Tab 6
SubterraMine
Demonstration Results

July 23, 2007

1 Introduction

SubterraCom Wireless Solutions ("SWS") conducted a detailed test of its underground communication, tracking, and monitoring system, SubterraMine, at Magnum's Campbell's Creek #7 mine on July 15, 2007. A professional engineer, licensed by the state of West Virginia, was present at all times to view the demo; both underground and above ground.

SWS' SubterraMine system provides tracking, text messaging, voice, and video capabilities through a state-of-the-art commercial-grade wireless mesh network. All these features were successfully demonstrated during the test in Campbell's Creek #7. The Magnum Campbell's Creek #7 mine has two operational sections. The test area selected covers the entrance to the mine and the first long stretch before the first section. The mine has a conveyer belt with 5 belt sections already in place. Miners and equipment are transported in and out of the mine on a track using battery operated man trips and rubber-tire vehicles. The SubterraMine configuration that was demonstrated consisted of:

a) Nine Subterra-ZAPs (Zone Access Points) that had wireless backhaul connection at 5.8GHz and access radios to supply connection for the devices at 2.4 GHz compliant with IEEE 802.11a/b/g standards. The Subterra-ZAPs are wireless routers that service incoming and outgoing traffic.

b) From a device perspective, we demonstrated the

   (i) Three Subterra-M8 Advanced devices (model 810A). The 810A is a portable wireless tracking and communication device that allows miners to send and receive text messages and SOS alerts, and the capability of being tracked.

   (ii) One Subterra-M8 Compact device (model 810C). The 810C is a portable wireless tracking and communication device that allows miners to send and receive SOS alerts, and the capability of being tracked.

   (iii) One Subterra-M8 SmartM8 device (model 810S), which is intrinsically safe PDA. It was used to demonstrate the text and voice capability (in one unit). As well, the 810S is capable of peer-to-peer communications (one-to-one).

   (iv) Two Subterra-M8 VoIP devices (model 810P), Wi-Fi VoIP phones which delivered unprecedented voice quality throughout the mine.

   (v) A commercially available wireless webcam was used to show the capabilities of the system in interoperating with off-the-shelf devices to add value to mining operations investment in a SubterraMine system.

c) One computer server running SWS's tracking and communication software, Subterra-VU. The Subterra-VU is the server software that allows users to monitor miners, send and receive messages. It links and controls the flow of information between the Subterra-ZAPs, the Subterra-M8s, and the monitoring workstations.

d) Power (120V 60Hz) was provided through the power stations in the mine at two locations and some critical devices had the power backup. One of the ZAPs shared an outlet with a pump throughout the test with no visible sign of degradation in its functionality.

The nine ZAPs used can be easily spread out to cover at least three to five times the area covered in this test without too much loss of the accuracy of tracking or coverage for communication. Time to deploy and providing of more coverage was the reason to decide on a smaller deployment for the demonstration. In other tests performed on the SubterraMine system, distances of up to 2700 feet were successfully covered for backhaul communication of ZAPs, and the limitation was the actual mine terrain, not the ZAPs' range.

The live feed from the camera shows there could be limitless possibilities when the wireless network is deployed. The tracking was also done to complete satisfaction, where the units were located accurate to within a cross-cut's width (mostly to 50-60 feet) and under a diverse set of situations, including near belt and power lines, while riding the man trip on the track and even behind stoppings.

A scenario where one of the ZAPs in the middle was shut down intentionally was tried out to show the robustness of the communication provided through redundancy. Phone calls from the end ZAP to the surface were not affected by the introduced fault in the network and fail-over has been transparent to the phones. This confirms lab tests showing a fail-over time of 75ms for the hand-off. In another scenario the failure of an antenna unit did not cause the network to fail and the self-healing and self-configuring features of the ZAPs provided an alternative path using the access radios to provide backhaul to the end ZAP.

Overall the performance was flawless and throughout the test area the phones were capable of connecting to a PBX server and devices to the SubterraMine server. The main test area has been designed to be the straight stretch extending beyond the third ZAP. In this section, three main entries including the belt, the track, and the only entry in the primary escape way were covered to 100%. Results show reliable connection in all entries and transparent hand-offs while moving. The quality of voice was superior to both existing systems in the mine (leaky feeder and page phones) and the mobility was beyond what those systems could offer. Overall, the demonstrated system surpassed the expectation of the coal mine operator.

