



Wrocław University of Science  
and Technology

# Monitoring of large scale complex systems - mining industry perspective. From local measurements, online monitoring systems to mobile inspection robots

**Radostław Zimroz**



This activity has supported under the Marie  
Sklodowska Curie programme through the ETN  
MOIRA project (GA 955681) by European  
Commission.

## Agenda

What is mining industry?

Large scale complex systems - mining industry perspective

Why do we need data?

What kind of data do we need?

How to collect data (sensors, data transmission)

Big Data for industry (storage, management, analysis)

Devices and systems for diagnostic data acquisition

Mobile equipment

Monitoring systems (SCADA)

Inspection robots





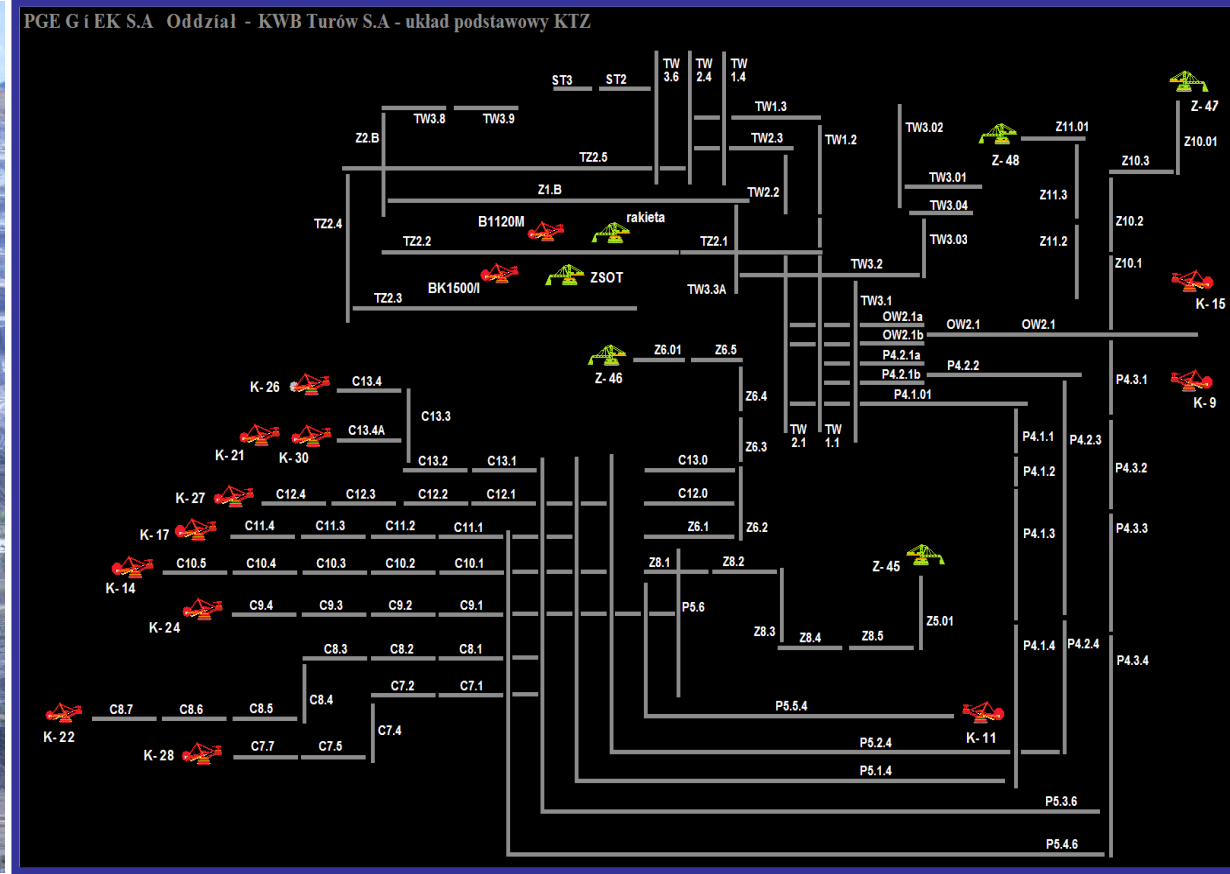
# What is mining industry?



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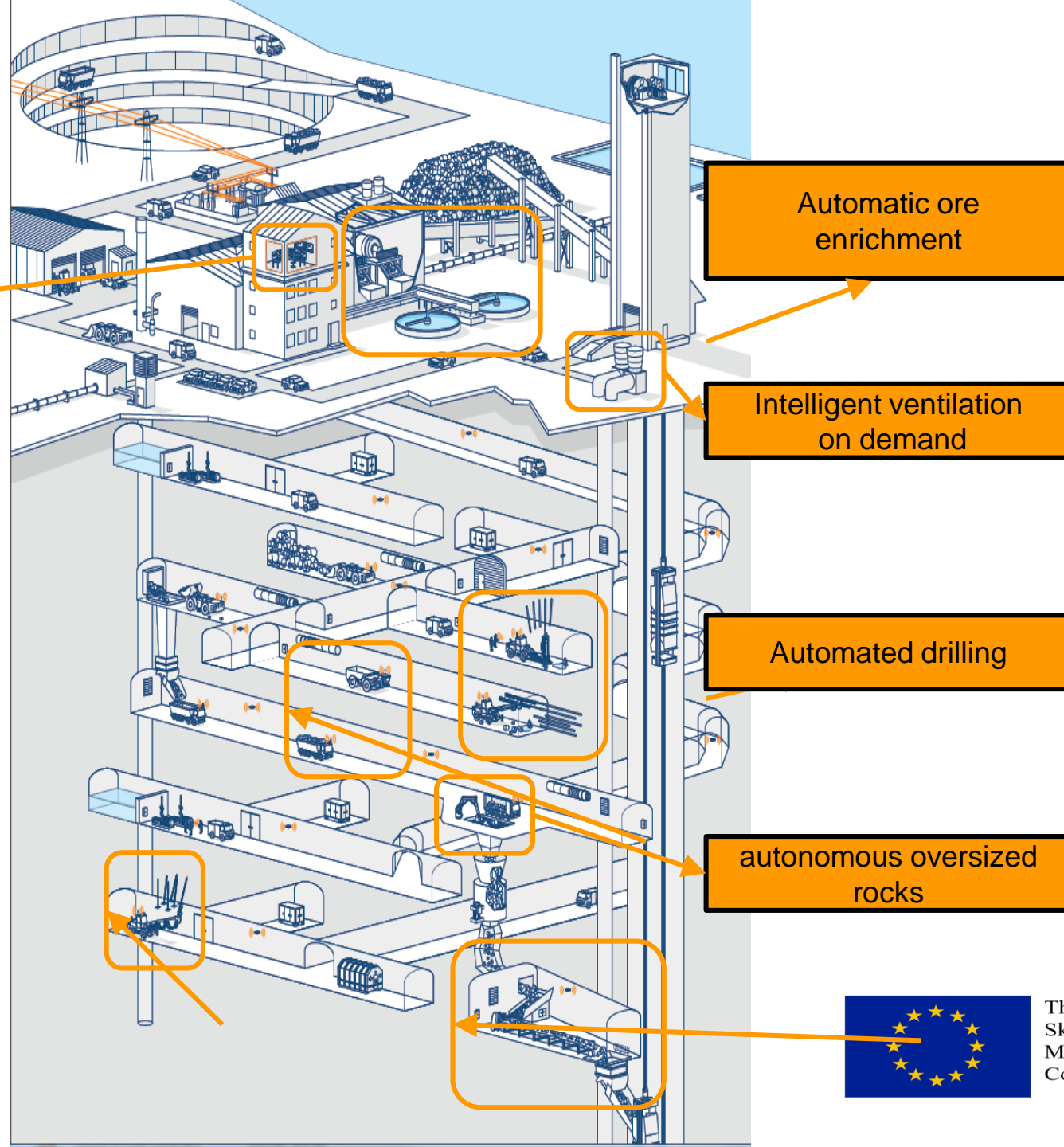
# Open pit mine



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# Digital mine



One Control Room

Automatic ore enrichment

Intelligent ventilation on demand

Autonomous transport

Automated drilling

Automated bolting

autonomous oversized rocks

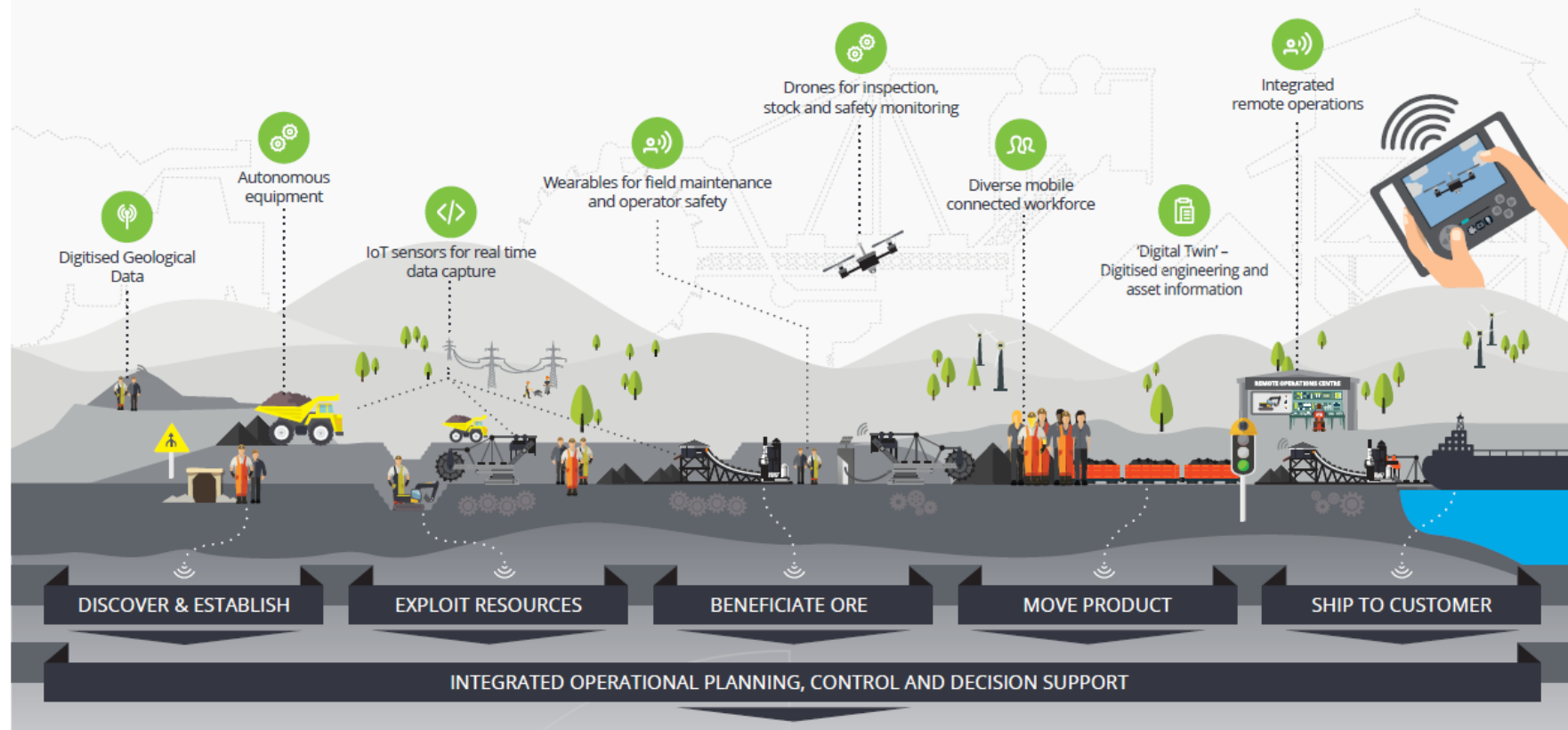
Transported Material analysis on the belt



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source: ABB





**A mine is a complex system.  
A mining is a complex, multistage proces, strongly depends on  
geology, technology, etc**

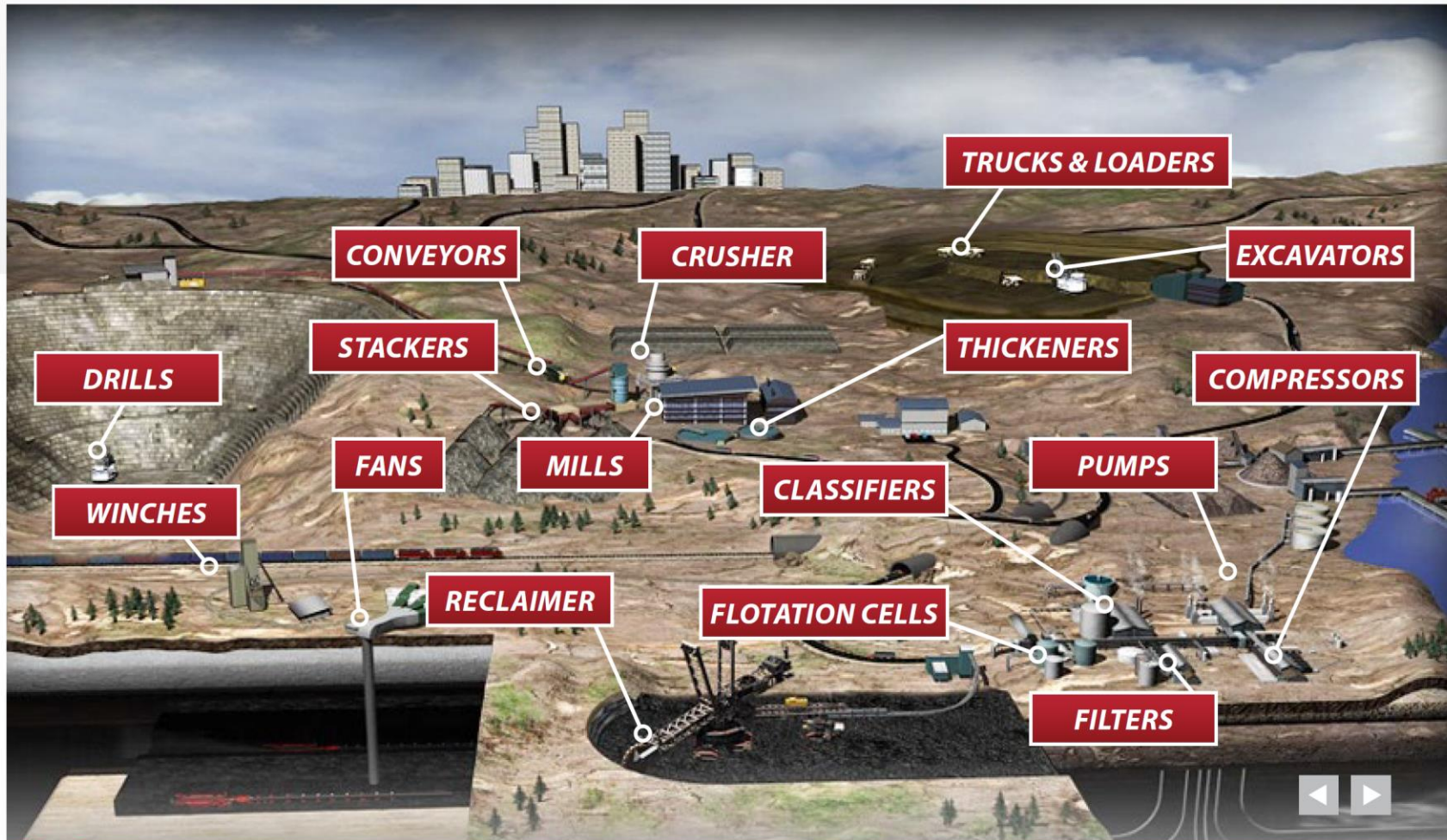
[deloitte-au-er-digital-mine-030817](#)



