UNDERGROUND MINE COMMUNICATIONS INFRASTRUCTURE GUIDELINES

Part II: Scenarios and applications

SUBMITTED BY
Underground Communications Infrastructure Sub-Committee of the Underground Mining Working Group

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Janice M. Burke
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Global Mining Guidelines Group
Heather Ednie, Managing Director
hednie@gmggroup.org
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1. FOREWORD

The Global Mining Guidelines Group (GMG) is a global, multi-stakeholder community to advance the availability and use of standards and guidelines for the international mining industry. This GMG document was prepared by a GMG working group. Draft documents are checked and approved by working group members, prior to approval by the GMG Governing Council.

Formed as part of the Canadian Institute of Mining, Metallurgy and Petroleum (CIM), GMG is supported by CIM and three other Partner Organizations: the Australasian Institute of Mining and Metallurgy (AusIMM), the Southern African Institute of Mining and Metals (SAIMM), and the Surface Mining Association for Research and Technology (SMART), as well as its Member Companies and participants.

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2. DEFINITIONS OF TERMS, SYMBOLS, AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AR/AP</td>
<td>Accounts Receivable/Accounts Payable</td>
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<td>CAE</td>
<td>Computer-Aided Engineering</td>
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<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
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<tr>
<td>EPCM</td>
<td>Engineering, Procurement, and Construction Management</td>
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<td>GIS</td>
<td>Geographic Information Systems</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>IT</td>
<td>Information Technology</td>
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<tr>
<td>MWD</td>
<td>Measurements While Drilling</td>
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<tr>
<td>PBX</td>
<td>Private Branch Exchange</td>
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<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
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<td>PTT</td>
<td>Push-To-Talk</td>
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<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
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<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
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<tr>
<td>UHF</td>
<td>Ultra-High Frequency (300 MHz to 3 GHz)</td>
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<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
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<tr>
<td>VHF</td>
<td>Very High Frequency (30–300 MHz)</td>
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<td>VOD</td>
<td>Ventilation on Demand</td>
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3. KEYWORDS

Autonomous equipment, Communications technology, Infrastructure, Remote-control, Semi-autonomous equipment, Underground mine, Wireless communication

4. INTRODUCTION AND BACKGROUND

The rapid development of industrial and communications technology in recent years increasingly benefits mining activities around the globe and has affected nearly every facet of the mining process. Companies are rapidly deploying these new tools and applications to gain the associated productivity and financial benefits. However, they face a key challenge in that they require the appropriate infrastructure to support data communications technology in the mining environment, particularly underground mines.

Many new technologies developed and sold by vendors require high-speed digital networks to manage the increasing volumes of data generated in the underground mining environment. The data range from video and voice communications to vehicle telemetry, dispatch, and other critical systems and services. In the past, each vendor required separate networks for their proprietary solutions. Today, industrial control and mining solution vendors are moving towards a single standardized, consolidated communications infrastructure based on the digital Ethernet (transmission control protocol/internet protocol or TCP/IP) network framework—or at least are developing communications interfaces to allow their devices to interconnect with this type of network—in mine sites to improve production and cost optimization. This allows mining companies to run multiple services over a single backbone, thereby improving management while lowering deployment and support costs. The rapid shift from traditional, legacy analog systems (e.g., leaky feeder) to high-speed digital networks has created a lag in the knowledge and experience that is required to properly plan, design, deploy, and maintain such systems.

This Underground Mine Communications Infrastructure Guidelines series is intended to provide a high-level view of the processes needed by mine personnel to meet planning and design requirements when creating or replacing underground mine communications infrastructure. The series of five parts is intended to step the user through the general tasks and components needed to define the technical requirements for an underground communications infrastructure that supports mine services now and into the foreseeable future.

4.2 Part Descriptions

The five parts within the Underground Mine Communications Infrastructure Guidelines series are arranged so the user learns a fundamental concept and then builds on their knowledge in each consecutive part. The following is a brief description of each part of the document series.

