College of Engineering

Department of Mining Engineering

OPTIMIZING THE UTILITY OF UNDERGROUND COMMUNICATION SYSTEMS

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INTRODUCTION

More communication means more data and more data means more problems can be solved

Every coal mine has a communication and tracking system

- Is it working everywhere?
- Is it in compliance?
- Is it over built?

I will discuss an evaluation methodology to assess how different systems and technologies perform in various mining applications, and whether they can satisfy the regulatory requirements

WE ARE DROWNING IN DATA, STARVING FOR KNOWLEDGE

ProgrammableWeb has over 14,000 live updating data sets

Data.Gov has almost 200,000 Datasets

Socrata Reformats and Adds to this Data

Data sets from universities hosted by Libraries are common place (see: http://lib.uky.edu/prodalphbu.html)

Lynda.Com Has 1 Million Paid Subscribers

- Doesn't include group memberships

Coursera has 15 Million users

Stackoverflow.com has over 50 Million regular users

Over 100 Million unique visitors to Quora monthly

Compare to monthly visitors: Facebook 2 Billion, 1.5 Billion on Youtube

BIG DATA VS THE HUMAN SCALE

Human scale data is information that can be consumed and processed by a typical human being

- We can see the trend or fool ourselves into seeing the trend
- Statistical Measures can be used to confirm/deny the trend existence

Big data is an evolving term that describes any voluminous amount of structured, semi structured and unstructured data that has the potential to be mined for information (http://searchcloudcomputing.techtarget.com/definition/big-data-Big-Data)

- Just find the statistical correlation to tell the story

DATA COLLECTION IN THE MINES

Captive data (Siloed Data)

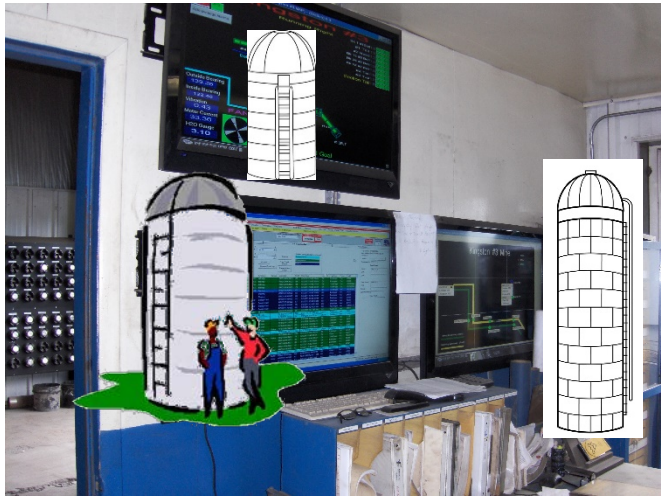
- Vendors/Manufacturers have data opacity and little to no automatic data sharing

Incredibly difficult networking

- Power is hard to get when away from the working face (Surface and Underground)
- Wireless on the surface has to go very far
- Wireless underground is often Captive Data or Very Expensive and certainly not ubiquitous

No interoperability of sensors

CONTROL ROOMS



DATA ANALYSIS IN THE MINES

Automatic/Automated relationship generation can be downright dangerous

- 'Humidity is related to mine water inundation'
- 'Roofbolter drill amperage is related to roof bolt length'

The Engineer's role in the data analysis question is to apply engineering principles to the relationships along with rigorous validation

RADIO AND TRACKING DATA

Compass Digital

Inertial Measurement Unit Digital

2 Spectrum Analyzers

6 Accolade handsets plus 3 on the operators MS SQL

Ordered by DeviceID, Time Inserted, Report Time, and GTPE Time
Survey Start: 2012-12-05 10:42:40