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# Mining/Minerals Process Overview



Variable Speed Applications | 4

Rockwell Automation Variable Speed Applications Mining



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# Large scale complex systems - mining industry perspective

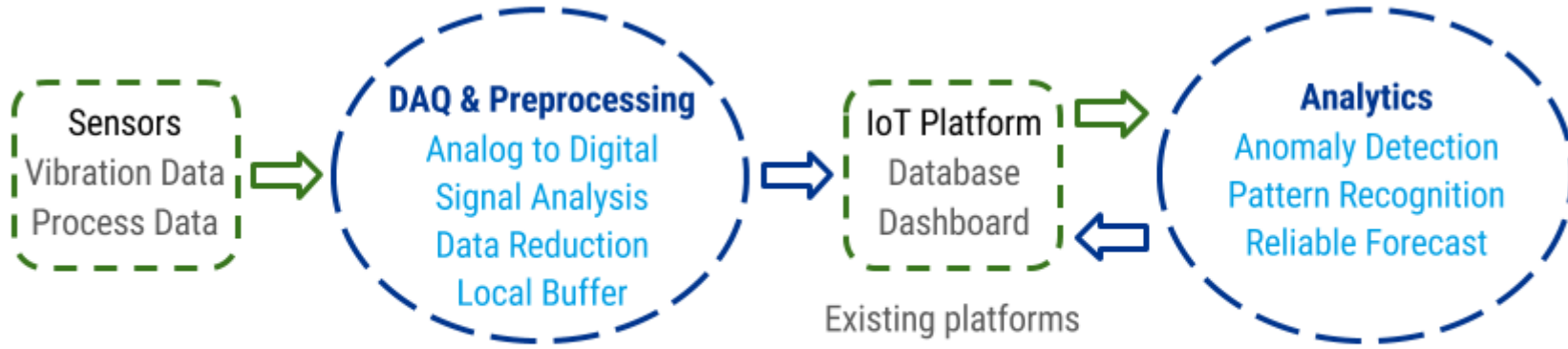
- Number of machines (or the components of the same type)
- Spatial distribution of machines (kilometers of roads to pass for inspection)
- Number of machines (different type) that need to collaborate in real time or in sequence
- Various processes performed by various machines
- Impact of environment (rain, snow – hardly accessible)



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# WE NEED DATA TO MANAGE THIS...



## Dedicated solutions by Industrial Analytics



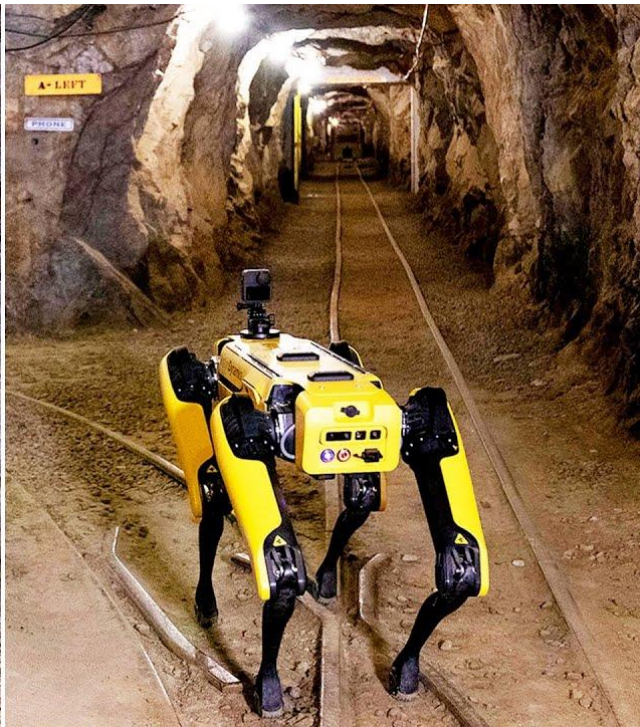
Data → knowledge?



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# Where we are?

There are many automatic, or even autonomous systems in the mining companies  
We measure many parameters, visualise them, use for control of the system or for diagnosis the process



## Robotics in Mining: innovation areas

	Emerging	Accelerating	Maturing
1	Robotic excavators	Defect detection techniques	CAD for drill planning
2	Autonomous steering systems	Tunneling machines	Remote controlled milling
3	Radar-guided navigation	Autonomous navigation	Autonomous rock drilling machines
4	Sensor-based control	Tunnel rescue/safety devices	SCARA robotic arms
5	Metal contour scanning	Magnetic route detectors	Excavator control system
6	Lane detection assists	Robotic coal mining	Autopilot mine shuttle
7	Mining conveyor	Hydraulic mining conveyors	
8	Navigation assists	Energy demand optimisation	
9	Mining inspection robot	Tunnel lining construction devices	
10	AI-assisted CAD	Tunnel safety devices	
11	Autonomous dredgers		



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# Diagnosis and prognosis challenges

- Complex
- Designed for heavy-duty
- They operate under non-stationary conditions
- Multiple faults
- Frequently overloaded
- Environmental condition
- Analysis huge number of the variable



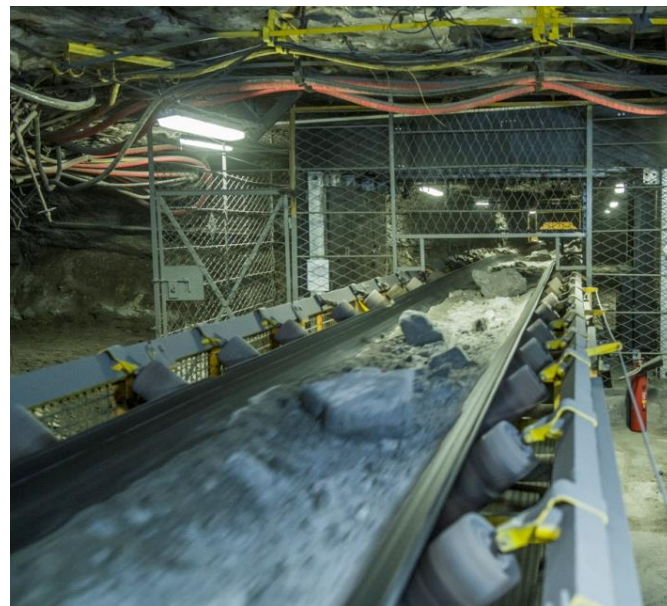
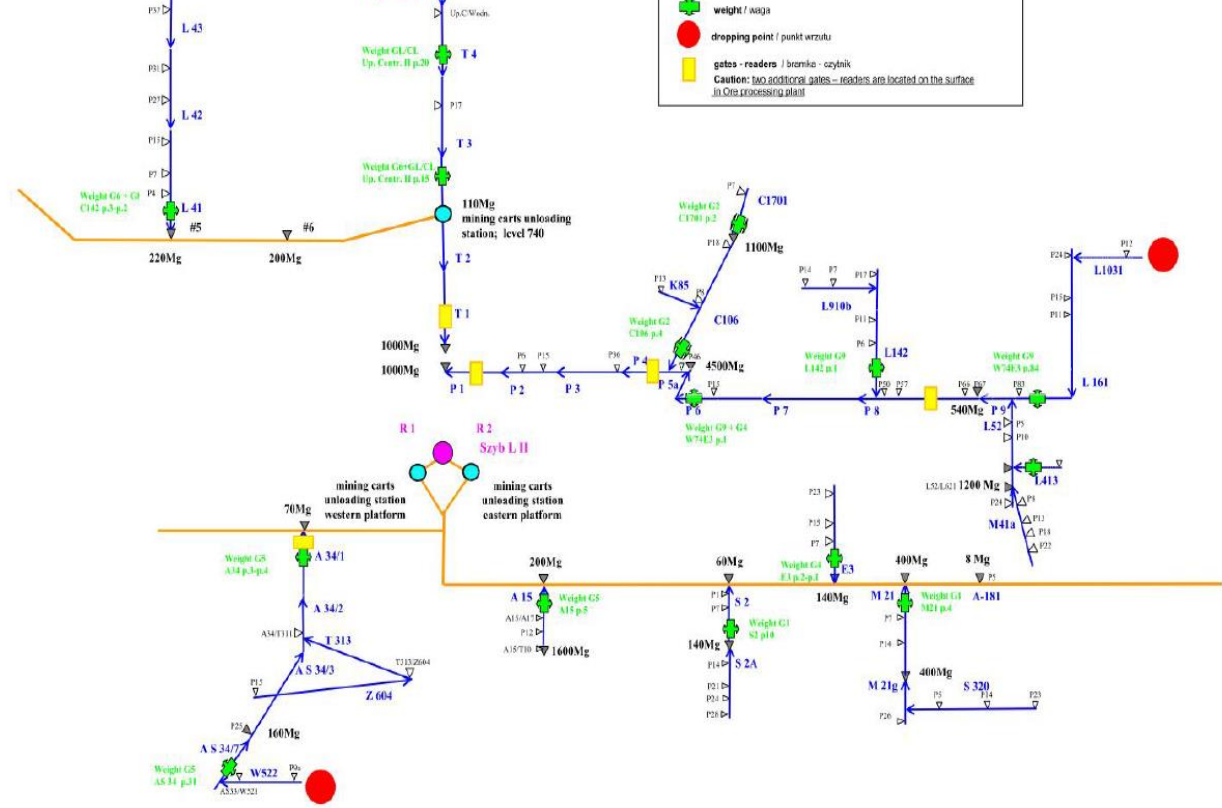
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# Belt conveyors



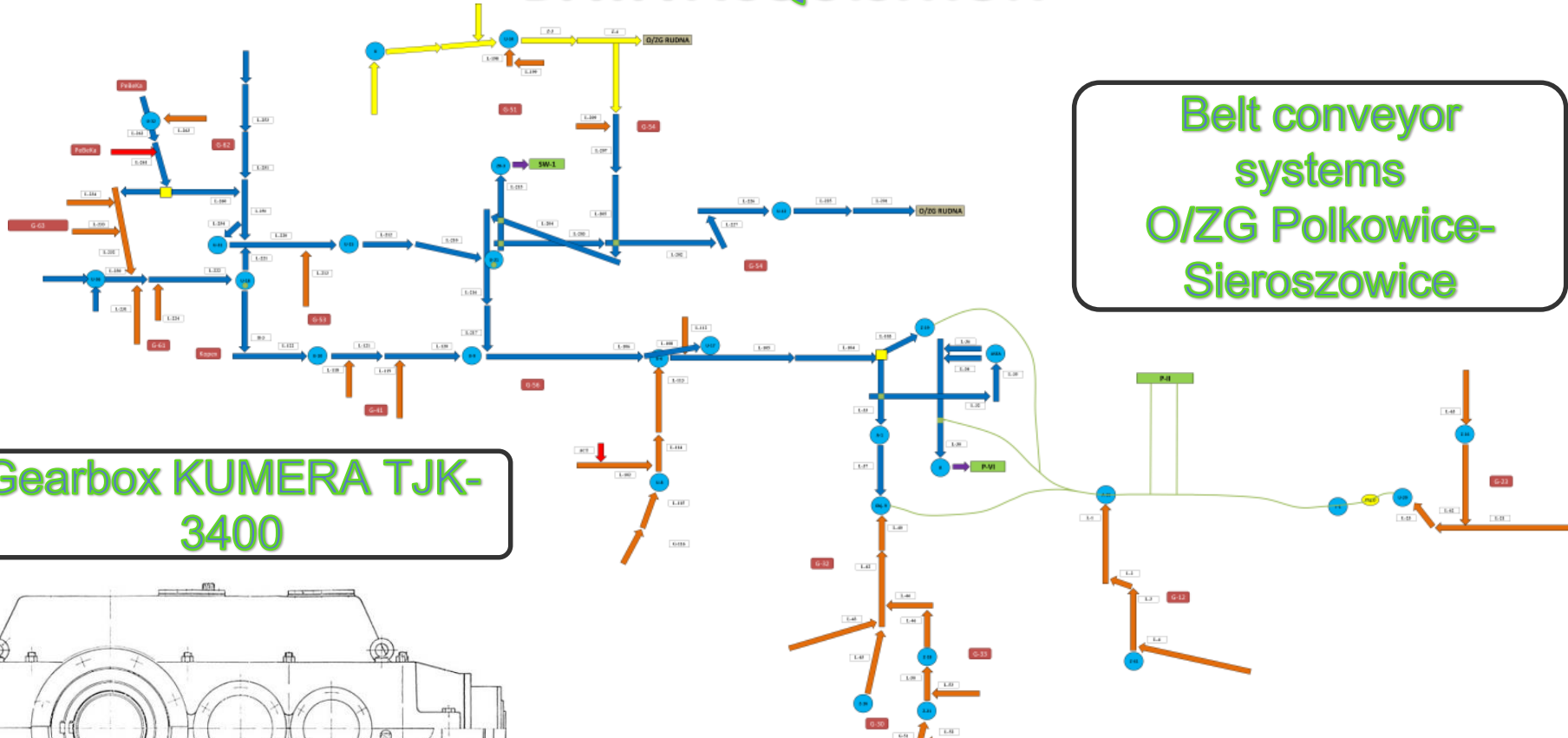
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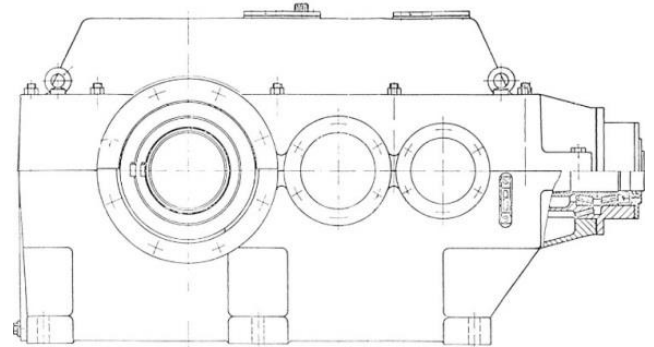