4.2.1 Positioning and Needs Analysis Part I provides a general overview of the guideline objectives, audience, and mine communications maturity lifecycle diagram. This dia-
gram provides a high-level overview of the services and supporting technology that is generally used in each phase of the mine lifecycle. The diagram initially shows business services and communications technology on the surface in the exploration phases and then shifts to the underground environment as the site develops.

4.2.2 Scenarios and Applications Part II (this document) provides scenarios of practical applications in underground mining today and in the near future. The scenarios relate how different communications infrastructure designs can be used and combined to achieve key technology goals. The business services design requirements comprise a series of checklists to step through the general tasks and components needed for each phase of underground mine planning and development. The checklist helps mine personnel and contractors identify the appropriate network communications technologies to support required services and solutions.

4.2.3 General Guidelines Part III compiles information to help the reader better understand the general concepts, techniques, and methods used in the industry to create and maintain a communications infrastructure. The content is designed to help non-information—technology (IT) personnel identify high-level requirements, and to provide resources to learn more the technologies.

4.2.4 Business Case Development Part IV is focused on the development of the business case and charter.

4.2.5 Planning, Deploying, and Support Considerations Part V provides more detailed project management practices, communications infrastructure technical design information, and sustainability support information.

5. SCOPE AND DEFINITION

Part II describes seven underground mine communications scenarios based on two key mining values: safety and productivity. To show the benefit of the technology for each example, the following questions can be considered:

1. What is the end state expected?
2. What exactly do you need?
3. Where do you need it?
4. What are the cost benefits?

Part II also provides checklists that can be used to identify the business/mining services in each phase of the mine lifecycle and the high-level digital communications requirements to implement these services.

6. SCENARIO 1: OPERATIONS BETWEEN SHIFTS

6.1 Problem Statement

Mining companies continue to be challenged to maintain consistent production schedules because of labour shortages, high costs, and government restrictions on time periods personnel are permitted to be underground. Companies need to find more effective ways to extend operational utilization, contain costs, and improve employee safety.

6.2 Objectives

The objective is to use remote-controlled, semi-autonomous, and autonomous equipment to address the challenges above. The mining company builds a control room on the surface to house remote-control consoles for fixed and mobile equipment in the underground mine, such as drillers, hammers, trucks, and loaders. This equipment has been modified for manual or remote-control operation via a network connection to the surface. Automatic drilling and positioning functionalities are recommended for efficient production. Drivers are trained to remotely operate equipment from the control room.

6.3 Communications Examples

1. Telemetry modules in mining vehicles provide “near real-time” data on, for example:
   - vehicle speed and location,
   - oil pressure and engine temperature, and
   - object avoidance proximity sensors and control.

2. Wireless remote-control equipment automates all vehicle driver functions.

3. Vehicle-mounted antennas provide wireless digital communications to vehicle systems.

4. Portable wireless access point appliances located in tunnels and stopes of active production areas create wireless “mesh” communications coverage throughout production areas.

5. The backbone/core communications system could be hybrid leaky feeder supporting digital communications, Wi-Fi®, fibre optic cabling, or a combination of technologies to provide the primary data connection from the surface to underground mine areas and also for data communications within the mine for voice, video, and other data services.

6. Head-end wireless bridges—strategically located throughout the underground workings—relay digital traffic from the wireless access points to the wired communications backbone cabling network within mine tunnels.
6.4 Mine Technology Used
1. Tele-remote vehicles
2. Autonomous remote vehicles
3. Tele-remote hydraulic hammers
4. Multi-machine operators
5. Tele-remote control
6. Automatic drilling
7. Mine communications network
8. Safety system area isolation

6.5 Design Example
Figure 1 shows an example of underground mine design incorporating remote-controlled, semi-autonomous, and autonomous equipment.