Miner to Miner Test Data

Equipment	Test Site	Comm Type	Distance Between Miners	Entry/Crosscut Conditions				SIO Score
				Height	Width	Scenario	Notes	
SmartM8 to M8A	SWS-071807-A	WiFi Messaging	1900 ft	72 inch	20 ft	2, 3, 7	Text Message transmitted from device at portal to device inside the mine	5, 5, 5
M8P to M8P	SWS-071807-A	WiFi Voice Call	Up to 800 ft	72 inch	20 ft	1, 3, 7	Voice call established and held next to the belt & the power line in the belt entry from 500 ft to 1400ft deep in the mine; Phone to phone communication, however showed same quality and coverage as surface to miner (refer to part 8 of the results)	5, 5, 5
SmartM8 to M8P	SWS-071807-A	WiFi Voice Call	Up to 200 ft	72 inch	20 ft	1, 3, 7	Voice call established and held next to the belt & the power line in the belt entry from 500 ft to 1400ft deep in the mine	5, 5, 5
M8P to M8P	SWS-071807-A	WiFi Voice Call	Up to 500 ft	72 inch	20 ft	1, 2, 3, 4, 6, 7, 8	Voice calls placed at multiple test points including all provided in part 8 of the results	5, 5, 5

Legend

- **Equipment** – The make and model of the device(s) whose function is being demonstrated
- **Test Site** – provide a unique reference code to the attached diagram (unique select three letters that will be unique to your company insert hyphen then 6 digit date insert hyphen then a unique letter for that test example ABC-051607-A)
- **Comm Type** – what type of communications used between the miners
- **Distance between the miners** – provide the demonstrated distance between the miners
- **Height** – what is the height of the entry or crosscut noting
- **Width** – what is the width of the entry or crosscut
- **Scenario** – relevant demonstration scenario number from list below (if not one of the standardized scenarios a description is required) (not all may be relevant to all technologies)
- **Notes** – any thing you feel are relevant for understanding
- **SIO Score –** this is a relative communication quality score (displayed as S#, I#, O#) (see "Reporting the Quality of Communications in Underground Mines" on the WV OMHS&T web site for further explanation)

Signal Strength	**Interference of any type**	**Overall Quality**
5-Excellent	5-No interference	5-Excellent
4-Good	4-Very slight	4-Good
3-Fair	3-Moderate	3-Fair
2-Poor	2-Heavy	2-Poor
1-Useless	1-Extreme	1-Unusable

Process Notes:

This demonstration assumes that all backbone equipment has ceased to function. It can not require the function of any devices other than the ones the miners carry with them.

1. An entry or crosscut with an axis that allows for uninterrupted line-of-sight
2. An entry or crosscut with an axis that has a curvature which precludes line-of-sight
3. An entry or crosscut with an axis that contains a belt noting belt width & placement
4. An entry or crosscut with an axis that contains a metal overcast
5. An entry or crosscut with an axis that contains a wire-mesh roof
6. An entry or crosscut with an axis that is blocked by stopping noting type
7. An entry or crosscut with an axis that has a power line parallel to path of transmission
8. The effectiveness to transverse one or more coal pillars

Miner to Reader Test Data

Equipment	Test Site	Comm Type	Number of Miners	Distance to Reader or Coverage Area	Rate of Travel	Describe Ride	Entry/Crosscut Conditions			
							Height	Width	Scenario	Notes
M8A	SWS-071807-A	WiFi	6	200 ft	10 ft/s	Man Trip	72-100 in	20 ft	1, 10	Miner at location A connected to ZAP607 at -50 to -75 dBm; also have ZAP609, ZAP606, and ZAP605 visible at connectable dBm levels (< -85)
M8A	SWS-071807-A	WiFi	6	375 ft	0 ft/s	N/A	72-100 in	20 ft	1, 3, 7	Miner at location B connected to ZAP612 at -50 to -75 dBm; also have ZAP609, ZAP606, and ZAP605 visible at connectable dBm levels (< -85)
M8A	SWS-071807-A	WiFi	6	75 ft	3 ft /s	On foot	72-100 in	20 ft	1, 4, 9	Miner at location C passing under the belt connecting to ZAP603 at -50 to -75 dBm; also have ZAP604 visible at connectable dBm levels (< -85)
Wireless Camera	SWS-071807-A	WiFi	6	225 ft	0 ft/s	Mounted	72-100 in	20 ft	3, 8	Camera mounted on belt head sending live feed of the belt wirelessly without line-of-sight to ZAP12