# DATA ACQUISITION



Belt conveyor systems  
O/ZG Polkowice-Sieroszowice

Gearbox KUMERA TJK-3400

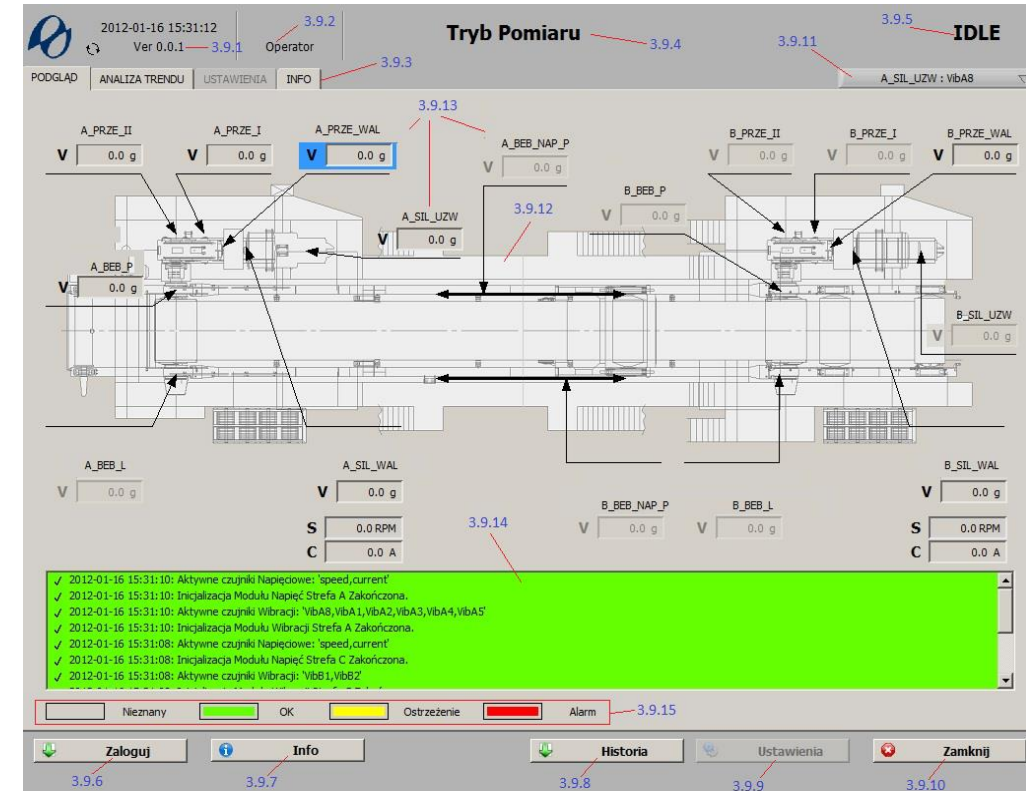


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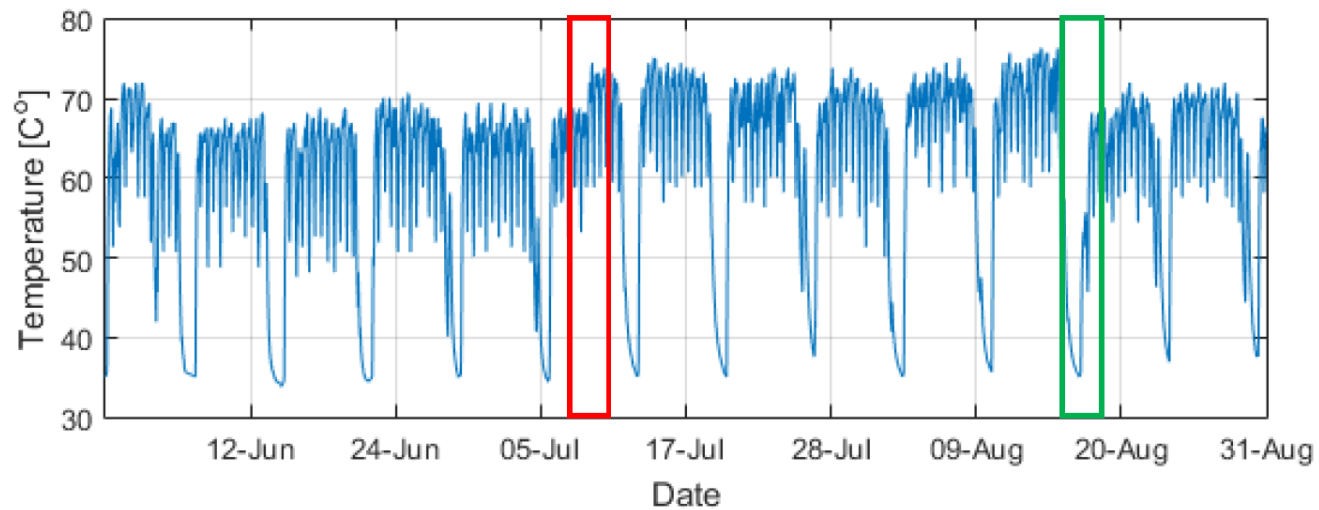
**Supervisory control and data acquisition (SCADA)** is a control system architecture comprising computers, networked data communications and graphical user interfaces for high-level supervision of machines and processes. It also covers sensors and other devices, such as programmable logic controllers, which interface with process plant or machinery.

## ONE CONTROL ROOM

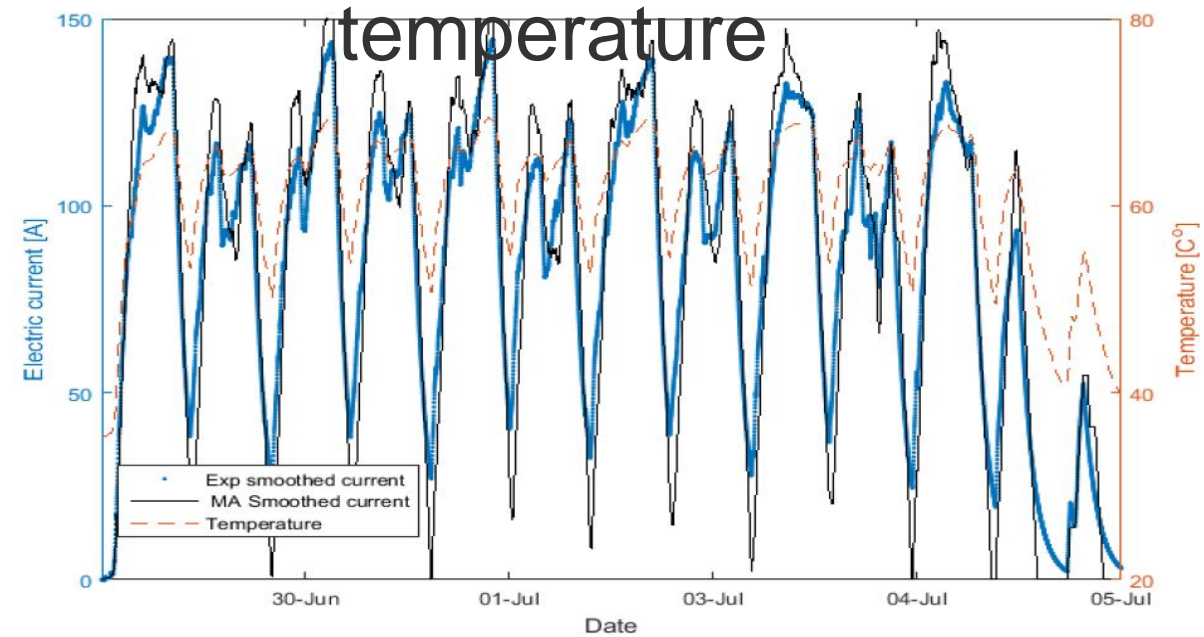


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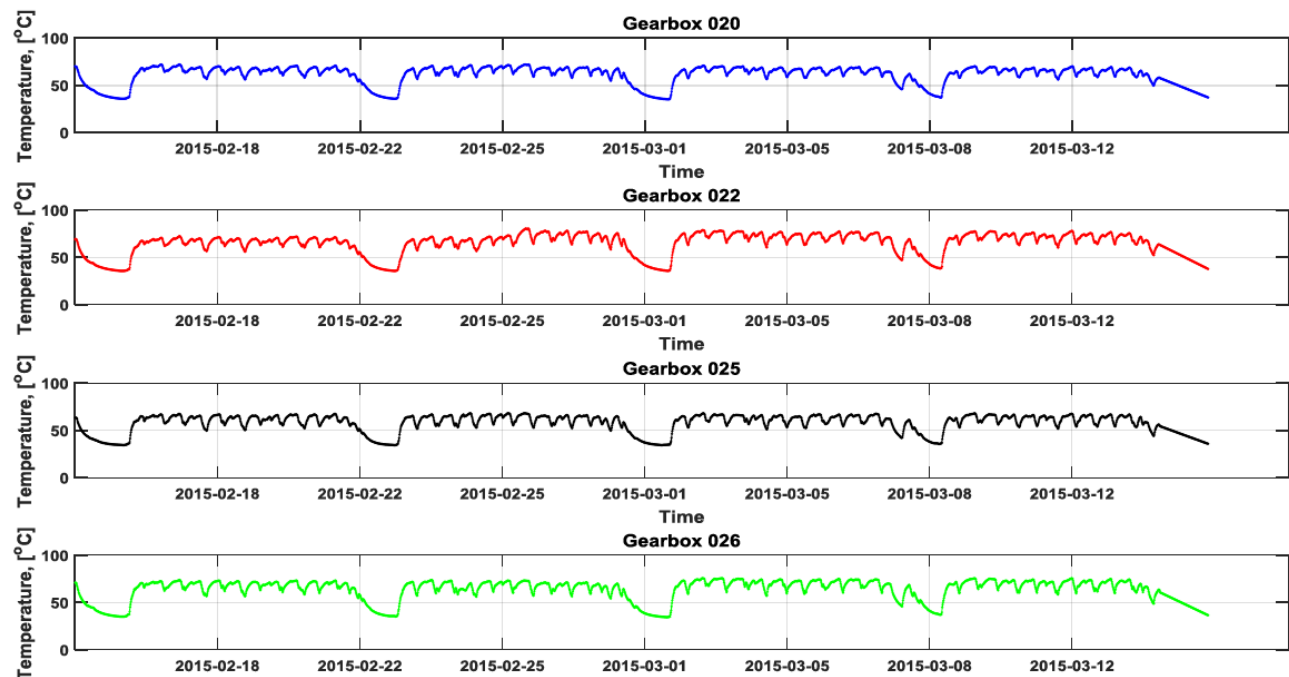
# Temperature



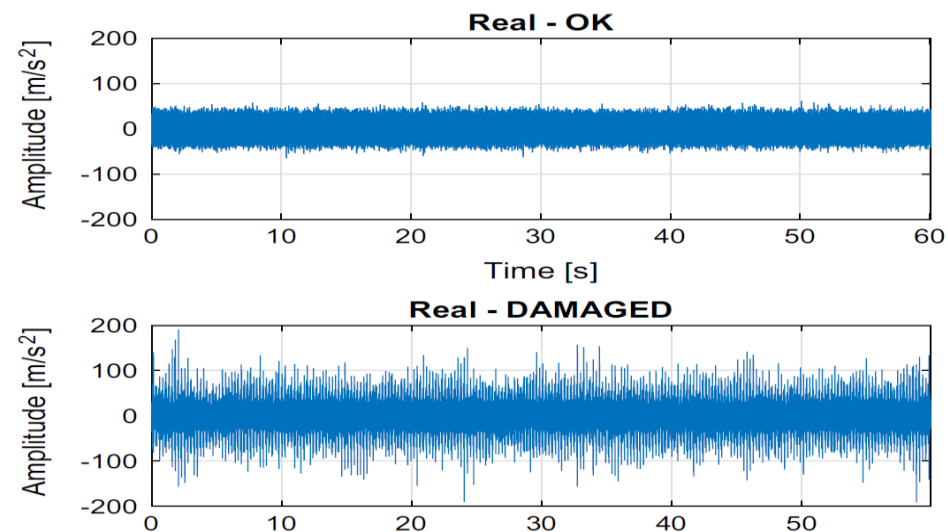
# Electric current and temperature



# Temperature



# Vibrations



Marie  
h the ETN  
open



# TEMPERATURE CURRENT MEASUREMENT -SCADA

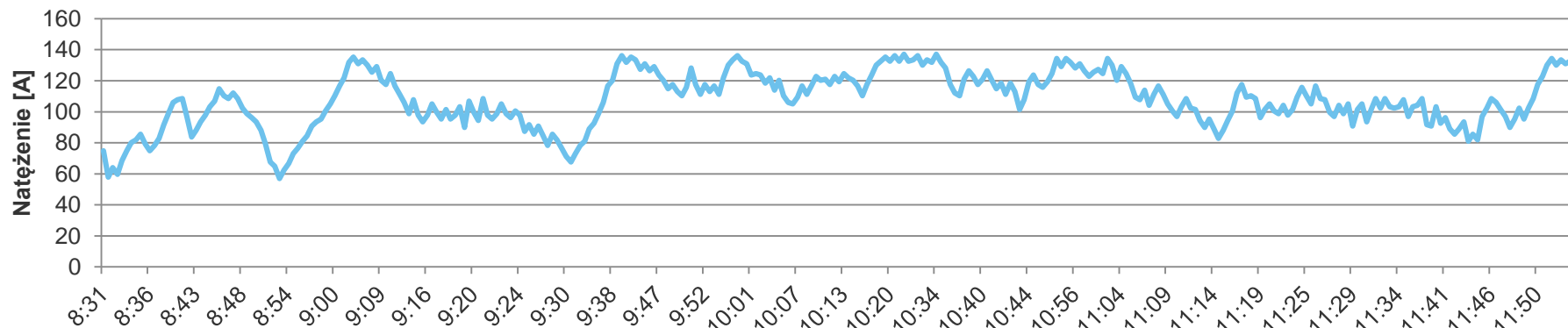
## Online monitoring system AOT

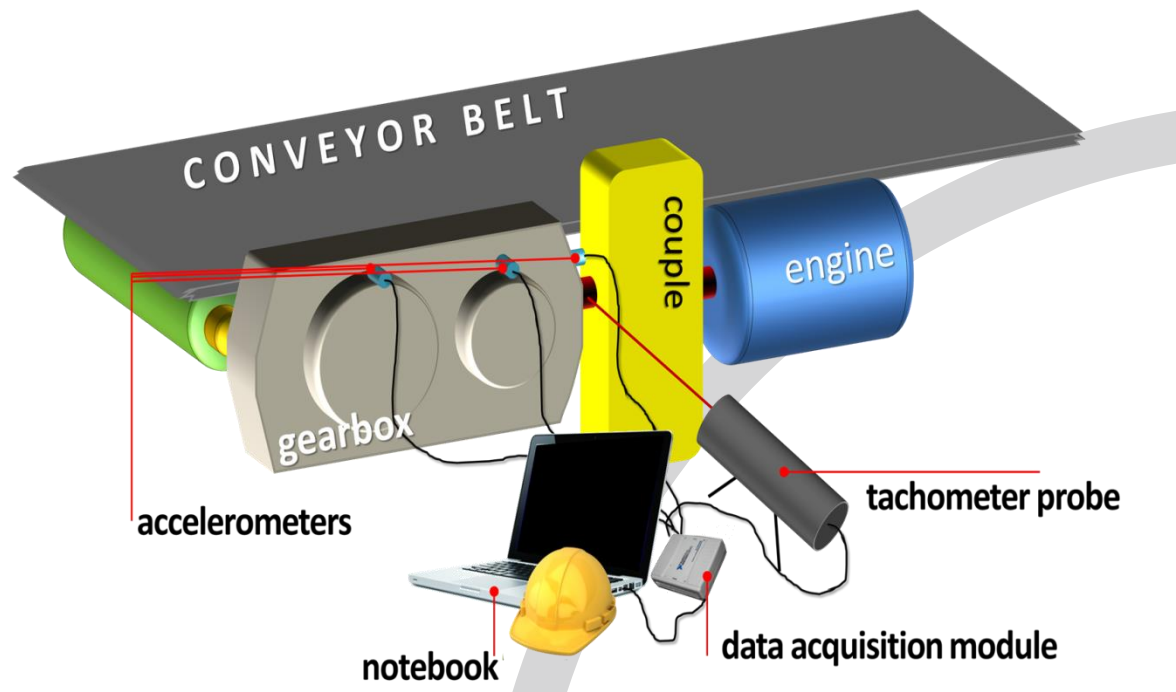


Temperature sensor TR 53



## Current measurement @ BC L210







# Portable solutions

Diag Manager

Diag Manager wersja 1.0

Politechnika Wroclawska

Wydział Geoinżynierii, Górnictwa i Geologii

Raporty Stan alarmowy Stan ostrzegawczy Praca wałków Praca kół zębatych Praca łożysk Ostatnia aktywność

Wyszukaj:

Ostrzeżenia	Historia	Data pomiaru	Pozycjonik	Przekładnia	Typ przekładni	Typ napędu	Rozruch	Kurtoza	Średnia V	G speed	Średnia DF1	Średnia DF3	Średnia DF2	Sigma DF1
	Zobacz	2010-02-18	L216	3	TJK 3400	TJK 3400+KUSSE	fałowniki	3.22	955.71	21.99	9.82	80.55	430.85	24.27
	Zobacz	2010-02-18	L216	1	TJK 3400	TJK 3400+KUSSE	fałowniki	3.55	950.47	45.19	56.38	66.88	494.5	13.35
	Zobacz	2010-02-18	L21	2	TJK 3400	TJK 3400+KUSSE	fałowniki	2.2	837.72	44.32	2.49	72.48	309.77	12.34
	Zobacz	2010-02-18	L21	4	TJK 3400	TJK 3400+KUSSE	fałowniki	3.37	924.06	122.13	1.43	69.99	311.37	64.66
0.52 1.01 0.42	Zobacz	2010-02-18	L217	3	KA 138	KA138+SET200	fałowniki	4.05	940.82	18.97	65.15	104.49	1410.66	77.02
1.07 0.04	Zobacz	2010-02-18	L217	1	KA 138	KA138+SET200	fałowniki	3.15	945.26	16.41	3.25	161.22	1066.03	34.6
0.16 0.81 0.42	Zobacz	2010-02-18	L217	4	KA 138	KA138+SET200	fałowniki	4.33	822.92	48.54	81.47	105.1	806.32	87.66
7.20 0.77 0.81	Zobacz	2010-02-18	L217	2	KA 138	KA138+SET200	fałowniki	4.24	950.27	24.05	71.97	203.37	771.17	64.47
0.81	Zobacz	2010-02-19	L220	1	TJK 3400	TJK 3400+VOITH VOITH	VOITH	2.05	995.03	5.94	5.09	43.94	809.24	28.25
0.11	Zobacz	2010-02-19	L320	2	TJK 3400	TJK 3400+VOITH VOITH	VOITH	3.41	991.05	39.74	61.13	40.36	447.55	10.7
0.91	Zobacz	2010-02-19	L320	1	TJK 3400	TJK 3400+VOITH VOITH	VOITH	48.01	4.54	39.7	445.13	10		
7.13 0.86 0.66	Zobacz	2010-02-19	L212	2	KA 138	KA138+SET200	fałowniki	4.51	45.11	71.26	212.29	856.91	26.84	
0.26 1.08 0.61	Zobacz	2010-02-19	L212	4	KA 138	KA138+SET200	fałowniki	3.73	88.63	56.95	82.64	152.54	1050.95	19.01
1.25	Zobacz	2010-02-19	L310	4	TJK 3400	TJK 3400+KUSSE	fałowniki	2.63	665.14	96.9	32.46	45.42	378.79	65.76
0.91	Zobacz	2010-02-19	L210	2	TJK 3400	TJK 3400+KUSSE	fałowniki	3.09	941.17	57.91	1.41	-43.79	905.58	22.75
0.71	Zobacz	2010-02-19	L210	1	TJK 3400	TJK 3400+KUSSE	fałowniki	3.03	942.49	75.42	1.54	82.18	711.88	12.44
0.86	Zobacz	2010-02-19	L210	3	TJK 3400	TJK 3400+KUSSE	fałowniki	3.09	941.08	36.95	1.92	45.1	802.13	17.34
0.66 2.15	Zobacz	2010-03-17	L42	1	TJK 3400	TJK 3400+SH160 SH	SH	3.04	996.74	0.58	7.67	397.97	1339.34	23.65
0.44 1.53	Zobacz	2010-03-17	L33	1	TJK 3400	TJK 3400+VOITH VOITH	VOITH	6.56	499.28	0.34	21.09	30.86	116.5	22.7
	Zobacz	2010-03-17	L33	2	TJK 3400	TJK 3400+VOITH VOITH	VOITH	14.38	964.16	612.92	15.29	25.5	252.3	40.59
0.66	Zobacz	2010-03-17	L33	1	TJK 3400	TJK 3400+VOITH VOITH	VOITH	14.38	964.16	612.92	15.29	25.5	252.3	40.59
0.66 1.16 1.26	Zobacz	2010-03-17	L104	4	KA 138	KA138+SH160/SE SH	SH	4.12	996.75	0.7	6.02	42.88	291.75	9.11
1.19 1.26 0.44	Zobacz	2010-03-17	L42	2	TJK 3400	TJK 3400+SH160 SH	SH	3.56	951.5	77.6	11.83	109.5	1203.14	118.2

Decisions

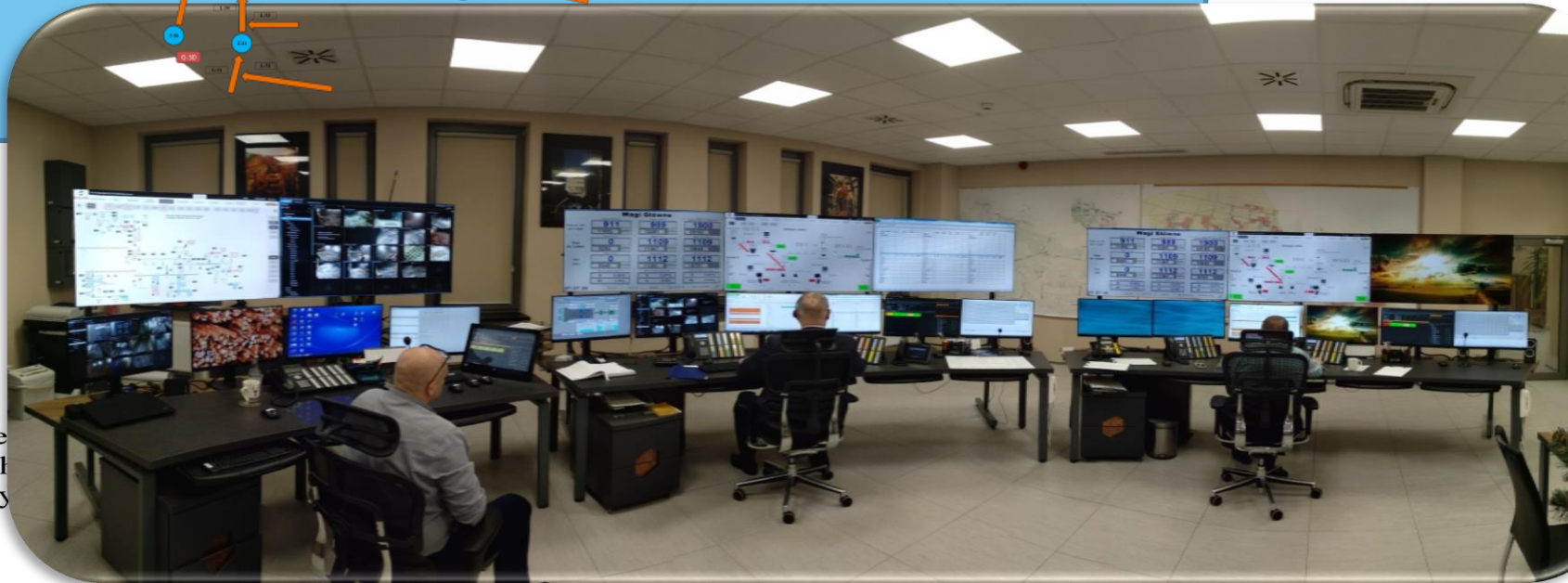
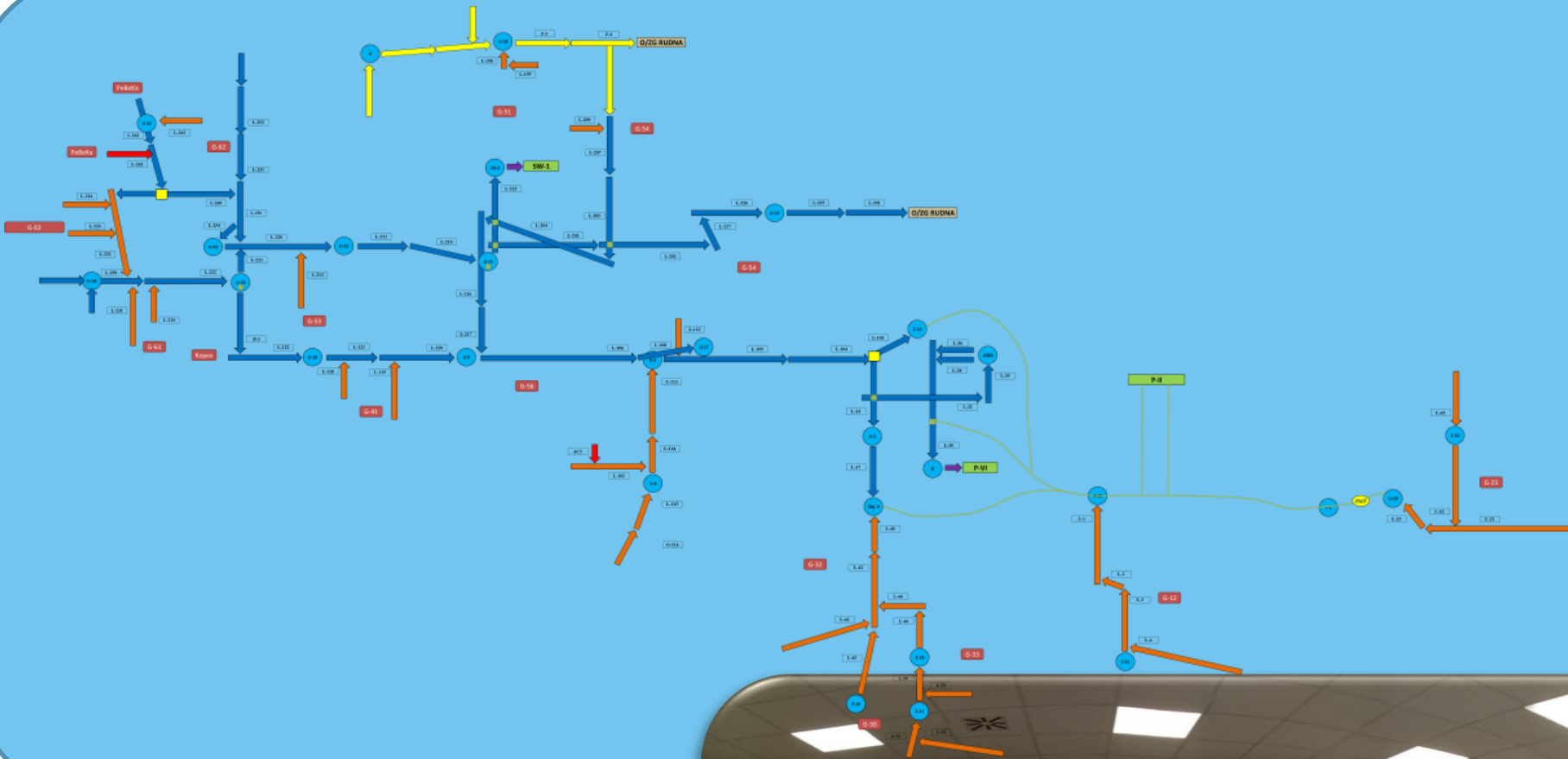
DATA BASE

GIS map

Computerised Maintenance Management System -DiagManager

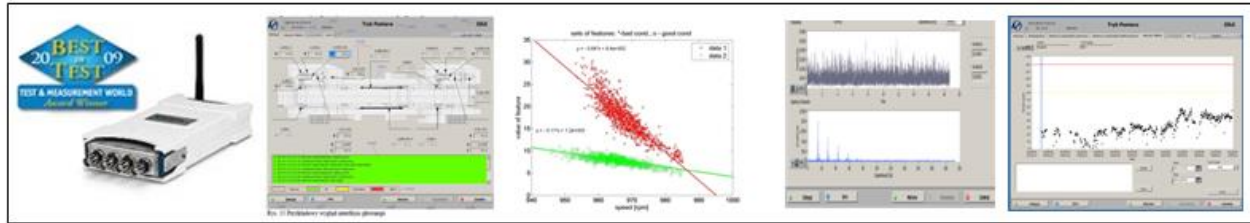
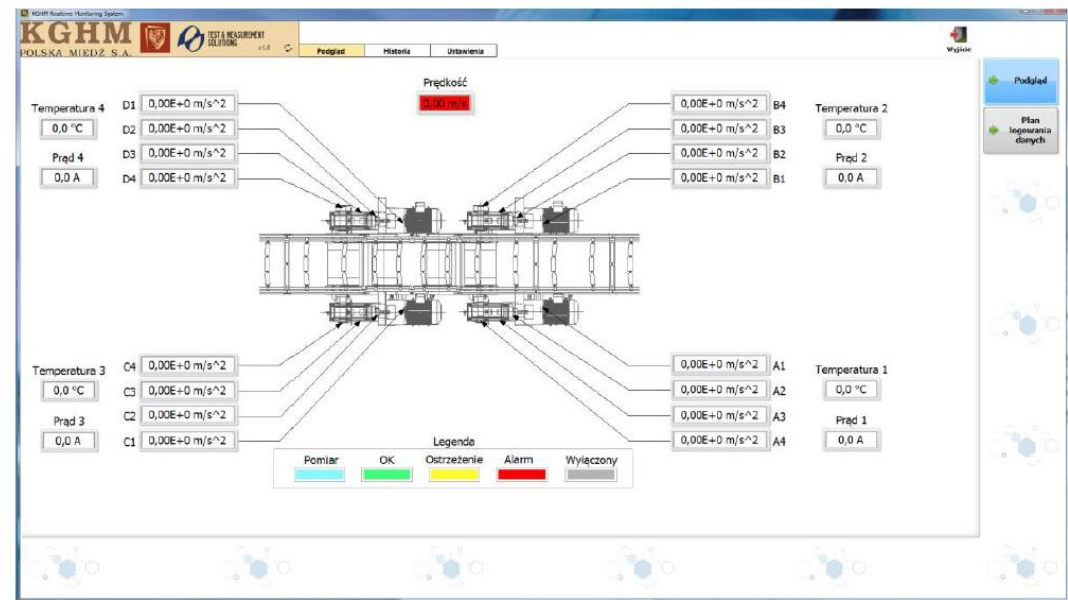
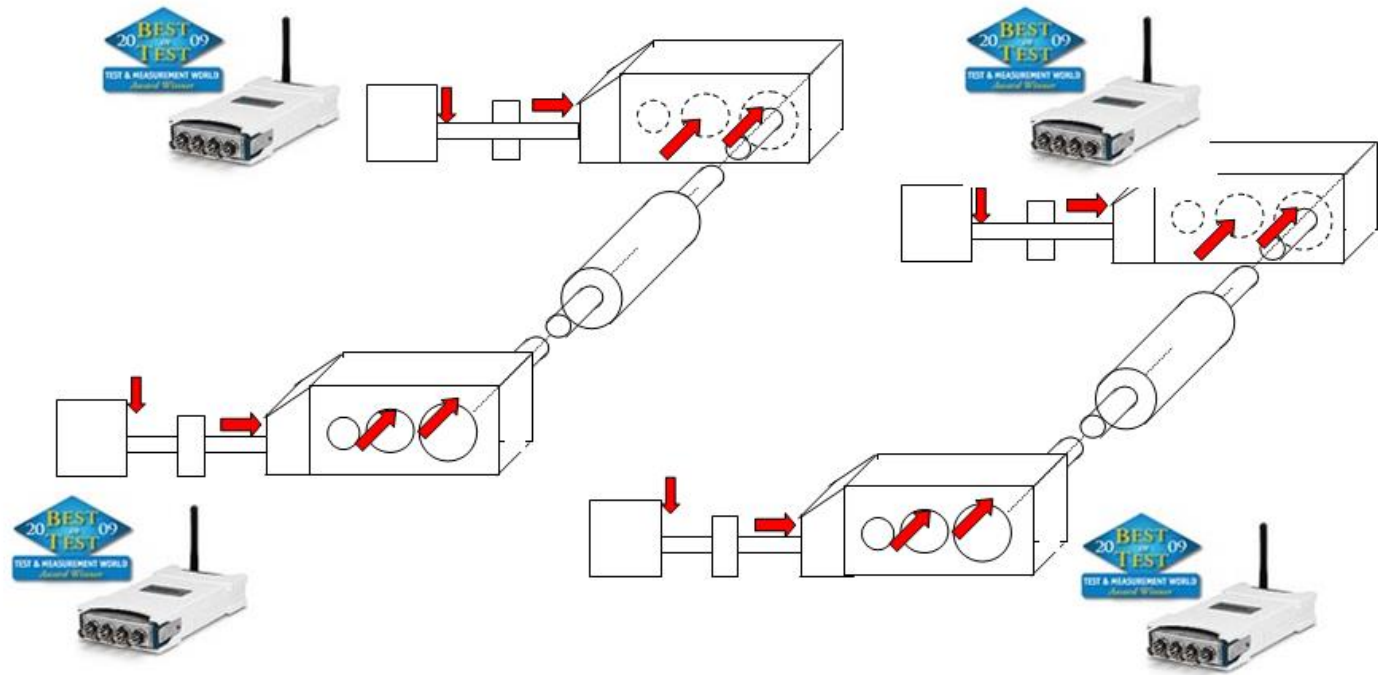