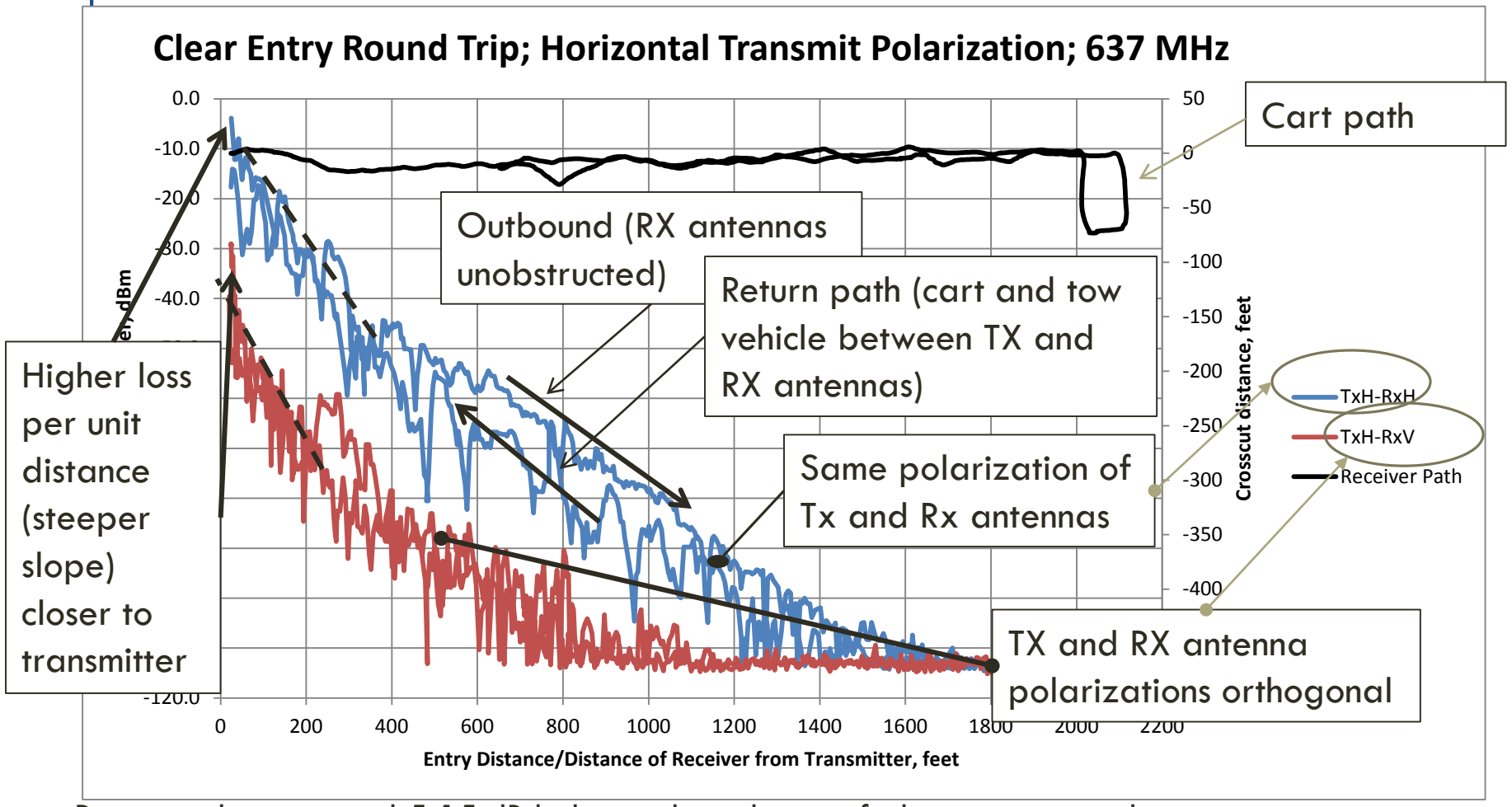
DeviceID ↓	Time Inserted ↓	Report Time ↓	TSPE X	TSPE Y	Avg(IA)	SDA(IA)	90%(IA)	Count	GTPE Time ↓	GTPE min X	GTPE max X	GTPE min Y	GTPE max Y
9388	10:42:31	10:43:11	1905718	350826	259	7	269	641	10:42:31	1905968	1905973	350725	350798
9388	10:43:11	10:43:21	1905758	350843	247	3	251	171	10:43:11	1905971	1905977	350717	350728
9388	10:43:21	10:43:51	1905761	350865	233	14	253	481	10:43:21	1905962	1905977	350720	350799
9454	10:42:31	10:42:41	1905925	350820	51	0	51	172	10:42:31	1905968	1905970	350791	350798
9454	10:42:41	10:43:01	1905941	350820	55	12	73	328	10:42:41	1905968	1905973	350749	350792
9454	10:43:01	10:43:11	1905915	350823	102	6	110	172	10:43:01	1905971	1905973	350725	350752
9454	10:43:11	10:43:21	1906010	350843	128	2	131	171	10:43:11	1905971	1905977	350717	350728
9454	10:43:21	10:43:31	1905764	350865	247	6	255	172	10:43:21	1905970	1905977	350720	350748
9454	10:43:31	10:43:41	1905909	350852	108	8	120	170	10:43:31	1905966	1905971	350746	350774
9454	10:43:41	10:43:51	1905922	350849	76	8	87	170	10:43:41	1905962	1905966	350773	350799
9537	10:42:41	10:42:51	1905932	350813	47	4	53	171	10:42:41	1905968	1905970	350775	350792
9537	10:42:51	10:43:01	1905938	350829	74	8	84	172	10:42:51	1905970	1905973	350749	350776
9537	10:43:01	10:43:11	1905889	350823	118	5	126	172	10:43:01	1905971	1905973	350725	350752
9537	10:43:11	10:43:21	1905974	350829	108	3	112	171	10:43:11	1905971	1905977	350717	350728