6.6 Deliverables (Business Outcomes)
1. Ore extraction can proceed in round-the-clock shifts with minimal transition time, thereby dramatically improving productivity and daily output.
2. Fewer workers are required in underground areas. Depending on the level of automation, these workers could be limited to maintenance and other general functions.
3. Vehicle automation provides more detailed telemetry on vehicle health and status, thereby facilitating predictive and better preventive maintenance scheduling and lower risk of incidents and abuse.
4. Vehicle automation increases productivity and decreases vehicle maintenance costs.
5. Fewer risks and safer conditions expand the pool of candidates to operate underground vehicles.

7. SCENARIO 2: ACCELERATE POST-BLAST RE-ENTRY

7.1 Problem Statement
Mining companies continue to face the challenge of improving equipment utilization and optimizing the mobile fleet investment. The goal for every drill and blast application is to resume rock extraction as quickly as possible after each blast. Dust and gases need to be evacuated before personnel can safely work in underground areas. Telemetry and automation can accelerate this process, so rock extraction can begin minutes after blasting.
7.2 Objectives
The objective is to accelerate post-blast re-entry employing several possible technologies, including environmental monitoring sensors, an automated ventilation control system, and remote-controlled and autonomous vehicles.

7.3 Value Proposition
The time required for dust and gas evacuation can be optimized with automation. Ventilation on demand (VOD) can provide overall cost advantages by lowering power requirements in unoccupied areas. In areas near a blast location, a portable, remote-controlled unit can be used to accelerate personnel access after detonation. Combined with the use of environmental sensors and remote-controlled and autonomous vehicles, advantages include:
1. more available hours of production,
2. increased utilization of equipment, and
3. improved safety with tele-remote rock extraction.

7.4 Mine Technology Used
1. VOD
2. Tele-remote vehicles
3. Wireless environmental sensors (stopes)
4. Ground stability sensors (e.g., seismic, GPS shift)
5. Human tracking
6. Wired mine communications network
7. Battery-powered wireless communications network

7.5 Design Example
1. Efficient remote-controlled/automatic ventilation system (e.g., VOD)
2. Tele-remote loaders operated from surface or safe underground location

7.6 Deliverables (Business Outcomes)
1. Improved worker health and safety
2. Increased direct production
3. Increased equipment utilization/lower fleet requirements

8. SCENARIO 3: MONITORING AND DISPATCHING SYSTEM

8.1 Problem Statement
Mining companies face the growing challenge of improving production efficiencies without jeopardizing worker safety.

8.2 Objectives
The objective is to monitor all underground activities and coordinate equipment and people to more efficiently plan production and maintenance and improve safety. Taking advantage of technologies for doing more with less—namely monitoring and dispatching systems for higher work flow efficiencies (more material extraction per shift)—can lower energy consumption and better utilize vehicles and workplaces. In addition, the ventilation network can be optimized for better performance and lower cost.

8.3 Value Proposition
The synergy of using technologies in conjunction with each other will allow new and existing operations to increase productivity, safety, and equipment lifecycle.

8.4 Mine Technology Used
1. Human tracking (for safety)
2. Collision avoidance and proximity warning
3. Vehicle tracking and telemetry (for production and maintenance)
4. Activity tracking
5. Drill plan dispatching
6. Cameras/closed-circuit television
7. Extensometer for rock mechanics control
8. Seismic three-dimensional accelerometer sensor
9. E-bolts to measure rock displacement
10. Wired mine communications network
11. Battery-powered wireless communications network

8.5 Design Example
1. Effective, real-time monitoring and dispatching reduces the gaps between serial processes (e.g., drill, blast, muck and ground support processes), thereby enhancing their effectiveness.
2. Adherence to the mining plan is improved through better tracking and dispatching.

8.6 Deliverables (Business Outcomes)
Cost-effective methods to improve production efficiencies provide the following deliverables:
1. improved equipment scheduling and queuing capabilities,
2. fewer equipment outages/production interruptions,
3. improved operations management,
4. timely production metrics, and
5. shorter equipment idle times.