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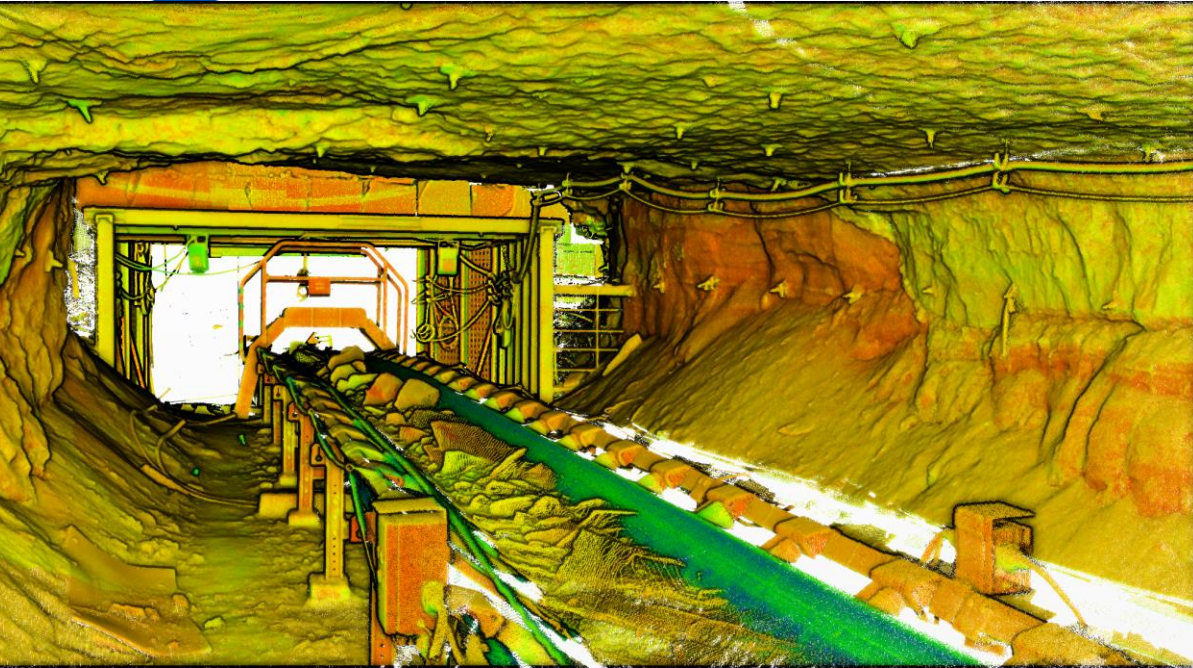
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Digital twin ?

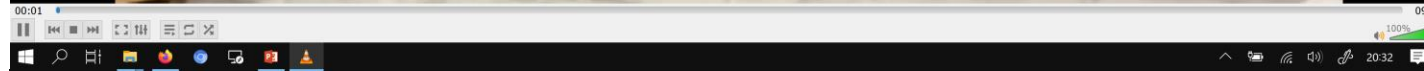
World's first fully autonomous dump truck leaving Minexpo 2016 - VLC media player  
Odtwarzanie Dźwięk Obraz Napisy Narzędzia Widok Pomoc



The World's first fully autonomous dump truck leaving Minexpo 2016



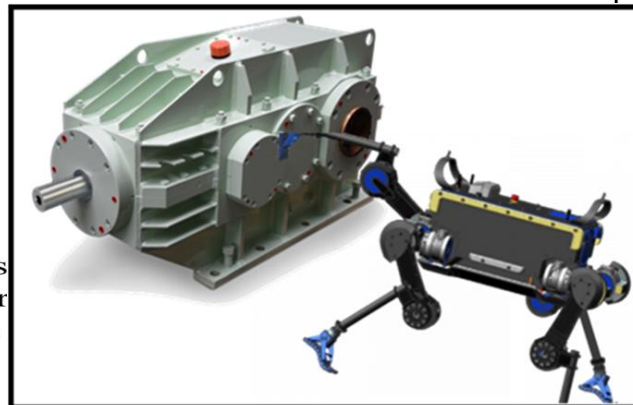
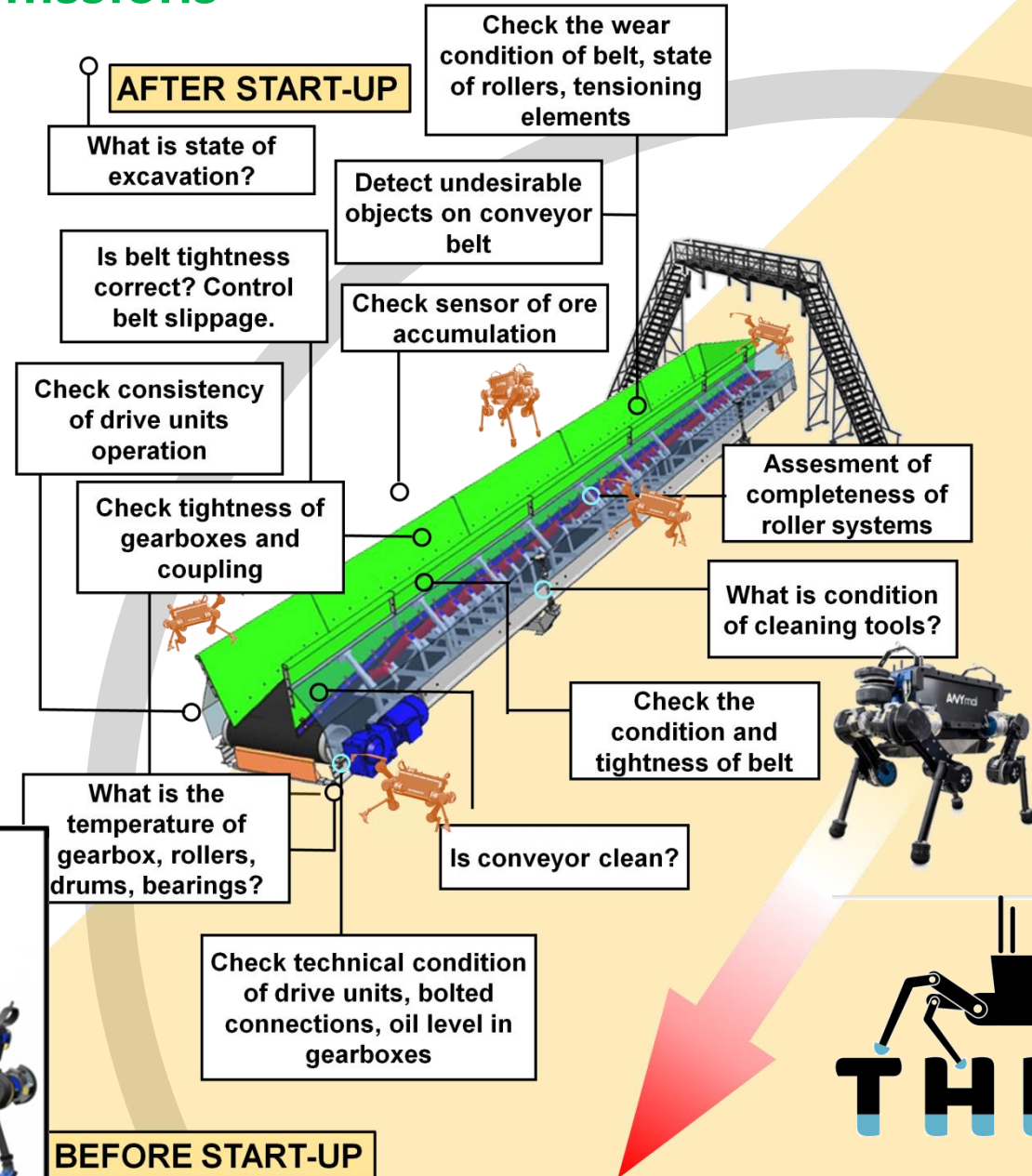
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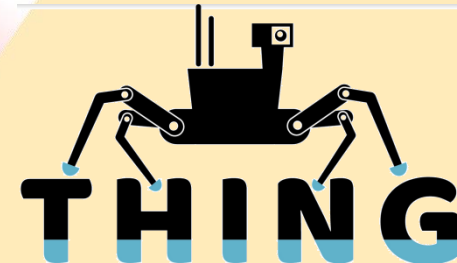


# Application: inspection missions

Responsibility of  
maintenance crew  
before and after  
the conveyor  
starts up.



This activity has Skłodowska Cur MOIRA project Commission.







# LHDs



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# On board monitoring system



Haul truck (HT) vehicle CB4-24TB.

Total weight: 26 600 kg  
Box capacity: 13,0 m<sup>3</sup>  
Nominal payload: 19,4 t  
Power rating: 179 kW

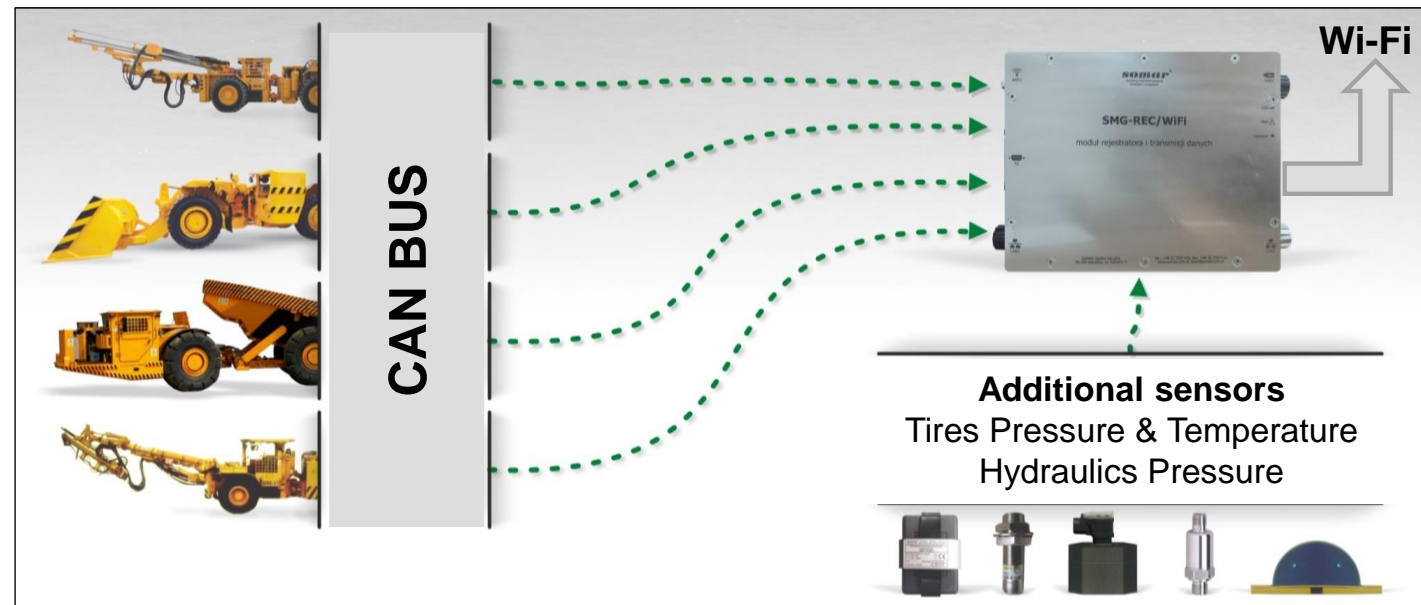


Load-Haul-Dump (LHD) vehicle LKP-1601B.

Total weight: 47 300 kg  
Standard bucket: 8,5 m<sup>3</sup>  
Tramming capacity: 160 kN  
Power rating: 295 kW

Vehicles are operated in very harsh conditions where frequent damages are occurring of sensors and cables

Monitoring data is collected from the numerous Electronic Control Units (ECU) via CAN bus from the standard or additional sensors

