Growth demands for increased productivity and safety set new challenges for equipment manufacturers around the world. Atlas Copco is continuously improving and optimizing mining equipment and tools to be able to meet the growing demands of today. By enabling the strength of a common control system on our new-generation mine equipment we can enhance customer value with smart functions and features on a large range of mining equipment.

The mechanization era enabled one operator to control one machine, an enormous productivity advantage. Moving the rock drills from the operator’s hands and placing them on booms and removing the operator from the production face to a secure and ergonomic cabinet increased safety and improved working conditions for the operator. The mechanization era was revolutionary for the mining industry, but mechanization has been around for a very long time.

The computerized or automated area for mining has been around a couple of decades and several improvements have been implemented thanks to onboard computers and network-based systems. The operator has help to control the equipment in the most efficient way, and some operating tasks and routines have also been fully automated. Even service and maintenance have improved, helping the operator and technicians to solve problems and detect errors faster and more precisely. But what about the control of the machine? Isn’t it still one operator for one machine?

Today Atlas Copco can be proud of enabling the next step for increased safety and productivity. Since 2012 the Simba Multi Machine control system has been available for remote-control production drilling applications and has been in operation in LKAB in Sweden since. Together with ABC Total and the new-generation Simba a single operator can supervise up to six production drill rigs. Thanks to the common control system the same functions are now, in 2014, available for Scooptram loaders.

There have been a number of steps towards automation of underground loaders and trucks in the past few years, including vehicle monitoring systems, load weighing systems, and several remote-control systems.

In 2005 Atlas Copco released a line-of-sight radio remote control for Atlas Copco loaders, the Scooptram RRC. This was the first automation product developed for the Atlas Copco loaders. The product has been a success due to its user-friendliness, durability, cost-efficiency, and ease of support, and today is operational in more than 30 countries world-wide.

The first RCS loader to be launched was the 14 t Scooptram ST14 loader with RCS, introduced in 2006. This was followed by a 7 t loader (ST7), an 18 t loader (ST18), and a 42 t truck (MT42), all being automation-ready with RCS.

In 2009 Atlas Copco released the Scooptram Automation system, a semi-automated system for Atlas Copco RCS loaders. The package includes an ergonomic and easy-to-use operator’s station, an RCS loader with additional sensors, a safety system isolating the loader from other equipment and underground personnel, and a standard wireless communication link (802.11) to the mine network (LAN). The loader adds features such as Tele-remote control, auto-tramming, and auto-dumping, which increase
both safety and productivity of the load and haulage operation.

In 2011 Atlas Copco delivered single-machine Tele-remote on Simba L6C’s to Australia. Simba Multi Machine Tele-remote was introduced in 2012 on six Simba W6Cs for Sweden (LKAB). All six production rigs can be controlled by a single operator. The remote-controlled Simbas can then be utilized through shift changes during blasting hours, increasing the productivity per shift.

In 2014 Atlas Copco released the Scooptram Multi Machine, a semi-autonomous system for multiple remote control of underground loaders. From one or more control rooms, one or several operators can operate a large number of loaders. A brand-new safety system ensures compliance with the strictest safety regulations. The modular safety system design allows a large production area to be divided in several production zones, restricting underground personnel from the vicinity of the autonomous loaders.

Why Multi Machine Tele-remote?
Remote control systems remove operators from exposed production areas, improving personal safety and working conditions. From a remote control room the operator can operate the machine as efficiently as if he/she were sitting in the cabin. The benefits for remotely operated machines have been mostly increased safety, while productivity has been maintained the same as for the manual operated machine.

To reduce the cost per ton, one operator has to accomplish more or the machine has to operate faster and more efficiently. However, there is a limit to how fast a drill rig can drill or a loader or truck can load, haul, and dump. Modern mining equipment is more productive than ever, but until recently productivity was constrained by the requirement of one operator per machine.

Atlas Copco are market leaders in auto-functions. Auto-drilling was introduced to the market as early as 1998 on a Boomer face drill rig. Since then the ABC Total package for drill rigs has added functions as auto-boom and feed positioning, and Auto-boom collision control. This ABC total package enables a complete round of fan drilling for the Simba production drill rig. An automatic bit changer function eliminates the exposure of personnel even further at the production face.

Since 2009 the Scooptram loader ST14 has incorporated auto-tramming and auto-dumping, and these features are now being introduced on all new RCS loaders and trucks.

These auto-functions allow the operator to supervise the machine while working with other work related tasks or simply sitting doing nothing.