M8P	SWS-071807-A	WiFi	6	75 ft	0 ft/s	On foot	72-100 in	15 ft	6, 8	Phone call placed after going through man door in Omega seals to primary escape-way at Location D connected to ZAP604 with signal levels from 5 to 2 bars
M8P	SWS-071807-A	WiFi	6	50 ft	0 ft/s	Stationary	72-100 in	20 ft	6	Uninterrupted phone call going through entrance metal door at Location E still connected to ZAP602 with signal levels from 5 to 2 bars
M8P	SWS-071807-A	WiFi	6	250 ft	3 ft/s	On foot	72-100 in	20 ft	3, 7, 8	Uninterrupted phone call walking next to belt and power line loosing line-of-sight going behind a pillar at location F still connected to ZAP612 with signal levels from 5 to 2 bars
M8P	SWS-071807-A	WiFi	6	250 ft	0 ft/s	Stationary	72-100 in	20 ft	6	Uninterrupted phone call going through man door in Omega seals to primary escape-way at Location G still connected to ZAP609 with signal levels from 5 to 2 bars
M8P	SWS-071807-A	WiFi	6	350 ft	0 ft/s	Stationary	72-100 in	20 ft	2, 8	Uninterrupted phone call leaving the boundary of the demo network to Location H still connected to ZAP609 with signal levels from 5 to 2 bars

Legend

- **Equipment** – The make and model of the device(s) whose function is being demonstrated
- **Test Site** – provide a unique reference code to the attached diagram (unique select three letters that will be unique to your company insert hyphen then 6 digit date insert hyphen then a unique letter for that test example ABC-051607-A)
- **Comm Type** – what type of wireless communications used between the miner and the reader
- **Number of miners** – how many miners passed reader at same time
- **Distance to reader or coverage area** – provide the distance between the miners and the reader or coverage area (in the case of wifi coverage cloud)
- **Rate of Travel** – how fast were the miners moving in feet per minute
- **Describe Ride** –- describe the means of travel (on foot or in vehicle with description of vehicle)
- **Height** – what is the height of the entry or crosscut noting
- **Width** – what is the width of the entry or crosscut
- **Scenario** – relevant demonstration scenario number from list below (if not one of the standardized scenarios a description is required
- **Notes** – any thing you feel are relevant for understanding

Process Notes:

Miner-to-reader testing is to be done with the tag on miners situated in realistic scenarios not with loose tags

1. **An entry or crosscut with an axis that allows for uninterrupted line-of-sight**
2. **An entry or crosscut with an axis that has a curvature which precludes line-of-sight**
3. **An entry or crosscut with an axis that contains a belt noting belt width & placement**
4. **An entry or crosscut with an axis that contains a metal overcast**
5. **An entry or crosscut with an axis that contains a wire-mesh roof**
6. **An entry or crosscut with an axis that is blocked by stopping noting type**
7. **An entry or crosscut with an axis that has a power line parallel to path of transmission**
8. **The effectiveness to transverse one or more coal pillars**
9. **Miners simultaneously passing a reader in opposite directions**
10. **Miners in a mantrip passing a reader at the maximum speed typical for the mine**

Miner to Surface Test Data

Equipment System/Miner	Test Site	Comm Type	Distance from Backbone or Node	Entry/Crosscut Conditions				SIO Score	Distance from Surface Comm-Center	Number Amps/Nodes to Surface Comm-Center
				Height inches	Width feet	Scenario	Notes			
M8A	SWS-071807-A	WiFi messaging	200 ft	72-100	20 ft	1	Miner at location A connecting to ZAP607 receiving message from dispatch	5, 5, 5	1975 ft	6
M8A	SWS-071807-A	WiFi messaging	375 ft	72-100	20 ft	1, 3, 7	Miner at location B connecting to ZAP612	5, 5, 5	1425 ft	5
M8A	SWS-071807-A	WiFi messaging	75 ft	72-100	20 ft	1, 4	Miner at location C passing under the belt connecting to ZAP603	5, 5, 5	600 ft	3
Wireless Camera	SWS-071807-A	WiFi live video feed	225 ft	72-100	20 ft	3, 8	Camera mounted on belt head sending live feed of the belt wirelessly without line-of-sight to ZAP612	5, 5, 5	1275 ft	5
M8P	SWS-071807-A	WiFi Voice	75 ft	72-100	20 ft	6, 8	Phone call placed after going through man door in Omega seals to primary escape-way at Location D connected to ZAP604	5, 5, 5	875 ft	4
M8P	SWS-071807-A	WiFi Voice	50 ft	72-100	20 ft	6	Uninterrupted phone call going through entrance metal door at Location E still connected to ZAP602	5, 5, 5	300 ft	2
M8P	SWS-071807-A	WiFi Voice	250 ft	72-100	20 ft	3, 7, 8	Uninterrupted phone call walking next to belt and power line loosing line-of-sight going behind a pillar at location F still connected to ZAP612	5, 5, 5	1300 ft	5