Data collection computer SQLite

Mine Map AutoCAD (SVG)

Human input analog

TOUR OF A TYPICAL ROUND-TRIP PLOT



Return path attenuated 5-15 dB below outbound; more fades on return path

Orthogonal polarization coupling 10-30 dB less than when same (freq. and antenna dependent)

A "BLACK BOX" APPROACH

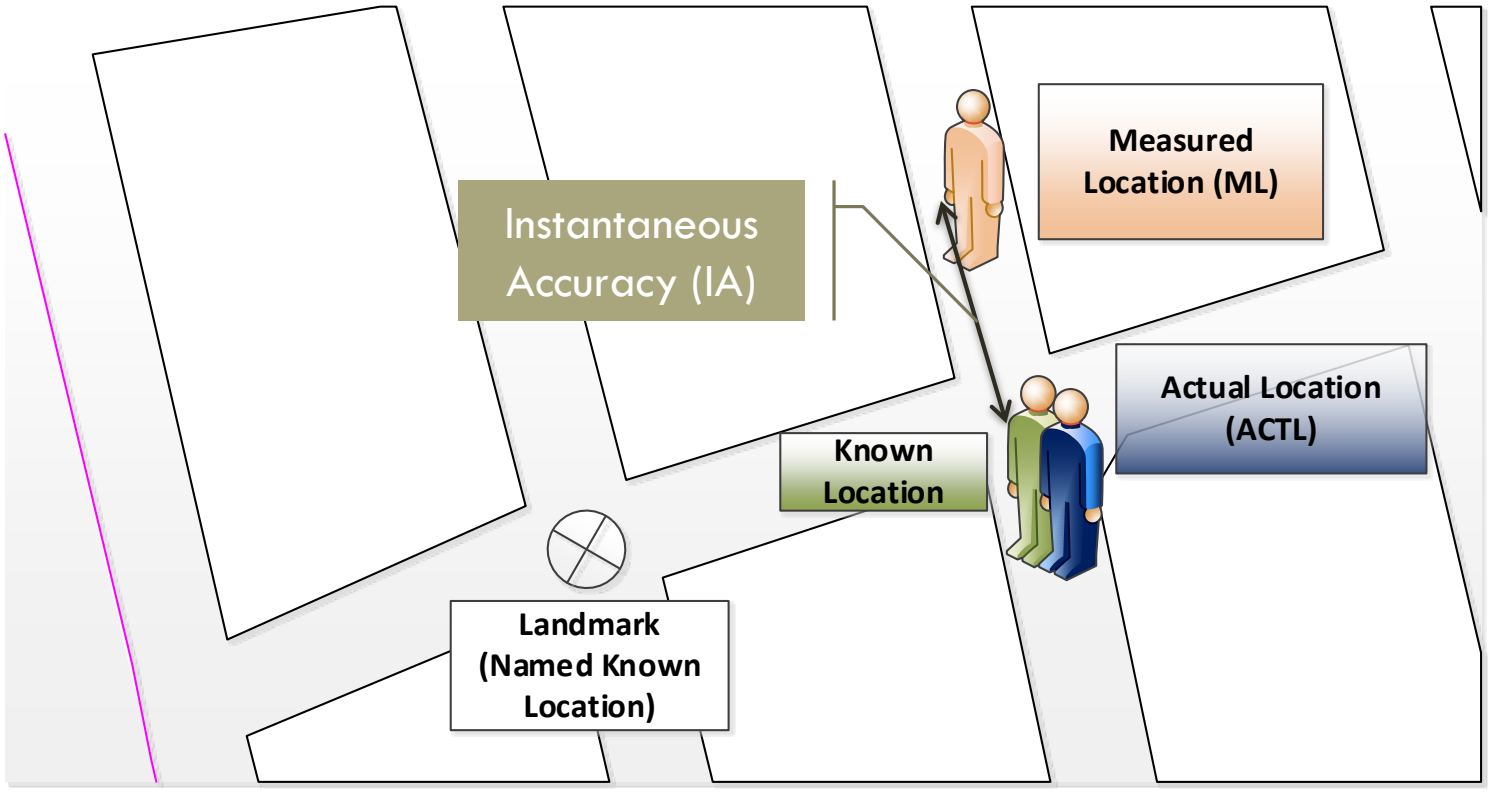
Radio quality can be inferred by tracking quality, which is more readily available