9. SCENARIO 4: AUTO DRILLING SUPPORT

9.1 Problem Statement
Autonomous drilling or “auto-drilling” is usually introduced to improve drilling quality—namely the accuracy of
drill holes—leading to better quality excavation, with less overbreak and damage to surrounding rock. Auto-drilling can also enhance the productivity of drills by minimizing lost time between drill holes, as well as the geotechnical understanding of the mine by providing records of key measurements while drilling (MWD).

The communications support for equipment management and programming can be handled in several ways, depending on the maturity of the underground communications system. Although universal serial bus (USB) memory drives/sticks can be used to transfer information related to auto-drilling, a semi- or fully online solution greatly reduces management overhead and chance of error or data loss.

9.2 Objectives
1. Increase the drill metres per shift and between shifts
2. Improve the accuracy of drilling activities
3. Finish the production drilling sequence as quickly as possible
4. Provide real-time geotechnical data about the face via MWD

9.3 Value Proposition
1. Manpower needs are reduced.
2. Timely geotechnical information from MWD improves the support plan and orebody model.
3. The drill rig is better utilized.

9.4 Mine Technology Used
A range of mine technologies can be used, presented below in increasing order of value:
1. Drilling data can be transferred to and from the rig on a USB memory stick. This method relies on people, is prone to error/loss/damage, and requires a mechanical connection to be made for each data transfer.
2. If the rig is within reach of a mine-wide communications system at least once per day, drill patterns and MWD data can be down- and up-loaded to a server with minimal manual intervention.
3. If the rig is continuously within reach of a low-data-rate connection, it can communicate with a server at any time, allowing managers continuous access to data regarding the state of the machine.
4. If the rig has access to a high-data-rate connection, as well as auto-drilling, the rig can be remote-controlled. Cases 2–4 require both a server on the mine network that can manage communications with one or more rigs, and IP-based communication with the rig, which may be intermittent.

9.5 Design Example
Figure 2 shows an example of communications support for equipment management and programming during auto-drilling.

9.6 Deliverables (Business Outcomes)
1. Increased production through drilling during shift changes and after blasts
2. Real-time geotechnical data from drilling
3. Better management information about drill use
4. With multi-machine control, potential for a single operator to supervise more than one drill rig
5. Improved equipment life because equipment is always operated within design limits

10. SCENARIO 5: AUTONOMOUS MINING ACTIVITIES

10.1 Problem Statement
The challenge is to move—with as few personnel as possible in underground work areas—as much material as is possible safely and quickly from the production face/draw bell to the ore pass/crusher/truck or re-muck location.

10.2 Objectives
The objective is to use programmed loader and truck cycles to enable fast, precise operation that is controlled within equipment limitations.

10.3 Value Proposition
1. Bottlenecks are reduced for material handling, cycle times, and productivity.
2. Safety is improved.
3. Equipment utilization is improved.

10.4 Mine Technology Used
1. Semi- or fully autonomous mine trucks
2. Semi- or fully autonomous underground loaders
3. Wired mine communications network
4. Battery-powered wireless communications network
5. Safety system area isolation

10.5 Design Example
Figure 3 shows an example of programmed truck and loader cycles integrated with the mine communications network.

10.6 Deliverables (Business Outcomes)
1. Increased material hauling/production
2. Improved safety for mine personnel
11. SCENARIO 6: UNDERGROUND ENVIRONMENT MONITORING AND ANALYSIS

11.1 Problem Statement
Collection and analysis of a broad range of data related to critical mine environment conditions are needed to improve the mining strategy and improve personnel safety in underground areas. Greater real-time monitoring capabilities allow personnel and equipment to respond quickly to environmental changes in the mine.

11.2 Objectives
The objective is to use the connectivity between the underground environmental monitoring systems and surface or internet services to benefit underground environment monitoring and data analysis.

11.3 Value Proposition
The ability to effectively monitor the underground environment can increase time available for ore extraction.