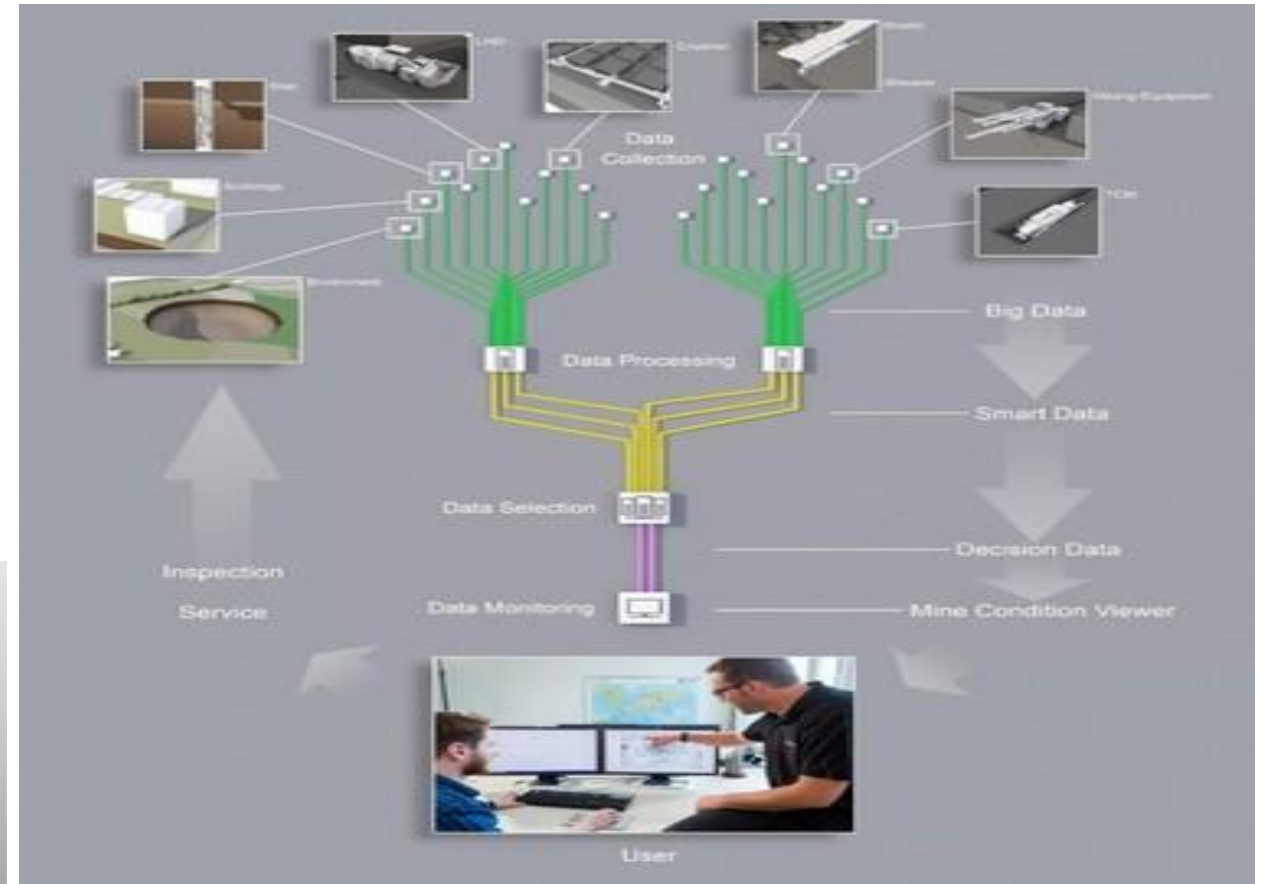
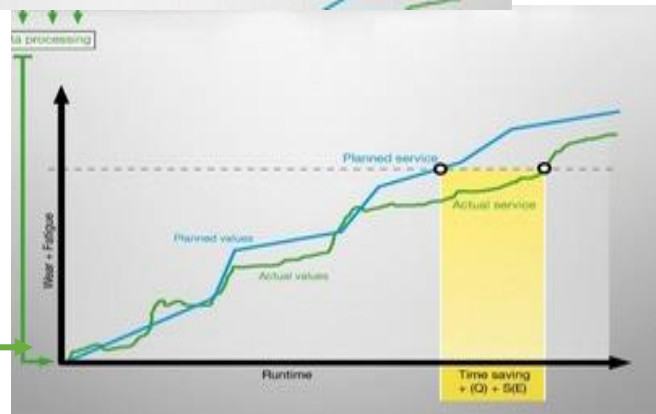




# MaMMa – MAINTENANCE OF MINE AND MACHINES

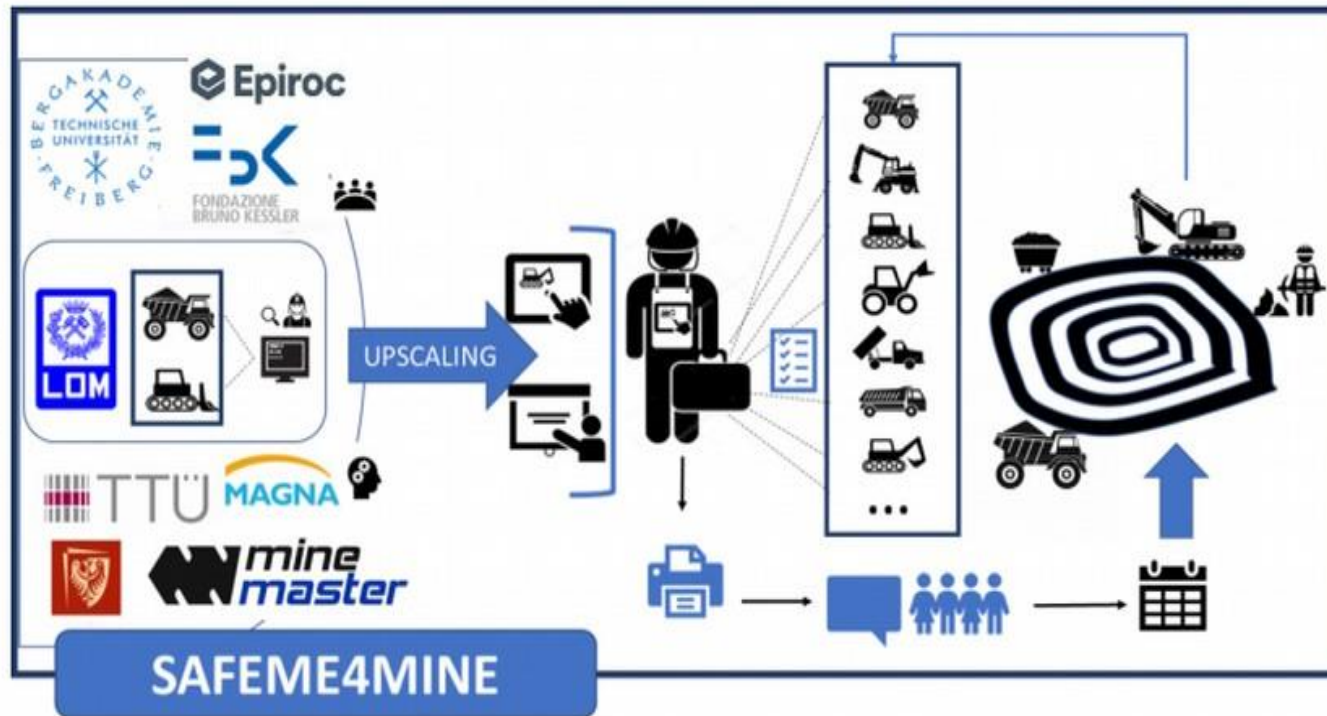


Prolonged and innovative mining machines utilisation by optimized maintenance and avoiding unfavorable operating conditions



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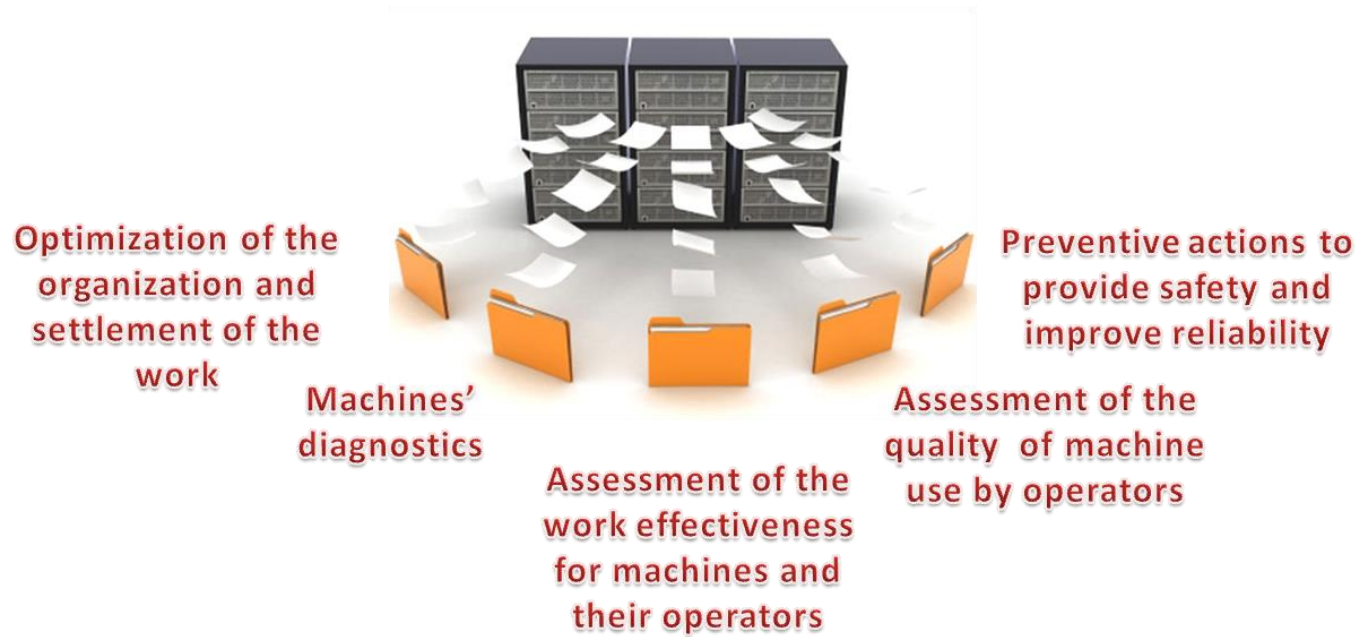
# SAFEME4MINE – PREVENTIVE MAINTENANCE SYSTEM ON SAFETY DEVICES OF MINING MACHINERY





# The data

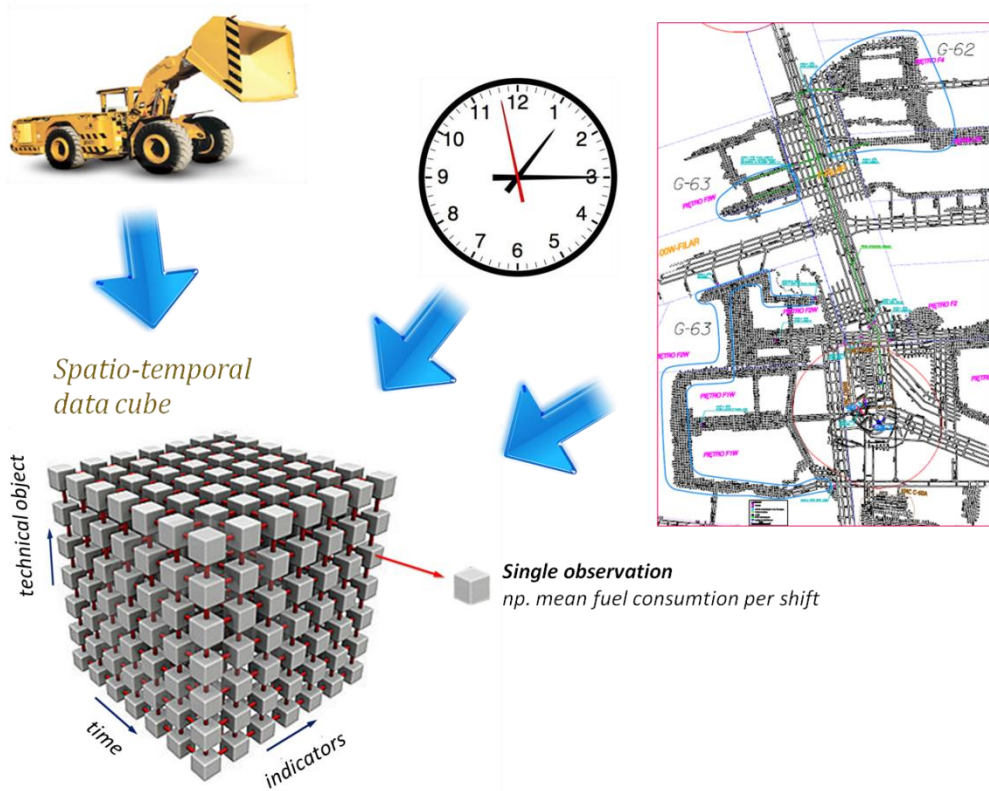
- Why do we need data?



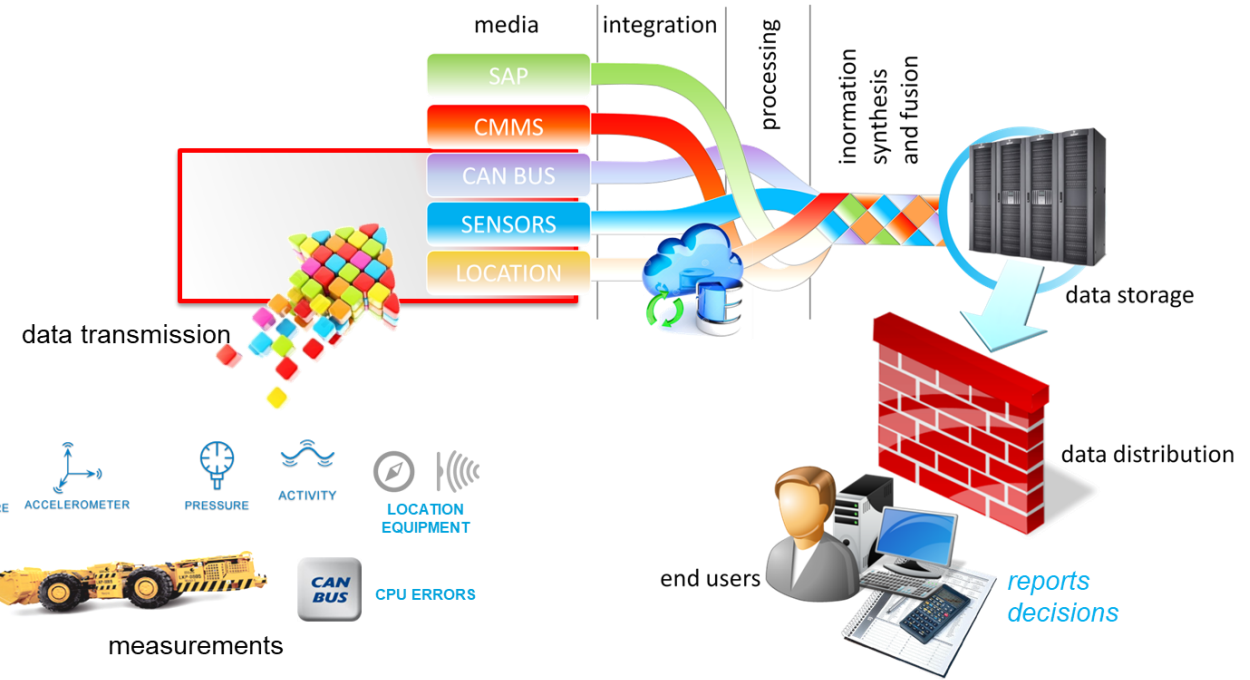
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# The data

- What kind of data do we need?