All data regarding the tracking system must be regarded as pairs of coordinate at the same point in time

Investigators have no knowledge of a tracked device's velocity, orientation, or the values it supplies to the tracking calculation

We do not know the internal workings of the tracking algorithm, therefore we do not know all parameters that impact the values

TRACKING TERMS



EVERY TRACKING SYSTEM HAS PROBABILITY DISTRIBUTION

DISCUSSION, STATISTICAL DEVIATIONS AND SAMPLES

MLs will be more accurate in some areas than in other areas within the same mine

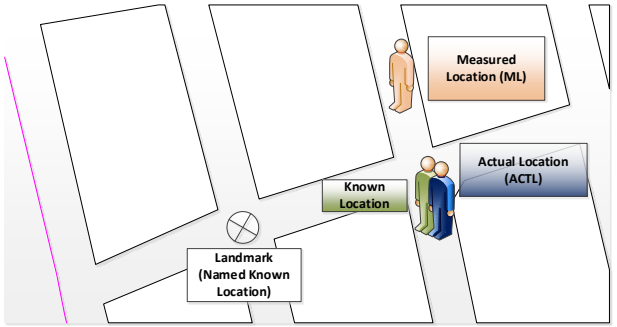
Measure this variability, tests at different locations throughout the mine should be performed, this is covered later

Collecting large amounts of independent data within a mine affords greater confidence in the distribution of position estimates

An unknown statistical distribution of accuracy varies with location, it will also vary over time, as mine conditions that may affect tracking system performance vary in time scales of minutes, hours, shifts, or days

Sample as much as you can, approximating the situation you are describing

COORDINATE SYSTEMS



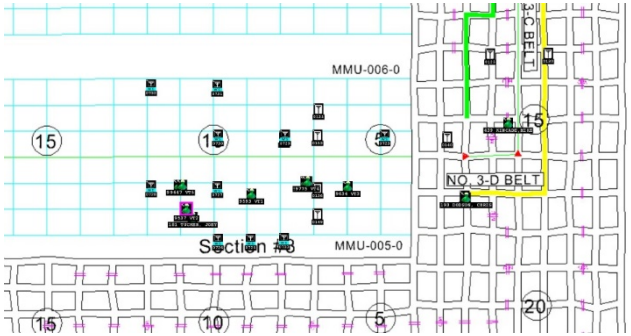
Each mine has their own coordinate system for their mapping

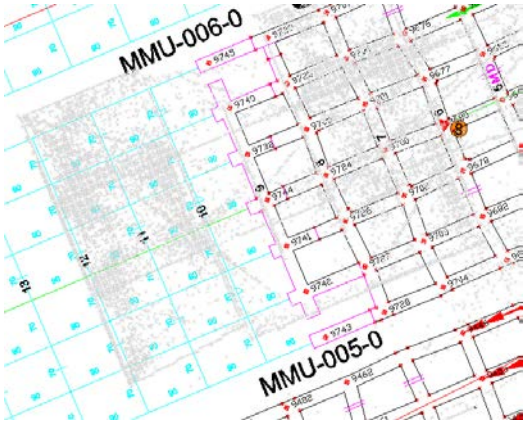
Each tracking system has its own coordinate system

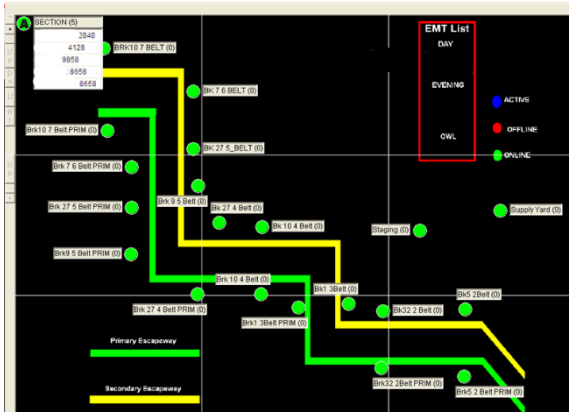
Only a few tracking systems use the mine's coordinate system