| Equipment System/Miner | Test Site | Comm Type | Distance from Backbone or Node | Entry/Crosscut Conditions | | | | SIO Score | Distance from Surface Comm-Center | Number Amps/Nodes to Surface Comm-Center |
				Height inches	Width feet	Scenario	Notes			
M8P	SWS-071807-A	WiFi Voice	250 ft	72-100	20 ft	6	Uninterrupted phone call going through man door in Omega seals to primary escape-way at Location G still connected to ZAP609	5, 5, 5	2300 ft	6
M8P	SWS-071807-A	WiFi Voice	350 ft	72-100	20 ft	2, 8	Uninterrupted phone call leaving the boundary of the demo network to Location H still connected to ZAP609	5, 5, 5	2400 ft	7

Legend

- **Equipment** – The make and model of the device(s) whose function is being demonstrated
- **Test Site** – provide a unique reference code to the attached diagram (unique select three letters that will be unique to your company insert hyphen then 6 digit date insert hyphen then a unique letter for that test example ABC-051607-A)
- **Comm Type** – what type of communications used between the miner and the system that allows communications to the surface
- **Distance from backbone** – provide the demonstrated distance between the miners and the first component of any system that allows the two-way communication with the surface communication center
- **Height** – what is the height of the entry or crosscut noting
- **Width** – what is the width of the entry or crosscut
- **Scenario** – relevant demonstration scenario number from list below (if not one of the standardized scenarios a description is required) (not all may be relevant to all technologies)
- **Notes** – any thing you feel are relevant for understanding
- **SIO Score –** this is a relative communication quality score (displayed as S#, I#, O#) (see "Reporting the Quality of Communications in Underground Mines" on the WV OMHS&T web site for further explanation)

Signal Strength Interference of any type Overall Quality

5-Excellent   5-No interference   5-Excellent

4-Good	4-Very slight	4-Good
3-Fair	3-Moderate	3-Fair
2-Poor	2-Heavy	2-Poor
1-Useless	1-Extreme	1-Unusable

- **Distance from comm**.-Center – provide the total distance from the point where the miner's communication entered any backbone systems and the communication center on the surface
- **Number of Amps/Nodes Comm-Center** – provide the number of powered components required between the device reading the tag and signal tracking device and the surface

Process Notes:

This demonstration assumes that all backbone equipment has ceased to function. It can not require the function of any devices other than the ones the miners carry with them.

1. An entry or crosscut with an axis that allows for uninterrupted line-of-sight
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6. An entry or crosscut with an axis that is blocked by stopping noting type
7. An entry or crosscut with an axis that has a power line parallel to path of transmission
8. The effectiveness to transverse one or more coal pillars

Reader to Surface Test Data

Equipment System/Miner	Test Site	Comm Type	Distance Reader to Surface Comm-Center	Entry/Crosscut Conditions				Number Amps/Nodes to Surface Comm-Center
				Height inches	Width feet	Scenario	Notes	
ZAP603	SWS-071807-A	WiFi	525 ft	72	20	2, 6	Wired (Ethernet cable) Signal can penetrate metal doors as shown by ability to connect to portal ZAP from between the two entrance doors Received = 10156 of 10159 (0% loss) RTD (min, max) = 1ms, 39ms Average RTD = 1ms	1
ZAP604	SWS-071807-A	WiFi	800 ft	72	20	2, 3, 7	48″ Belt crosses the path at right angle with low over-hang and grid guard Average RTD = 8.3 ms	2
ZAP605	SWS-071807-A	WiFi	1000 ft	72	20	1	Average RTD = 10.1 ms	3
ZAP606	SWS-071807-A	WiFi	1625 ft	72	20	1, 7	Average RTD = 13.6 ms	4
ZAP607	SWS-071807-A	WiFi	2175 ft	72	20	1, 7	Received = 10149 of 10159 (0% loss) RTD (min, max) = 5ms, 46ms Average RTD = 8ms	5
ZAP610	SWS-071807-A	WiFi	2150 ft	72	20	1, 7	Primary escape way behind Omega Seal Average RTD: 27.3 ms	5