11.4 Mine Technology Used
1. Sensor network technology and analytics
2. Battery-powered, underground, wireless communications network
3. Underground wired and wireless networks connected to an aboveground network
4. Server/computer
5. Internet connection

Figure 2. Communications Support for Equipment Management and Programming during Auto-Drilling
11.5 Design Example
Figure 4 shows an example of mine environment monitoring integrated with the mine communications network.

11.6 Deliverables (Business Outcomes)
1. Improved safety for mine personnel and equipment
2. Higher quality and quantity of mine information delivered in a timely manner for improved decision making

12. SCENARIO 7: POST-ACCIDENT COMMUNICATION

12.1 Problem Statement
Real-time data relayed through data communications and localization networks are essential for the rescue team to significantly accelerate rescue operations and save lives.

12.2 Objectives
The objective is to provide a reliable data communications network to quickly communicate with the trapped or injured workers, and enable the rescue team to assess an incident and plan the rescue operation.

12.3 Value Proposition
The time required to start a rescue operation can be greatly shortened by having real-time data from the underground sensor networks. Data such as gas level, ground stability, water level, and personnel locations are critical to plan an effective rescue operation and keep the rescue team safe. Specific advantages include:
1. allow a mine-wide evacuation signal to reach everyone in the mine;
2. improve the rescue team reaction time;
3. allow the rescue team to visualize the conditions they will encounter underground;
4. keep the rescue team connected with the control room; and
5. quickly re-establish the communication link to the trapped workers.

12.4 Mine Technology Used
1. Uninterruptible power supply on all network infrastructure
2. Fibre-optic/coaxial data network
3. Wireless mine communications network
4. Battery-powered wireless communications network
5. Safety-enabled miner cap lamp that can receive an evacuation signal wirelessly, detect man down, provide emergency communications, provide miner location, and message the miner
6. Wireless gas sensors (stope)
7. Ground stability sensors (e.g., seismic, displacement, timing synchronization)

12.5 Design Examples
Figures 5, 6, and 7 show examples designs for evacuation notification, personnel tracking, and dissemination of information for the rescue team, respectively, integrated with the mine communications network.

12.6 Deliverables (Business Outcomes)
1. Improved safety of the rescue team
2. Higher speed and effectiveness of rescue operations
3. Improved chance of survival for injured or trapped personnel
4. Faster resolution of the incident and return to normal operation
Figure 5. Evacuation Notification

Figure 6. Personnel Tracking Location
13. SCENARIO 8: UNDERGROUND MAPPING AND SAMPLING

13.1 Problem Statement
An up-to-date geological and sampling model is a key deliverable from the geology/resources department at a mine. Most of this work is still undertaken using old technologies such as tapes, geological hammers, and paper notebooks. In a deep gold mine, a geologist can spend 85% of their day getting to and from the working face to be mapped and sampled. Once there, the geologist manually captures data to create an interpretation of the geology—with varying quality depending on experience and drawing ability—and may miss some critical features. Once captured in the notebook, the data must be manually converted to digital format to update the geological databases and models.

Near real-time geological capture systems have already proven their worth on extraterrestrial missions such as the United States National Aeronautics and Space Administration Mars Rover program. Further, ruggedized, wearable technology (Figure 8) is in use in by the military. Thus, there is no technical reason why these technologies cannot be combined for use in a terrestrial underground mine situation.

13.2 Objective
The objective is to use direct digital capture to dramatically reduce the time needed to collect geological map-
ping and sampling data, including images. Samples can be taken with more spatial precision using “e-pegs” in the mining tunnels. Captured data can then be transmitted in real time to the geological office on the surface, where they can be reviewed to ensure they are of sufficient quality. If required, data can be recaptured. The data captured can also be archived for future use when updating geological and grade determinations. This method of data capture and upload will not only be quicker than current methods, but will allow for more peer review as part of the on-the-job training of geologists and technicians.