For remotely operated machines, these auto-function allow one operator to accomplish more. A case history for the Simba Multi Machine production drill rig will explain how LKAB Malmberget introduced the system to their mine and the results.

The benefits of a Multi Machine system depend on the mine and the set-up and usage of the system. Centralized control of every machine increases the utilization and efficiency of the fleet. Maintenance and production interferences can be more easily managed. Operating costs can be reduced since there is no need to have an operator for each machine. However, the cycle time between the different auto-functions and the tasks to be performed limits the number of machines that a single operator can manage.

The Tele-remote system for Simba production drill rigs includes ulti Machine control and video surveillance with pan-tilt-zoom cameras. All functions available on the manual rig can be accessed from the remote operator’s station, such as ABC total. Remote control enables production drilling to continue between shift changes and during blasting hours, increasing productivity further.

The Simba vehicle installation
The Simba Multi Machine system is built with the RCS as a base. Sensors, antennae, network modules, cameras, a safety module, and a control unit are added to the RCS for fast and reliable control of the system (Figure 2).

The operator’s station
The operator’s station includes the standard RCS Simba control panel with an additional joystick for remote camera control, the standard RCS display, a video monitor and server cabinet with video decoder, machine allocation server, safety module, and communication hardware.

The operator can remotely monitor and control the parked production drill rig and take action if the automatic ABC
Total sequence stops for any reason. It is possible to control the same RCS functions and controls as from inside the cab. Figure 3.

With Multi Machine control the operator can supervise and control up to six Simbas from one or several operator’s stations. All rigs are monitored by the camera surveillance system. The vehicle diagnostics, key performance indicators, and status are displayed on the Atlas Copco Machine Server (ACMS) touch monitor, where the operator also selects the rig to operate. Figure 4.

The Scooptram Multi Machine
The semi-autonomous system includes Tele-remote control, Multi Machine control, and Auto-tram and Auto-dump functions. This makes it possible to avoid human exposure in unsafe areas such as unsupported stopes, or in any other load, haul, and dump applications. Scooptram Multi Machine is designed to be efficient, reliable, and easy to use. The remote operator’s station provides the operator with an ergonomic and safe working environment with full control and support of the system.

The Scooptram vehicle installation
The Scooptram automation is built with the RCS as a base. Sensors, antennae, network modules, cameras, a safety module, and a rugged high-performance computer module are added to the RCS vehicle. Figure 5.

The operator’s station
The operator’s station includes the control panel, a monitor, server cabinet, desk, and chair. The operator handles the vehicle and the system with the control panel and obtains visible feedback from strategic onboard cameras and a lasers-view, which is displayed at the operator’s desk monitor. Full vehicle data information is displayed along with remote on-line diagnostics. Figure 6.

With Multi Machine control the operator can operate several loaders from one or several operator’s stations. The system is flexible and can operate a single loader or a number of remotely controlled loaders. The number of loaders that can be controlled by a single operator depends on the operator’s capabilities and the cycle time.

The Tactical Display provides the user with an overview of the entire system. The current status of the machine, area isolation system, and infrastructure can be easily monitored by the operators, production management, maintenance management, or any other party that could benefit from this information. The Tactical Display is tied to a map of the mine, with assets like draw points and dump points visible.
as well as machines with their current location and assignment status. Figure 7.

The safety system

The area isolation system is a highly flexible modular system designed to safely isolate the automated machines from the rest of the mine. This is achieved through the use of light barriers together with an area restriction stop light and a check in/check out area. Should a barrier be breached, only the automation machine in that production zone will be safely shut down, allowing the remaining machines to safely continue operation in their respective automation production zones.

Each area isolation system can have a total of 30 automation production zones and a maximum of 90 barriers. Each automation production zone can contain one
automated machine, giving a total of 30 machines running simultaneously in one area isolation system.

Set-up of production zones is done through the master touchscreen PLC cabinet, which allows any barrier to be assigned to any production zone, providing a truly flexible system.

For every automation production zone, a check in / check out area allows one automated machine to safely enter and exit the zone. This is achieved by using a unique key that can be connected to only one machine at a time, ensuring safe automation operation at all times.

A safety barrier consists of a safety box, a light barrier, and an area restriction stop light. Multiple light barriers can be added to create multiple automation production zones, or to safely isolate a single automation production zone. To comply with local regulations, physical barriers might also be required and could be integrated with the safety system.

The area isolation system is connected through Ethernet, connecting the production area (including one or several zones), the operator’s station safety module, and the machine’s safety PLC. In addition to a reliable Ethernet network, 110/230 V Power is also required. Figure 8.

