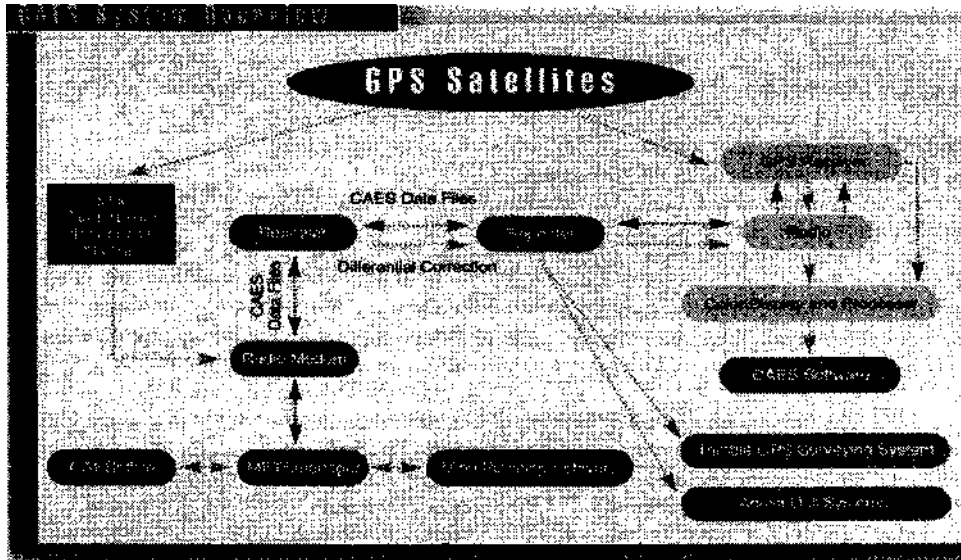
Spearheading the introduction of these new technologies to mining are two largest mining equipment manufacturers, Caterpillar and Komatsu. While originally lacking the expertise in control

systems and mine communications both have recently formed alliances with providers of this expertise. Caterpillar has formed a number of alliances with such companies as Mincom (mining software and computing), Trimble Navigation (GPS technology), and Aquila Mining System (equipment performance control and management). Komatsu took a more direct route by outright acquisition of Modular Mining Systems (mine control systems and equipment dispatch), after rounding out the in-house

reliable separation of ore and waste, or separation of various- types of mined materials (Greene, 1999, Harrod and Sahn, 1998).

The most widely publicized advanced real-time mine information management systems are CAES (Computer Aided Earthmoving System, see fig. 1) and METS (Mining and Earthmoving Technology System). The system combines several crucial technologies into one package, namely:

Figure 1. CAES System overview



equipment manufacturing capacity by acquisitions Demag of Germany (hydraulic shovels) and Dresser of USA (off-highway trucks). There is intense competition between these two companies in various aspects of mining, including the development of total mine of the future.

### 3.2. METS - Mining and Earthmoving Technology System

Both Caterpillar and Komatsu are developing new mine control strategies and systems. These incorporate collection and processing of real time information on equipment status and location, thus facilitating generation of optimum assignments. In the next step, this information is being tied in to the digitized terrain and orebody models to facilitate

- Digital orebody model created with Mincom's Minescape software; this module provides the system with knowledge of spatial position of ore, waste and their respective properties
- Centimeter accuracy GPS developed by Trimble that provides real time information on position of the mining equipment and allows tracking progress of mining
- VIMS (Vital Information Management System) of Caterpillar that provides real-time information on status of equipment, both in terms of its performance and health monitoring

The tasks imposed by the mine plan, such as production of certain tonnage of material with defined grade and within prescribed time are entered into METS system Manager Module. Likewise entered into this module is the equipment at hand and its

performance characteristics. METS Manager processes this information, together with that gathered by the sub-systems named before, ensuring that all mining related tasks are performed in an optimum way. Several of these systems are now installed in US mines, all reporting significant improvements in performance as a result. Typical of the applications is that reported on by Phelps, 1998. Modular Mining, a subsidiary company of Komatsu, is developing competing system.

### 3.3. Autonomous truck operation

While work on development of economically feasible autonomous truck operation has begun over a decade ago, it has been largely unsuccessful. It is only recently that availability of the RTK (Real Time Kinematic) GPS systems that allows centimeter accuracy truck positioning provided added impetus to this work. At present the autonomous truck technology is proven to be technically feasible. Most notably a fleet of four autonomous Komatsu trucks operates on a trial basis in an Australian mine. The initial indications are that this technology is superior in all respects to the manually operated trucks.

## 4. TOTAL OPEN PIT MINING SYSTEMS

The discussion above indicates that most of the basic technologies required to develop a fully automated open pit mine are currently in place, or will become available soon. These include:

- Data acquisition systems that provide accurate, real-time information on location and status of all pieces of mining equipment, and facilities
- Digital orebody models with ability to interact with the mining equipment and control its advances on one side, and interacting with the computerized mine plans on the other
- Vital signs monitoring systems that allow collection of reliable equipment performance data on one side, and provide equipment health diagnostics on the other
- Wide band, high speed, bi-directional communication systems that facilitate fast transmission of voluminous data

The availability includes both the hardware, sufficiently durable to withstand harsh mining environment, and software with ability to fulfil the intended function under a variety of site-specific conditions. Continuing strong competition between major technology suppliers make further rapid progress of these technologies feasible.

The final hurdle that must be overcome to achieve full automation of open-pit mining operation is development of an intelligent supervisory / managerial system able to coordinate and control the performance of all the other systems named above. The first step towards development of such system, the METS is already in place. The experience gathered with it will likely prove of great value in further work on development of autonomous mine.

## 5. CONCLUSIONS

Significant progress has been taking place in development of component technologies of a fully autonomous open pit mine. These technologies include hardware and software related to: real time definition of equipment status and position, digital modeling of orebodies, equipment monitoring and control, and ability to efficiently transmit voluminous data. To facilitate autonomous mine operation all these technologies need to be made compatible, and a system manager needs to be developed to coordinate their outputs and inputs. Work on development of such system continues at present.

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