## Information fusion



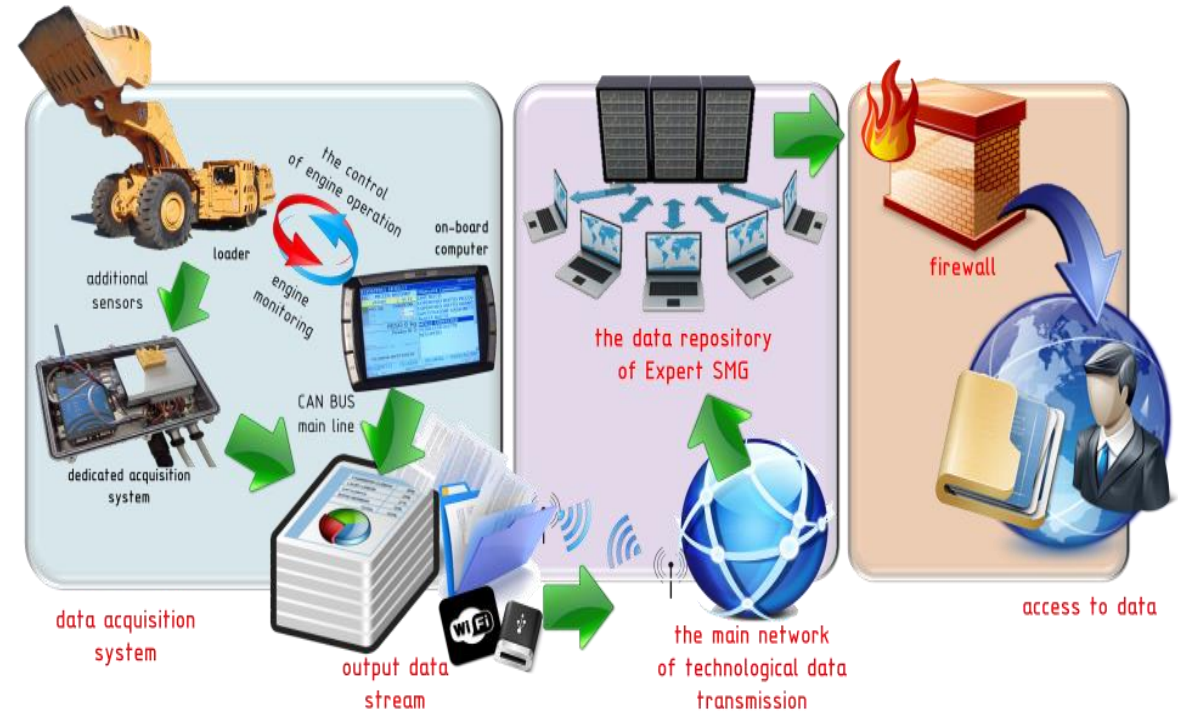
~30-40 variables from single machine  
1s. frequency of sampling

- **What** to measure
- **How** to measure
- **When** transmit to computation center
- **How** to transfer such amount of data (1500 machines, 30 channels)





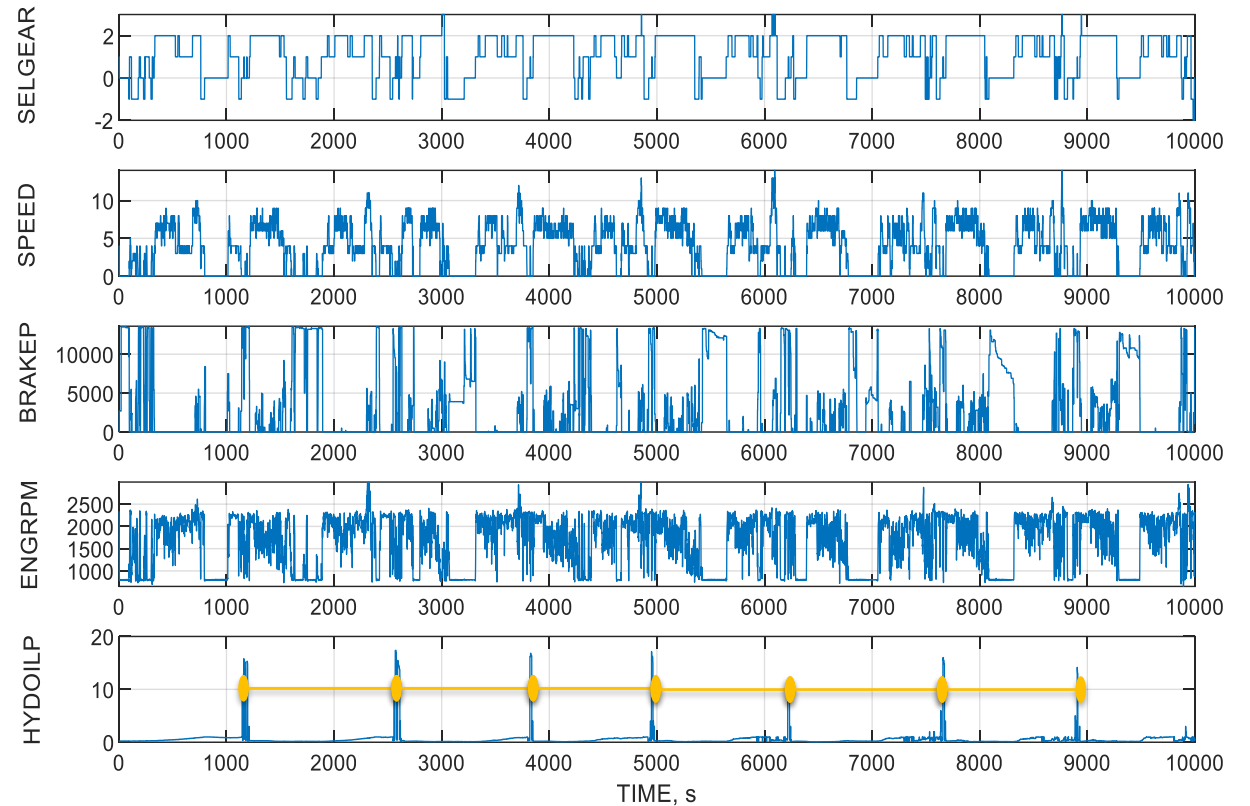
# Mobile machined (LHD: LoadHaulDump)



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# Examples of monitored parameters and analyzed signals

No	Parameters	Description	Units	Sampling, s
1	DATE	Date	yyyymmdd	-
2	TIME	Time	hhmmss	1
3	BRAKEP	Brake pressure	KPa	1
4	ENGCOOLT	Engine cooling temp.	°C	90
5	ENGEXB	Manual brake	0/1	1
6	ENGHOURS	Hours of work	Hours	90
7	ENGOILP	Engine oil temp	KPa	30
8	ENGRPM	Engine rotations	RPM	1
9	ENGTPS	Engine acceleration	%	1
10	FUELUS	Fuel consumption	L/h	1
11	GROILP	Gear oil pressure	KPa	1
12	GROILT	Gear oil temp.	°C	15
13	HYDDRV	Hydraulic drive	0/1	5
14	HYDOILP	Hydraulic pressure	MPa	15
15	HYDOILT	Hydraulic temp.	°C	1
16	INTAKEP	Intake air pressure	KPa	5
17	INTAKET	Intake air temp.	°C	15
18	SELGEAR	Gear selection	-4..0..4	1
19	SPEED	Machine speed	km/h	1
20	SWITCHMOVE	Switch direction	0/1	1
21	TRNAUT	Gear automatic mode	0/1	1
22	TRNBPS	Brake pedal position	0...100	1
23	TRNLUP	State of lock-up	0/1	1



Operational cycles (1 working shift)

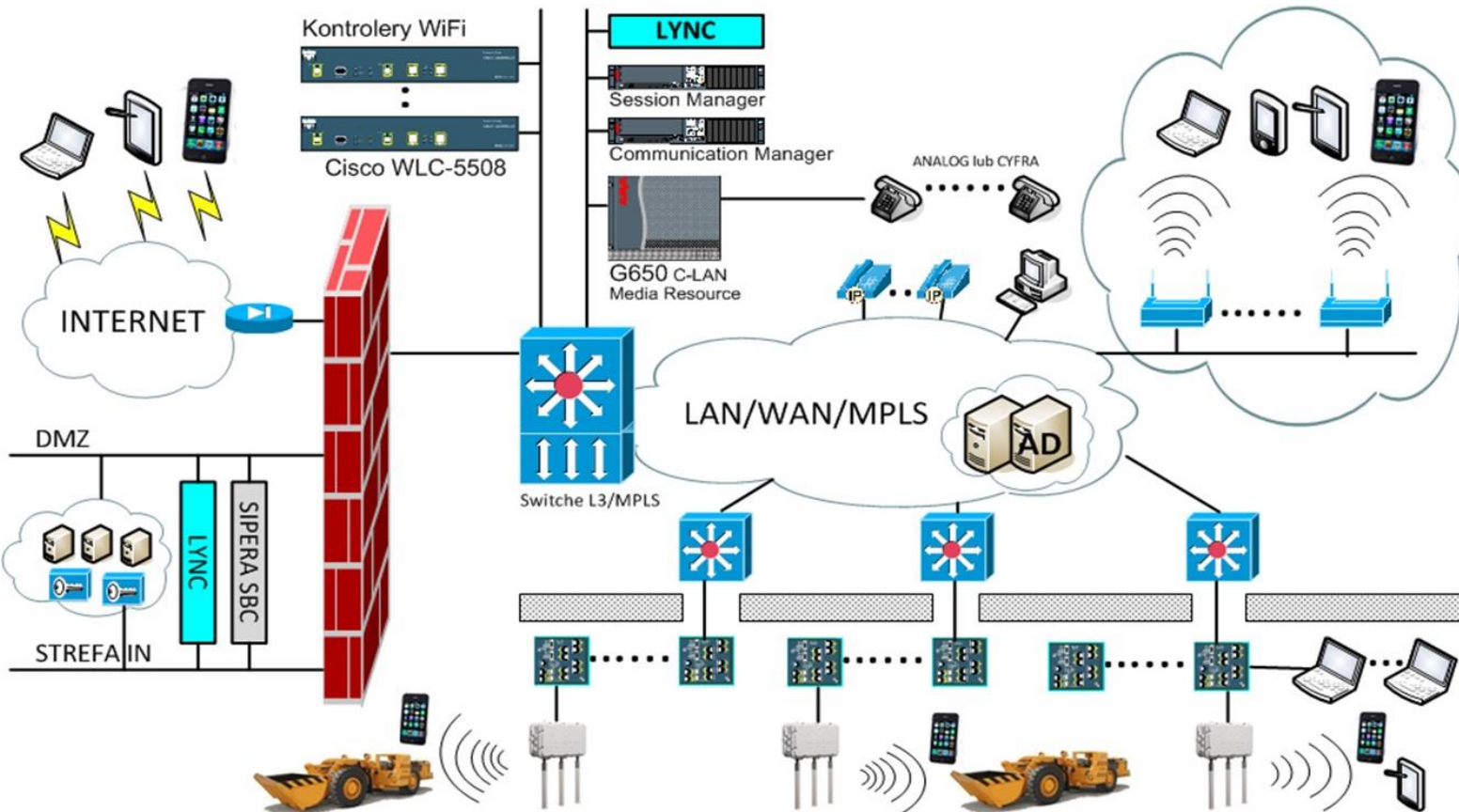
The developed procedure can reliably identify and count the cycles of a HT's unloading when the signal of hydraulic pressure (HYDOILP) is not available due to either sensor or cable damage



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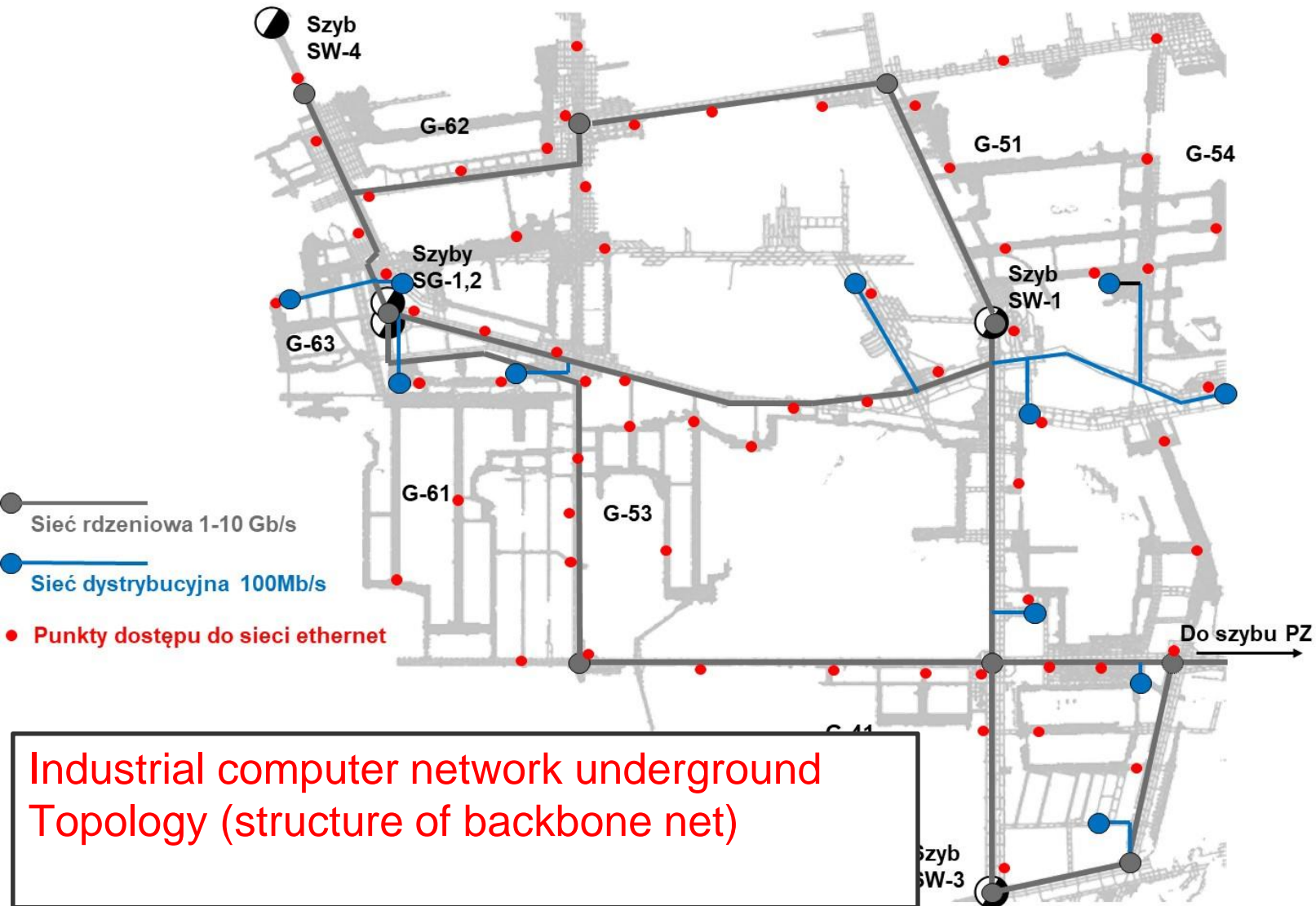
# Industrial computer network underground



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# The data

- How to transmit the data?



Industrial computer network underground  
Topology (structure of backbone net)



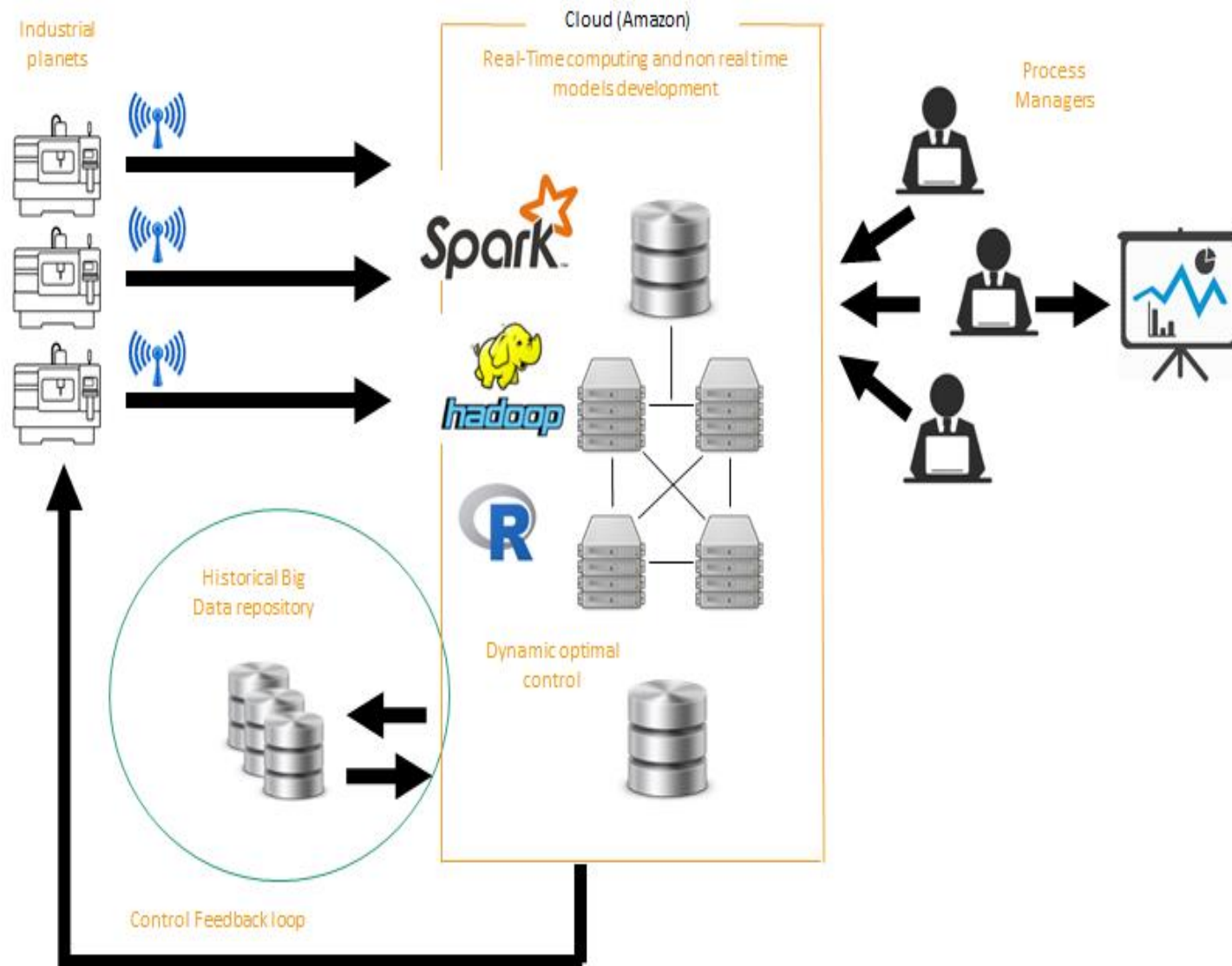
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# The data

- How to store and process the data?