Communication network

For the machines to operate in semi-autonomous or Tele-remote mode, WLAN coverage is required throughout the automation work area. A communication network is installed, normally controlled and maintained by the mine itself. The local area network (LAN) and wireless local area network (WLAN) must be compliant with the Ethernet standard IEEE 802.3 as well as the Wi-Fi standards IEEE 802.11 a, b, or g. The network requires a reservation of 20 fixed IP addresses to be able to use a dynamic host configuration protocol (DHCP) server. One vehicle utilizes a bandwidth of approximately 2 Mb/s while in operation. The access point (AP) has to be set up as a single-channel network, using one of the three orthogonal channels 1, 6, or 11. The WLAN cannot be encrypted in any way and must broadcast its Service Set Identifier (SSID). Signal strength to the vehicle should not drop below -60 dBm. The AP needs to be complemented with power and Ethernet and requires bandwidth of at least 2 Mb.

When a smaller production area for one or two vehicles is required, Atlas Copco can provide the communication hardware needed. The number of access points or switches required depends on the size and layout of the automation production area. Atlas Copco can assist with a communications audit to determine the infrastructure required. Figure 9.

A new era of safety and productivity

The functionality of Multi Machine gives new possibilities to increase safety and productivity. It is today available for Simba production drill rigs and Scooptram underground loaders, and will be extended over time to additional Atlas Copco equipment.

Increased safety

Underground safety is all about minimizing the risk for the operators and personnel. In any underground mine operation most serious injuries and fatalities occur in the productions area at or close to the production face.

Tele-remote control minimizes the time that the operator is exposed at the face of the production area. When an area has been equipped with communication network infrastructure and safety barriers, a Tele-remote loader can extract a full face without any human exposure. A production drill rig will require an operator for the rig set-up at the face for each drill fan, but after that the operator can remotely supervise and control a complete drill fan. This results in minimum exposure of underground personnel in the production area and face.

For self-operating equipment, a safety-classed safety system is required. The Tele-remote controlled production drill rig is parked during remote operation but the booms and drills are autonomous controlled during auto-drilling and boom positioning. This requires a safety system that allows shutting down the rigs from a remote location.

For semi-autonomous underground loaders are tramming in high speed without supervision by an operator. For compliance with mining regulations the area needs to be sealed off from personnel. With Multi Machine a safe and
Flexible safety system has been designed that allows several loaders to operate in several production cells. Since these cells are separated from each other, maintenance can be safely carried out on a vehicle in one area without affecting the other vehicles.

Increased productivity
The current mining trends of lower ore grades, deeper mines, increased cost of labour, and the increased demand of natural resources require increased efficiency and productivity. With Multi Machine control one operator will be able to produce more than ever before.

A production drill operator can now supervise several rigs from a single operator station in a remote control room. Although most of the work is supervision, the operator can be utilized for additional supervision tasks as well, such as monitoring pumps, fans, the network etc.

A loader operator can control as many underground loaders as the loader cycle time allows. The cycle time normally depends on haulage distance of the mucked ore. Three to four loaders is probably human maximum for most applications. This is because the process is semi-autonomous and the remote loading needs to be Tele-remote loaded for each cycle.

- Autonomous control of the drill rig and underground loader ensures that the equipment is operated within its capabilities, thus reducing wear and tear. Productivity will also be more controlled since the outcome of each shift is known more precisely.

- Both the rig and the loader can be operated between shift changes and during blasting hours. This adds more hours of operation each shift, which also increases productivity at the end of the day.

- To gain increased productivity the mine will need to plan for implementing Tele-remote equipment.
- A stable network is the foundation of high availability of any Tele-remote system. Parts of the production areas also need to be sealed off for the semi-autonomous loaders.
- Any interruption an isolated production area during operational hours will affect the operation. Area inspections, maintenance, or traffic through the area need to be planned so as to not interfere with normal operation.
- New maintenance skills need to be implemented in the service organization. Network support is new for most underground mines. A reliable network is essential for any remote operation.