All comparisons of ACTL and ML must be done in the same coordinate systems

The coordinate system must translate to real units (e.g. feet)





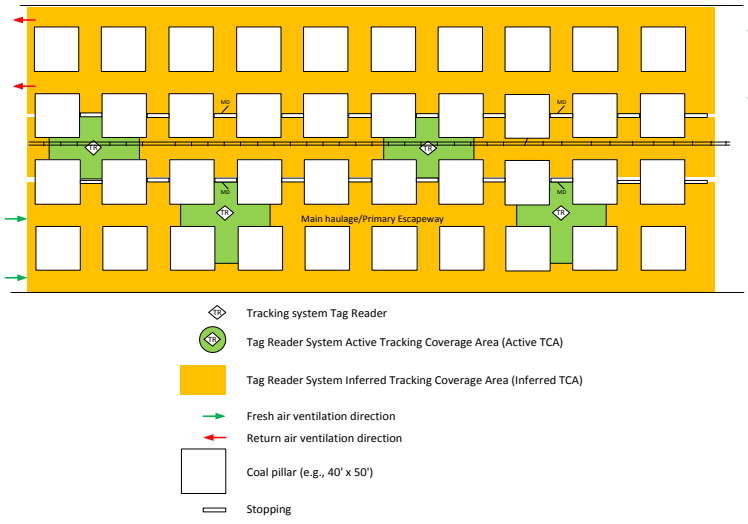


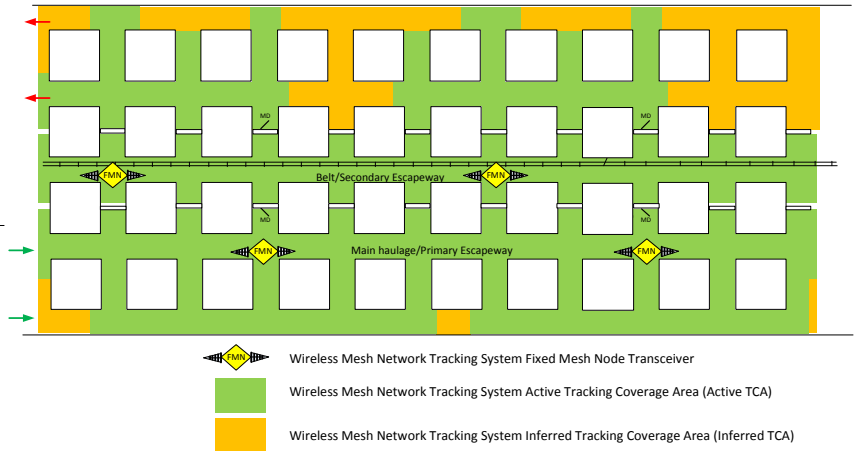
MEASUREMENTS OF SYSTEM PERFORMANCE: METRICS

- Tracking Coverage Area: The tracking system's coverage of the required spatial area.
- Tracking Accuracy: The tracking system's accuracy of measured positions – the magnitude of the difference between the tracking system's measured locations and the actual locations of tracked entities.
- Tracking Coverage Time: The tracking system's coverage on the basis of time – throughout the duration of operations.

METRICS: TRACKING COVERAGE AREA

Tracking Coverage Area: The area within the mine where the tracking system either actively measures a tracked device's location, or infers it based on the spatial limitations of the mine and information other than active measurements





METRICS: TRACKING ACCURACY

There are several measurements of accuracy that might be used for evaluating mine tracking systems:

Average Accuracy (AA)

Standard Deviation of Accuracy (SDA)

90% Confidence Distance (90%CD)

Relative Accuracy (RA)

All are based on Instantaneous Accuracy (IA)

90% CONFIDENCE DISTANCE

The 90% Confidence Distance is the distance from a tracked device's actual location (i.e., ACTL) that is greater than 90% of the collected Instantaneous Accuracy measurement magnitudes ("90th percentile").

For example, the 90% Confidence Distance of a hypothetical tracking system was measured to be 743 feet. That means that 90% of the Instantaneous Accuracy ML results were less than or equal to 743 feet from their corresponding ACTLs.

A test may require that 90% of ML measurements be within 1,000 feet of the true location, in which the hypothetical tracking system installation would be found to pass the test.