13.3 Value Proposition
The time taken to complete the mapping and sampling data capture and upload can be greatly reduced, which will increase the time available to interpret the new data and update the models. The approach offers several advantages.
1. More realistic 3D models
2. More consistent data capture because the image of the face will be part of the dataset
3. Peer review during the mapping operation and used to build
5. Potential to use other underground staff to do the work
6. Potential to use an extension to existing underground machines or small rovers to do the work
7. Increased safety because geologists and technicians spend less time at the face

13.4 Mine Technology Used
The ruggedized, flame-proof, battery-powered wearable technology comprises:
• RGB (red, green, blue) camera;
• infrared/ultraviolet camera;
• voice capture software (for taking notes);
• tablet for displaying images and annotating using mapping software;
• X-ray fluorescence analyzer (to give initial grades for samples);
• bar code reader (to log the samples);
• positioning system reading e-pegs;
• sample extraction unit (replacing hammer);
• gas sensors (safety feature); and
• link to mine communications system.

13.5 Design Example
See Figure 8b for an example of an ergonomically designed harness with built-in technology.

13.6 Deliverables
• Improved safety: personnel location is known, they spend less time at mine face
• Increased productivity: shorten the time to complete the task
• Realistic models: more accurate and precise data, ability to capture images as a data source

14. IDENTIFICATION OF SERVICES REQUIREMENTS
Figures 9–13 are examples of high-level checklists that can be used to identify the business/mining services in the exploration, advanced exploration, construction, production, and mature mine phases of the mine lifecycle and the high-level digital communications requirements to implement those services. As an illustration, when evaluating vendor solutions such as fuel control, dispatch, and human tracking, the checklists can help identify necessary digital communications systems and components. Checklists such as these are also helpful references when discussing the underground mining system requirements with management, or when discussing the communications infrastructure design and sustainability needs with IT and operational technology teams.
Figure 9. Business Requirements during the Exploration Phase
### Mandatory Requirements:

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<th>Description</th>
<th>Date:</th>
<th>Approvals</th>
<th>Comments:</th>
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<td>Telephony PABX system</td>
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<td>Internet service (satellite, DSL, cable modem, etc.)</td>
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<td>Define minimum bandwidth requirement</td>
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<td>For locally saved files (e.g., Word, Excel, PowerPoint)</td>
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<td>Firewall</td>
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<td>Coordinate with IT to meet standards</td>
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<td>Layer 3 Ethernet switch</td>
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<td>Coordinate with IT to meet standards</td>
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<td>Hard disk drive, tape drive, cloud service</td>
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<td>User computers</td>
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<td>Define with IT and HR for count and standards</td>
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<td>Interfaces with the campus IT network</td>
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### Custom Requirements:

#### Field

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<td></td>
<td></td>
<td></td>
<td></td>
<td>Field and site disaster/emergency use</td>
</tr>
</tbody>
</table>

#### Site Office

<table>
<thead>
<tr>
<th>Description</th>
<th>Required</th>
<th>Not Required</th>
<th>Potential Need</th>
<th>Initials</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAN optimization appliance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>e.g. Admin Office, Project staff trailers, etc.</td>
</tr>
<tr>
<td>User computers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coordinate with IT to meet standards</td>
</tr>
<tr>
<td>Cellular coverage (Edge, 3G, 4G)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coordinate with IT to meet standards</td>
</tr>
<tr>
<td>Printer(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Identify local cellular providers</td>
</tr>
<tr>
<td>Battery backup services for critical systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Computer, telephone, etc.</td>
</tr>
<tr>
<td>Wireless network (Wi-Fi)-internal offices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coordinate with IT to meet standards</td>
</tr>
<tr>
<td>Wireless network (Wi-Fi)-outdoor campus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coordinate with IT to meet standards</td>
</tr>
<tr>
<td>Fax services (machine or network application)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coordinate with IT to meet standards</td>
</tr>
<tr>
<td>Remotely-accessed applications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Managed at a corporate or regional level</td>
</tr>
<tr>
<td>Video conferencing equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coordinate with IT to meet standards</td>
</tr>
</tbody>
</table>