The product becomes a project
All Atlas Copco’s underground automation systems offers are set up as projects that include project support offer. The project is preceded by an evaluation of the customer’s requirements, and followed by a service agreement for continuous support during operation (Figure 10):

- Customer request / feasibility study
  Business case reviewed
  • Define what to do, project specification developed
  Make sure that the project is feasible
  • Audit at customer
  Risk analysis
  • Tender / offer

- Order / concept study
  • Cross-functional evaluation of possible concepts and decide on technical solution
  Compile a project execution plan
  • Order specification describing how to execute the project to meet all customer demands
  • Order confirmation
  • Agree with customer on KPIs to measure the success of the project

- Design and verification
  • Start execution of project
  Design of system
  • Verify that the system fulfills the customer requirements

- Production
  • Manufacturing of system
• Make system ready for delivery to the customer

Mine production / ramp up
• Installation and commissioning at site
• Training
• Set up support organization
• Ramp up mine production
System is fully operational
• KPI fulfilled

Closing
• Follow up to ensure a high quality focus, and customer satisfaction

Above is an example of how a project could look. Most customer requests are different and the cooperation project could be big or small. Atlas Copco will make sure that the customer has the correct product for the application and the support structure to maintain the system.

A Multi Machine case history

A zero tolerance approach toward workplace injuries has been an ambition at Malmberget for many years. Increasingly, this has led mine planners to reduce the number of personnel working in hazardous areas, which has been a driving factor behind automated drilling. Another reason has been the need for absolute precision in longhole drilling with a deviation of less than 1%. This enabled LKAB, starting in the late 1980s, to increase the vertical height between the sublevels and the length of each hangingwall from the previous 12–15 m to 28 m, which altogether would boost production by 25%. The increase in crude ore production per-blast hole was almost tenfold, from 1 200 t to 10 000 t. A mass mining method had been instituted with a high level of safety thanks to the ability to drill straight holes as long as 55 m using the Simba W469 rigs. Malmberget, which today has 1 300 employees, is currently in the midst of another transitional period. Apart from a generational shift that is taking place in the workforce, in which young and technology-savvy operators are being phased in, the mine decided to conclude a comprehensive upgrade of its production drilling fleet and, as at Kiruna, retire the ‘BK’ rigs after long and trusted service.

Among the modern features of the Simba WL6 C model, apart from increased power, is a new water pump system that increases efficiency and reduces water spillage, a new air venting system that ensures longer pump life, and a pump pressure control that boosts hammer efficiency. In addition, and perhaps more importantly, the Simba WL6 C rigs are equipped for tele-re mote operation and ‘full fan’ automated drilling using WLAN communication and a completely new data system and interface – taking operators out of hazardous mining areas.

Since Malmberget took delivery of the sixth and final Simba WL6 C rig, the team of operators in the 1 000 m control room has been refining their skills to meet a strict production target of 350 drill metres per rig per 24 hours. This translates to 2 100 m per week and 120 000 m per year per rig. See Figure 11.

Tele-remote operation and monitoring

The high level of automation now at the mine’s disposal is based on the computerized Rig Control System (RCS) on the Simba rigs working in the ABC Total mode. The system enables ‘full fan’ automation; in other words, a complete fan of production blast-holes can be drilled without human input. Drilling can be carried out throughout the night when no personnel are present in the mine. The Tele-remote function enables the Simba WL6 C to be operated from the safety of a control room with the aid of continuous video supervision and a laser guidance system on the rigs. This provides the operators with access to the same information that is shown on the rig’s monitors.

At Malmberget, the Tele-remote system is currently used for rigs located 1 km to 6 km from the control room. Communication is both via LAN and WLAN and the rigs’ interface, known as Rig Remote Access (RRA). Developed

Figure 11. Malmberget Production Manager Bengt Anttila keeps a close check on the performance targets for automation, set at 350 drill meters per rig, per 24 hours, or 2 100 ms per week
Motion sensors and safety

By increasing the level of automation in the mine, Malmberget is strengthening its efforts to minimize the exposure of personnel to the risk of rock falls and other hazards in production areas. Nonetheless, operators need to be on standby and ready for any eventualities such as breakdowns, stoppages, or incidents at the face.

The Atlas Copco designed system for rod handling is devised so that it makes three attempts to resume drilling. If by the third attempt it is unable to continue, the rig goes into standby mode and sends out an alarm notification. But these are not the only situations when drillers need to be inside the drift. After each fan has been completed, the operator needs to reposition the rig manually from the cabin to the flow sheet. Similarly, if drilling is in progress and a support function breaks down, an extra precaution is provided by the rig’s motion sensors, which detect if a person comes within a 2 m radius of the production area, a situation in which the drilling function stops automatically.

Figure 12. Working at a safe distance in the 1 000 m level control room, Malmberget’s operators are in charge of two drill rigs each using Tele-remote technology from Atlas Copco

Despite these systems, technology does not solve all problems and according to the production manager, one of his biggest responsibilities is to make sure that new operators always have at least one senior driller they can turn to for help or advice in the case of stoppages or rock fall.