Legend

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- **Test Site** – provide a unique reference code to the attached diagram (unique select three letters that will be unique to your company insert hyphen then 6 digit date insert hyphen then a unique letter for that test example ABC-051607-A)
- **Comm Type** – what type of communications used between the reader and the surface
- **Distance to reader or coverage area to surface communication** – provide the distance between the reader or coverage area (in the case of wifi coverage cloud) and the surface
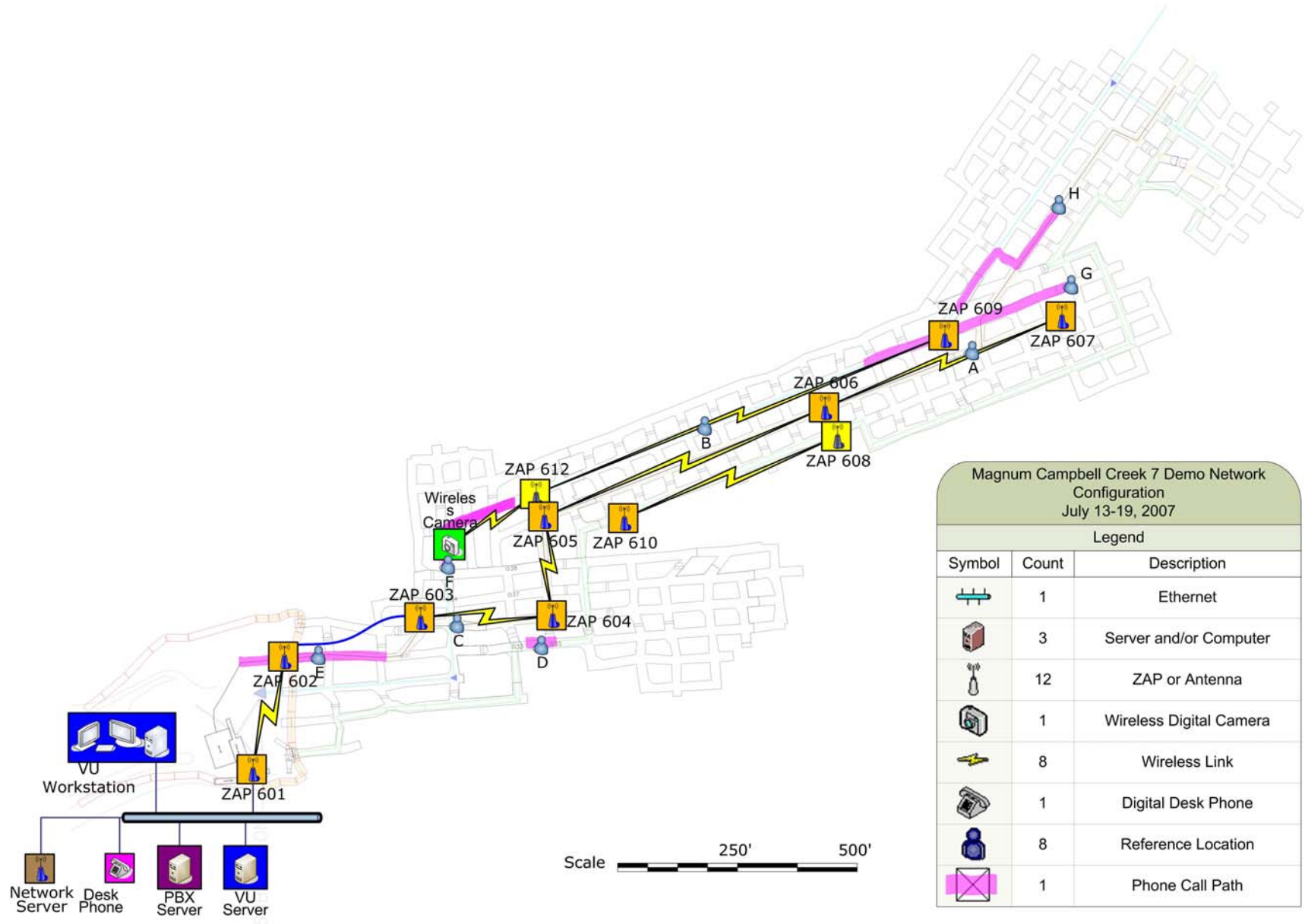
- **Height** – what is the height of the entry or crosscut noting
- **Width** – what is the width of the entry or crosscut
- **Scenario** – relevant demonstration scenario number from list below (if not one of the standardized scenarios a description is required) (not all may be relevant to all technologies)
- **Notes** – any thing you feel are relevant for understanding
- **Number pf Amps/Nodes to Surface Comm**-Center – provide the number of powered components required between the device reading the tag and signal tracking device and the surface

Process Notes:

Miner-to-reader testing is to be done with the tag on miners situated in realistic scenarios not with loose tags
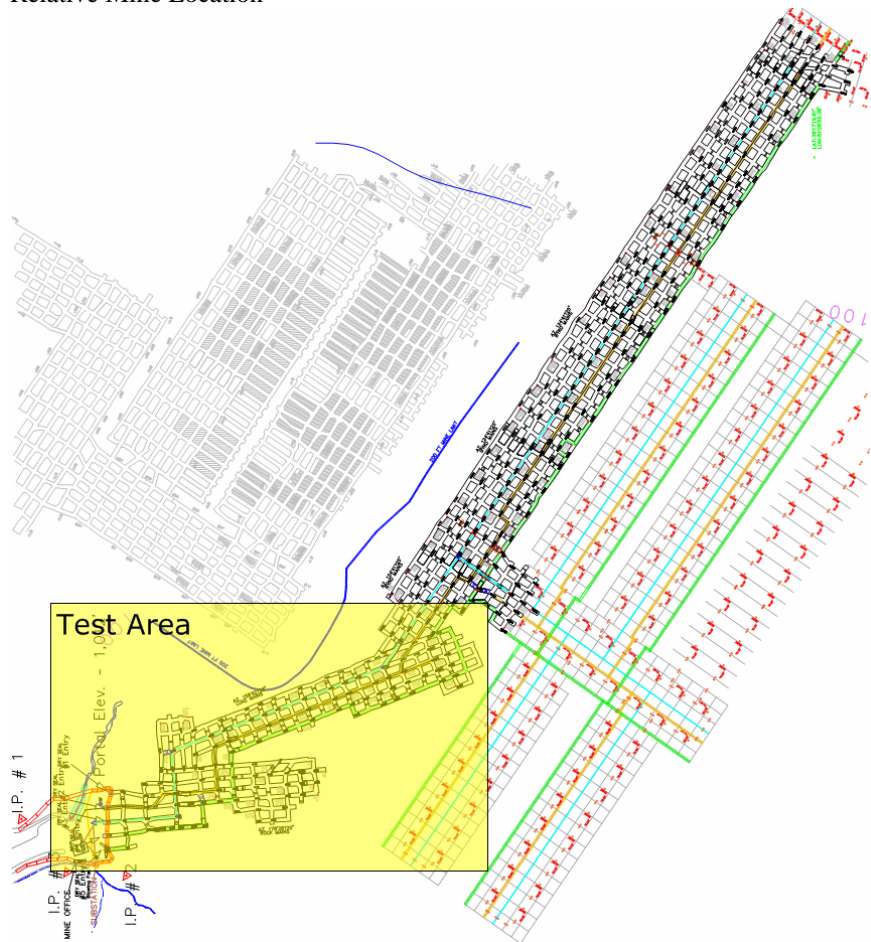
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6. **An entry or crosscut with an axis that is blocked by stopping noting type**
7. **An entry or crosscut with an axis that has a power line parallel to path of transmission**
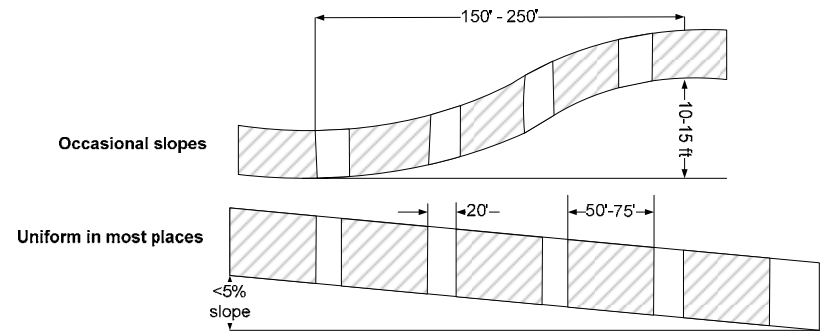8. **The effectiveness to transverse one or more coal pillars**

Top View

Magnum Campbell Creek 7 Demo Network
Configuration
July 13-19, 2007

Legend		
Symbol	Count	Description
	1	Ethernet
	3	Server and/or Computer
	12	ZAP or Antenna
	1	Wireless Digital Camera
	8	Wireless Link
	1	Digital Desk Phone
	8	Reference Location
	1	Phone Call Path

Scale   250'   500'

Name of Mine	Date of Testing	Certifying Engineer
MAGNUM COAL - CAMPBELLS CREEK #7 MINE	**July 18, 2007**	**Mark A. Cornell, P.E.**