**Severity Level:**

- 5 Health and safety-life threatening
- 4 Regulation/environmental
- 3 Production impact
- 2 Efficiency impact
- 1 Very low impact

---

**Figure 10. Business Requirements during the Advanced Exploration Phase**
<table>
<thead>
<tr>
<th>Services Supported</th>
<th>Severity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Underground voice communications (2-way radio, telephony)</td>
<td></td>
</tr>
<tr>
<td>2. Campus IT network connectivity</td>
<td></td>
</tr>
<tr>
<td>3. Industrial control system/operational technology network connectivity (PLC, sensors, etc.)</td>
<td></td>
</tr>
<tr>
<td>4. Security surveillance system</td>
<td></td>
</tr>
<tr>
<td>5. Vehicle/asset management tracking</td>
<td></td>
</tr>
<tr>
<td>6. Human tracking</td>
<td></td>
</tr>
<tr>
<td>7. Mine emergency system</td>
<td></td>
</tr>
<tr>
<td>8. EPCN/engineering contractor-communications requirements</td>
<td></td>
</tr>
<tr>
<td>9. Enterprise resource planning (supply chain, AR/AP, job/process costing, etc.)</td>
<td></td>
</tr>
<tr>
<td>10. Project management</td>
<td></td>
</tr>
<tr>
<td>11. Fuel tracking management</td>
<td></td>
</tr>
<tr>
<td>12. Mine 3-D modeling</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mandatory Requirements</th>
<th>Approvals</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Date</td>
<td>Initials</td>
</tr>
<tr>
<td>Campus fibre optic data backbone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campus WAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground network-fibre optic backbone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground wireless communications system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site WAN system-internet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT computer room or modular shelter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cybersecurity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Custom Requirements</th>
<th>Select One</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Underground network-high availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAN private connection to corporate network</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expanded VHF/UHF 2-way radio system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Install underground digital wireless system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile devices, tablets, smartphones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video conferencing equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video/voice conferencing applications</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Severity Level:** (Select the number based on the highest impacting factor)

- 5 Health and safety-life threatening
- 4 Regulation/environmental
- 3 Production impact
- 2 Efficiency impact
- 1 Very low impact

Figure 11. Business Requirements during the Construction Phase
Figure 12. Business Requirements during the Production Phase
**Revision:**

**Lifecycle Stage:** Mature Mine  
**Implementation Horizon:** Years  
**Country:**  
**Province/State:**  
**Name of Designer:**  
**Date:**  
**Sponsor:**  
**Role:**

**Description:**
Support for ongoing sustainability of the services implemented and now operating in production within the mine environment.

**Services Supported:**

<table>
<thead>
<tr>
<th>Number</th>
<th>Service Description</th>
<th>Severity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Autonomous vehicle management</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Vehicle dispatch services</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Vehicle health and maintenance tracking (telemetry)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Fuel control/tracking services</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Plant automation system (SCADA)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Laboratory information management system (LIMS)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Manufacturing execution system (MES)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Production information management system (PIMS)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Access control system</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Remote detonation system</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Geotechnical and hydrology monitoring and control</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Ventilation – remote monitoring and control</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Proximity warning system (people and vehicle)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Miner evacuation and rescue</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Human tracking system</td>
<td></td>
</tr>
</tbody>
</table>

**Mandatory Requirements:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Date</th>
<th>Initials</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cybersecurity</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Custom Requirements:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Not Required</th>
<th>Potential Required</th>
<th>Initials</th>
<th>Comments</th>
</tr>
</thead>
</table>

**Severity Level:** (Select the number based on the highest impacting factor)

- **5** Health and safety-life threatening
- **4** Regulation/environmental
- **3** Production impact
- **2** Efficiency impact
- **1** Very low impact

---

*Figure 13. Business Requirements during the Mature Mine Phase*