This is one of the first lessons that is taught during the four-week training courses held regularly throughout the year in close cooperation with Atlas Copco. These courses consist of both theory and manual on-site drilling where operators learn to handle the controls in the Simba cabin.

While the screens and gadgets in the control room central give an impressive overview and are able to perform many jobs due to high-capacity cameras and the possibility of sharing screens and data, there are other elements of conventional drilling that are lost, such as sound. Traditionally, quite often the decisions made by drillers are based on what they hear as well as see. Suppliers such as Atlas Copco have made attempts at placing microphones on the rigs and feeding the sound into the control room, but it has proven difficult to relay the subtle noises in the drift that can be crucial indications of an impending error.

Zero accidents

The ore at Malmberget is hosted in Precambrian volcanic rock with a varying content of abrasive biotite schist. This means that while conditions are outstanding in some sections of the mine, other areas can be very unstable and require extensive rock reinforcement and ground support. This is a large cost factor at LKAB that is never compromised, especially since both Malmberget and Kiruna are mining at greater depths than before.

Preventive maintenance is essential

Malmberget has a full service agreement with Atlas Copco for all of its production drilling rigs. Lead times were expected to be reduced further in 2013 as the company’s service crew was due to move from premises in central Gällivare into one of the main workshops in the mine.

Although full fan automation enables drilling to continue through the night, adding significant value in terms of production metres, downtime is obviously costlier than with conventional mechanized drilling where an operator can immediately attend to an issue. In the case of breakdown during the day, however, service personnel are usually on site within 30 minutes, but only if they are needed.

Together with Atlas Copco, the mine is working continuously to find solutions to the issue of nighttime drilling. One of the problems with the magnetite ore is that it puts great pressure on the stingers, which can cause frequent stoppages. Alternative components are being tested and the potential is there for each rig to drill at least 100 m per night shift. Another important requirement is a stock of machine parts, ordered in advance, and to inspect the equipment before service. See Figure 13.

To increase availability of the rigs, Malmberget also employs a system whereby complete components are exchanged and reconditioned in the workshop.

The IT challenge

Among the biggest challenges for mines seeking to bring automation into their operations is to set up IT systems that can be applied to a variety of equipment and different software. At Malmberget, this task is approached with the same dedication as the day-to-day drilling, blasting, and...
hauling. Although Kiruna is a few steps ahead in terms of how widespread automation has become in the mining process, Malmberget has a different set of preconditions as it extracts ore from 12 orebodies instead of just one.

Another key aspect is the impact that automated loading has on the mine layout, as entire sections of the mine need to be closed off to personnel. For the time being, Malmberget’s priority is to expand WLAN communications in all areas of the mine and further develop the monitoring capabilities for production drilling.

Clearly, compared with just a few years ago, mining technology is in the midst of being revolutionized and a discussion about drilling today is as much, if not more, focused on systems capabilities as it is on the set-up of machinery, drill string diameters, and rock mechanics. Tomorrow’s operators will undoubtedly be used to a different way of working, facing challenges of a different kind such as delays on networks and how to make troubleshooting even more efficient.

**The future around the corner**

Atlas Copco has been offering automation systems and integrations for several years. By using self-operating equipment we reduce human exposure to the mining environment and routine or repetitive work. What these automated functions or systems do depends on the application and what safety or productivity gain needs to be improved. Our goal is to continue to increase human safety and at the same time increase efficiency.

The technology developed on the RCS platform and launched on today’s equipment will be available on additional new-generation equipment in the near future to meet the growing demands from our global customers.

Atlas Copco’s common Rig Control System will greatly extend the bounds of what can be achieved through the automation of mining machinery. The productivity and cost benefits of this are unquestionable and will be required for today’s and tomorrow’s underground mining applications. Only the imagination set the limitation on what can be accomplished.
Oscar Lundhede

Atlas Copco

Oscar Lundhede joined Atlas Copco in 2005, initially involved in the production of underground LHD vehicles with a specialisation in control systems. From there, he progressed to a Technical Service role with primary responsibility for Radio Remote Control systems on Scooptram loaders. During this time, Oscar played a leading role in the development of the Scooptram Automation system, which enables tele-remote and semi-autonomous operation of Atlas Copco LHD’s. He is currently a Product Manager for Automation at the Atlas Copco Underground Rock Excavation division in Örebro, Sweden, with responsibility for the development of automation solutions across the underground mining product range.

Oscar holds a Master of science degree in Electrical Engineering from Örebro University, Sweden, and has also spent time as a Radio Link Commander in the Swedish military.