RECORDS COLLECTED BY A MINE SURVEY CREW

Record Locations

- Records will be taken directly underneath spads, entries
- Offsets at 25 ft. and 50 ft. offsets in four directions (Inby, Outby, Left and Right) where possible (optional)

Record Information

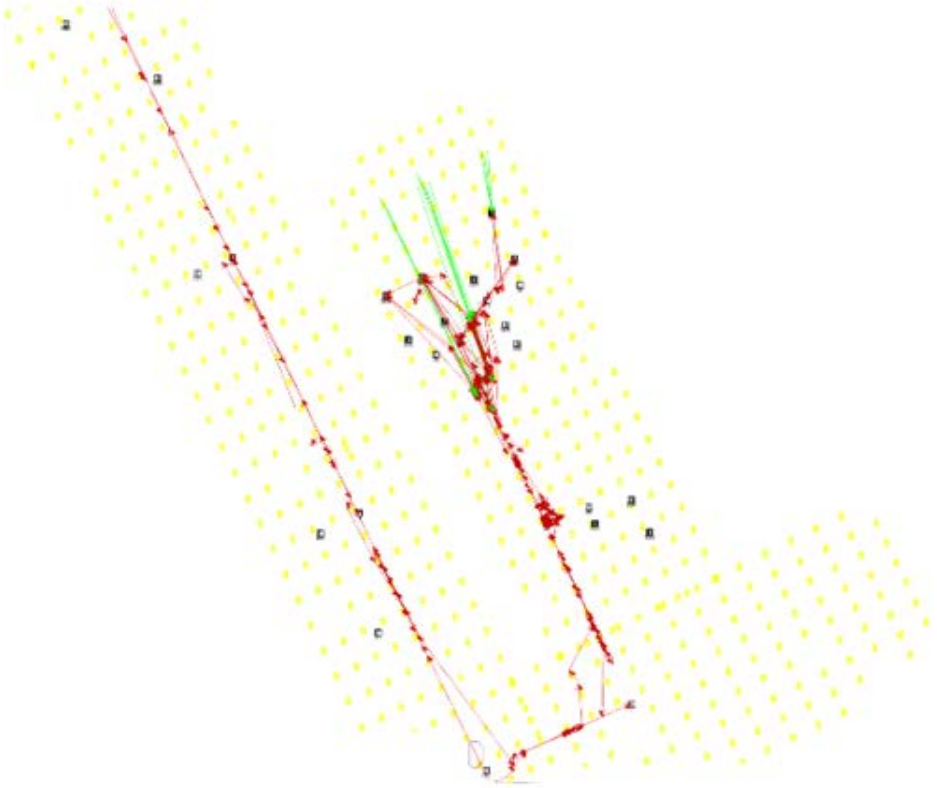
- Spad ID number
- Position relative to spad (distance in feet, direction)
- Tracked Device ID
- Date and Time (hh:mm:ss)
- Time is synchronized to tracking system

Tracking System Location Estimation Acquisition Time

- The handset is stationary for ML recording interval. The system makes a position estimate update once every ML recording interval.

SURVEY CREW DATA

	Date	- 6-14-2012	
	Radio	10 - 197	
Time	Spad	offset	Direction
6:05:14	8671	—	—
6:10:55		20'	O
6:11:31		20'	R
6:12:02		40'	R
6:28:08	8675	—	—
6:28:39		20'	I
6:29:10		20'	R
6:29:51		20'	L
6:30:18		40'	L
6:44:45	8677	—	—
9:06:42	8659	—	—
9:09:25		20'	O
9:19:20		20'	I
9:21:54		20'	L
9:23:26		20'	R
9:23:56		40'	R
9:37:18	8661	—	—
9:46:55		20'	O
9:49:50		20'	R
9:50:35		20'	I
9:51:12		40'	I
9:51:54		20'	L



BASELINING A TRACKING SYSTEM

These are tests of the “noise” and speed inside of the tracking system, results of which should be used as a filter for all other testing

Mine Condition Survey

- Get to know the radio environment in your mine

Tracking System Variation when Stationary Testing

Multiple Tracked Devices Effects Testing

Travel Speed Testing

Susceptibility Testing

CONCLUSIONS

Where there are networks there are sensors, there's data available

The challenge is efficient maintenance of the network, such that the main purpose is achieved, that the miners can communicate and that the tracking system is working and sufficiently accurate

Get a good idea of how your system is working, get a good idea of what it takes to expand the system. Ask us, we can help.