Relative Mine Location

Test Area

I.P. # 1

I.P. # 2

Side Elevation

150' - 250'

10-15 ft

Occasional slopes

20'

50'-75'

Uniform in most places

<5% slope

Name of Mine	Date of Testing	Certifying Engineer
MAGNUM COAL - CAMPBELLS CREEK #7 MINE	**July 18, 2007**	**Mark A. Cornell, P.E.**

Survivability/Re-Establish

Element(s)	Dynamic Impact	Fire	Static Pressure	Power Interruption
SubTerraCom Wireless network	Lose 6 nodes	Lose 1 node	Lose 6 nodes	None
	Dynamic and self-configuring nodes (kept as spare) can be practically deployed in a few hours and the network will self-heal to establish connection based on whatever radio connection is or becomes available. Also replacing antennas that are the only parts of the ZAPs exposed (the ZAPs can be deployed in covered holes in the ground to protect them from exposure to accidents) would be trivial and not so costly. Having multipath connections into the network from different entries would also keep it alive in case of blockage or accidents in one entry. Phone system can also have redundancy in the gateways (or proxies) that would enable ongoing operation in clusters of the network despite lack of communication back to the main server. The trapped miners can coordinate efforts in the blocked area until rescue arrives.	The network can be designed to with stand 1 or 2 sequential nodes and fall back on other radios to keep connection. Of course throughput will be slightly less in such a case but in a test scenario where ZAP606 was lost, the connection at the end of the tunnel around ZAP607 remained untouched. Introducing redundant paths for the backhaul communication can improve fault-tolerance and can be designed into the network as the mesh network is built to have such redundancy. In worse case scenarios where no backhaul radios are available to be used for connection, the access radios can automatically be selected to keep inby ZAPs connected to the outby (as an option).	Dynamic and self-configuring nodes (kept as spare) can be practically deployed in a few hours and the network will self-heal to establish connection based on whatever radio connection is or becomes available. Also replacing antennas that are the only parts of the ZAPs exposed (the ZAPs can be deployed in covered holes in the ground to protect them from exposure to accidents) would be trivial and not so costly. Having multipath connections into the network from different entries would also keep it alive in case of blockage or accidents in one entry. Phone system can also have redundancy in the gateways (or proxies) that would enable ongoing operation in clusters of the network despite lack of communication back to the main server. The trapped miners can coordinate efforts in the blocked area until rescue arrives..	The ZAPs are available in a number of configurations including up to days of battery backup. Remote monitoring of the health of the ZAPs and their battery backup can also prevent costly and time-consuming troubleshooting.

Legend

- **Element** – provide the name and description of each element of the product/system
- **Dynamic Impact** – in the top cell describe what is likely to happen if the Element is in the path of explosion moving down an entry and in the lower cell describe what options there are for re-establishing the system in the case the element is rendered non-functional and what testing was done to verify performance

- **Fire** – in the top cell describe what is likely to happen if the Element is subjected to a fire and in the lower cell describe what options there are for re-establishing the system in the case the element is rendered non-functional and what testing was done to verify performance
- **Static Pressure** – the top cell describe what is likely to happen if the Element is subject to a static pressure as the result of an explosion and in the lower cell describe what options there are for re-establishing the system in the case the element is rendered non-functional and what testing was done to verify performance
- **Power Interruption** – in the top cell describe what is likely to happen if power to the Element is interrupted and in the lower cell describe what options there are for re-establishing the system in the case the element is rendered non-functional and what testing was done to verify performance

Process Notes:

For purposes of comparison, manufacturers should reference the Sago Reports on the WV OMHS&T web page. The reference scenario is that event.
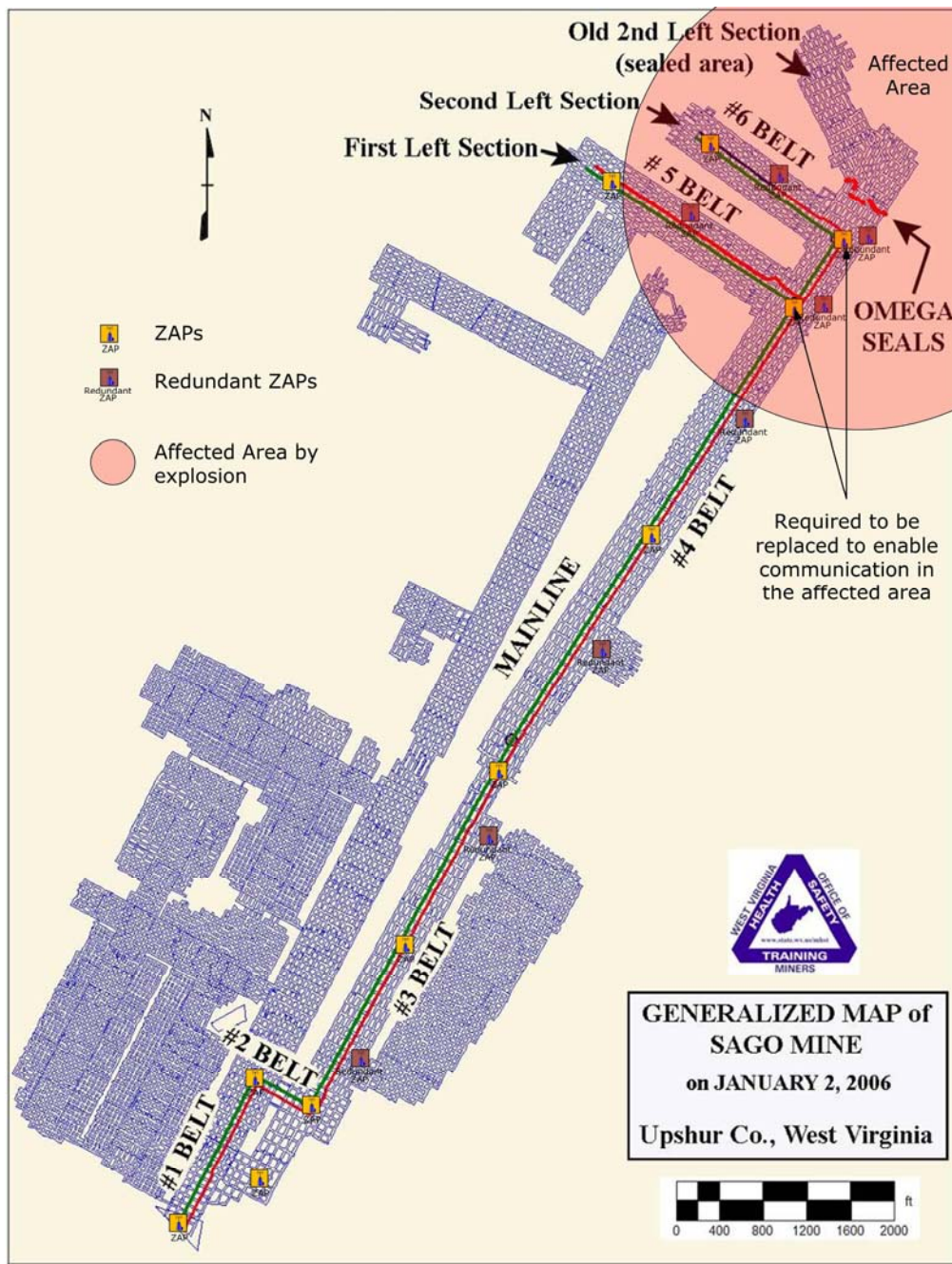
It is difficult to predict specific impacts on each technology because of the variety means of placing specific elements of the communication-tracking systems within the entry or cross section. Generally most likely worst case event is an explosion which will destroy all devices protruding from the rib, roof or floor for a distance of 2000 feet. The second most likely worst case event is a fire or extreme heat that has propagated though out an area of 500 feet of entry or cross cut and has destroyed all man-made devices protruding from the rib, roof or floor. Manufacture may assume their devices will survive these events if they have demonstrated survival and are able to document such. In all other cases the response should assume that all elements of their product have been rendered non-functional and should discuss means for re-establishing functionality.

Redundant signal pathways and hardening options provided by the technology may be described in addressing survivability.

Provisions for rapid reconnection unique to the technology should be described.

Representative Mine Layout (Noting Proposed Element Locations)	Survivability Options Provided Assuming Explosion in Old 2nd Left	
	Individual System Element(s)	ZAPs and optional antennas
	Damage by Dynamic Impact	Only a few units need replacement and mostly low-cost antennas (in the example on the diagram, only the two ZAPs (or their antennas) need replacing and the whole mine can restart communicating again.
	Damage by Fire/Heat	The redundant ZAPs can alleviate the need for immediate replacement in case of fire or heat damage to one or in some cases two of the ZAPs
	Damage by Static Pressure	See damage by dynamic impact above
	Function in Power Interruption	Power backup can safeguard the ZAPs from failure. Remote monitoring of the health of the ZAPs and their battery backup is also available which reduces the chance of faults.