# Cloud systems for condition monitoring



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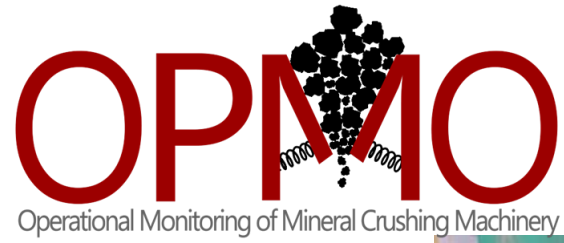
# Other applications



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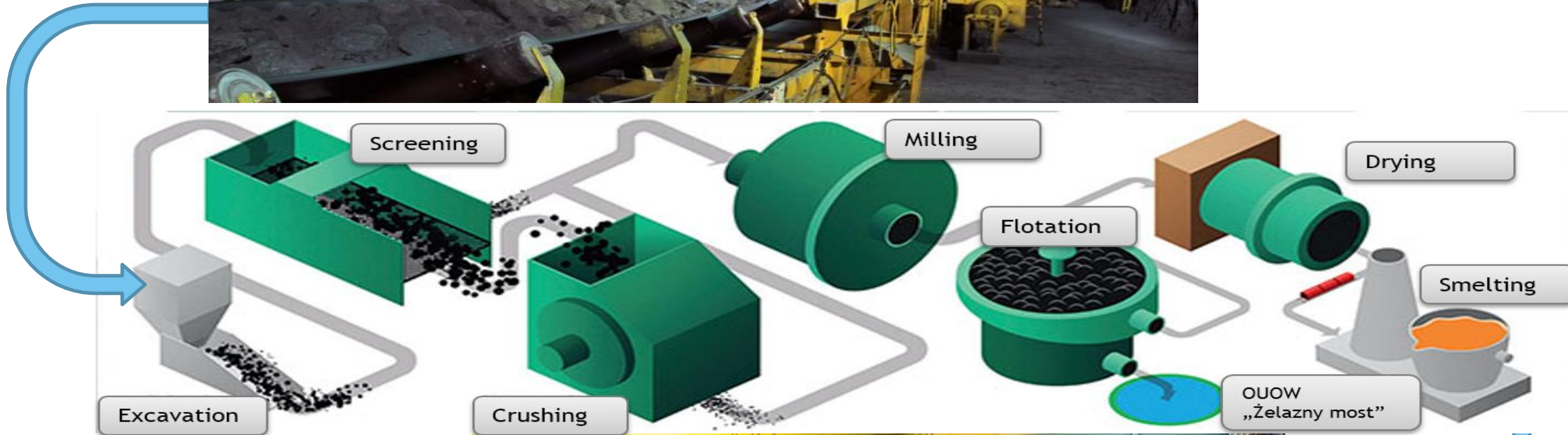


# OPMO project – crushing and sieving of minerals



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- Mineral processing – copper ore case



... has supported under the Marie Curie programme through the ETN of ... by European ...





← Screen

Crusher  
↓





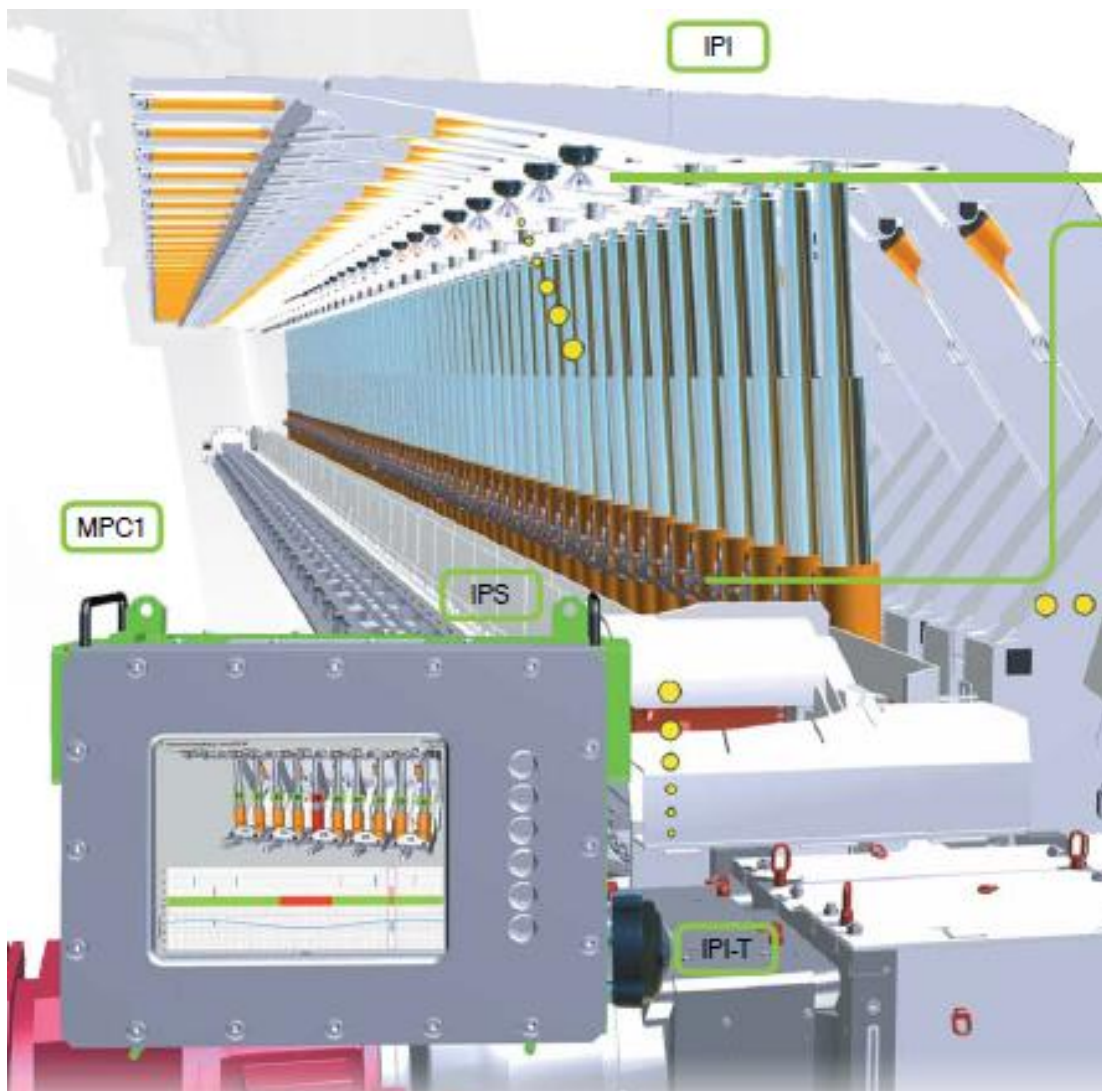
Existing SCADA



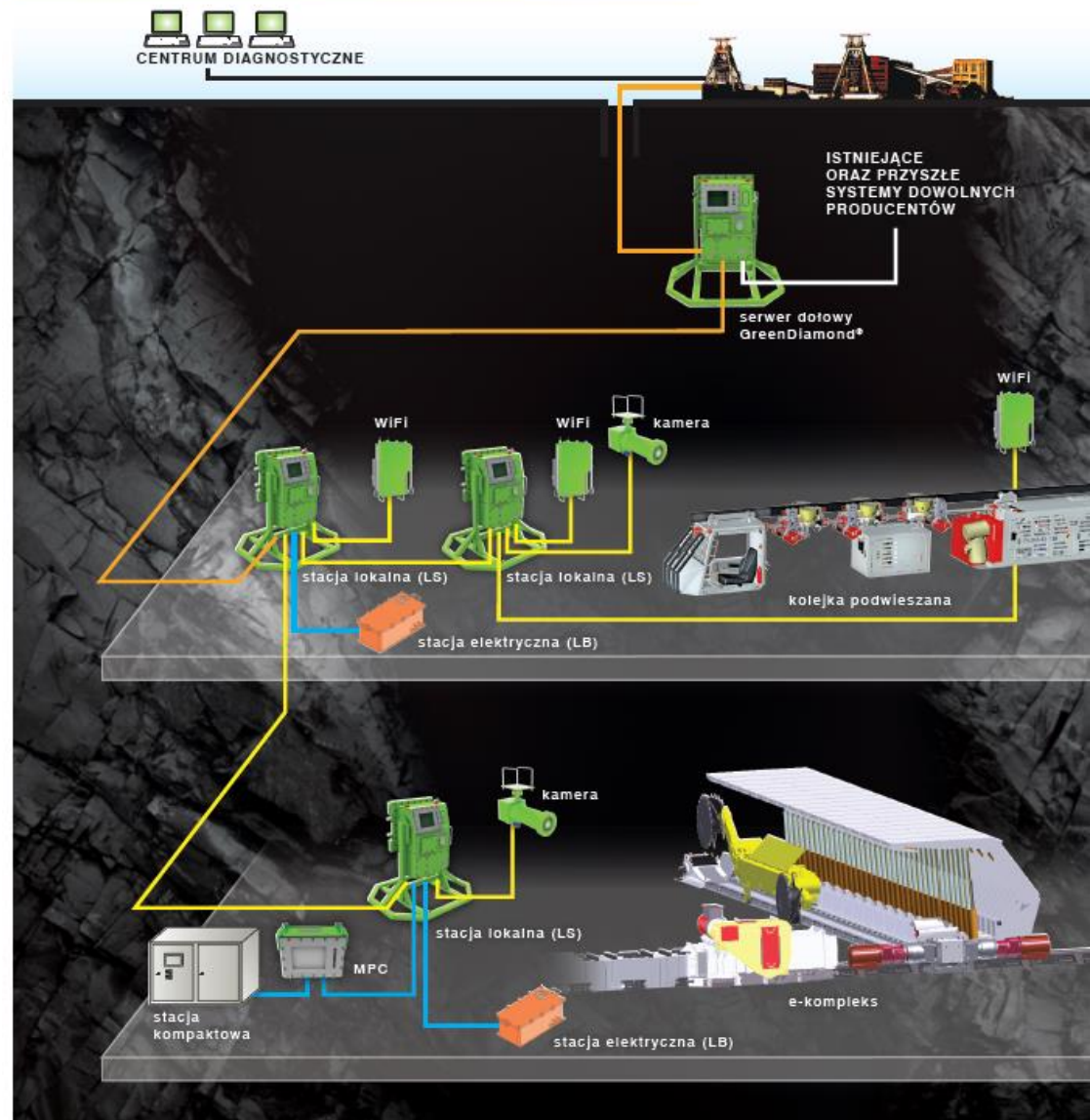
This activity has supported under the Marie Skłodowska Curie programme through the ETN MOIRA project (GA 955681) by European Commission.



# Longwall mining systems



## E-KOPALNIA - OTWARTY SYSTEM ETHERNETOWY



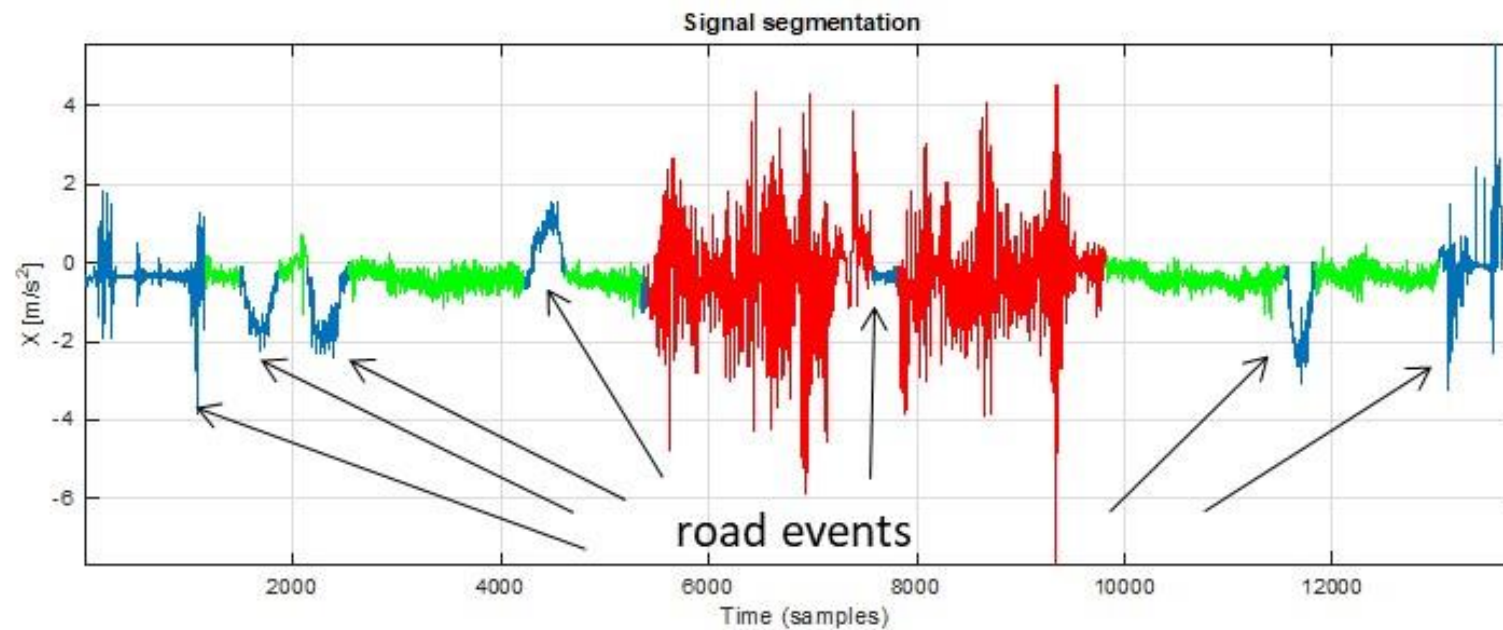
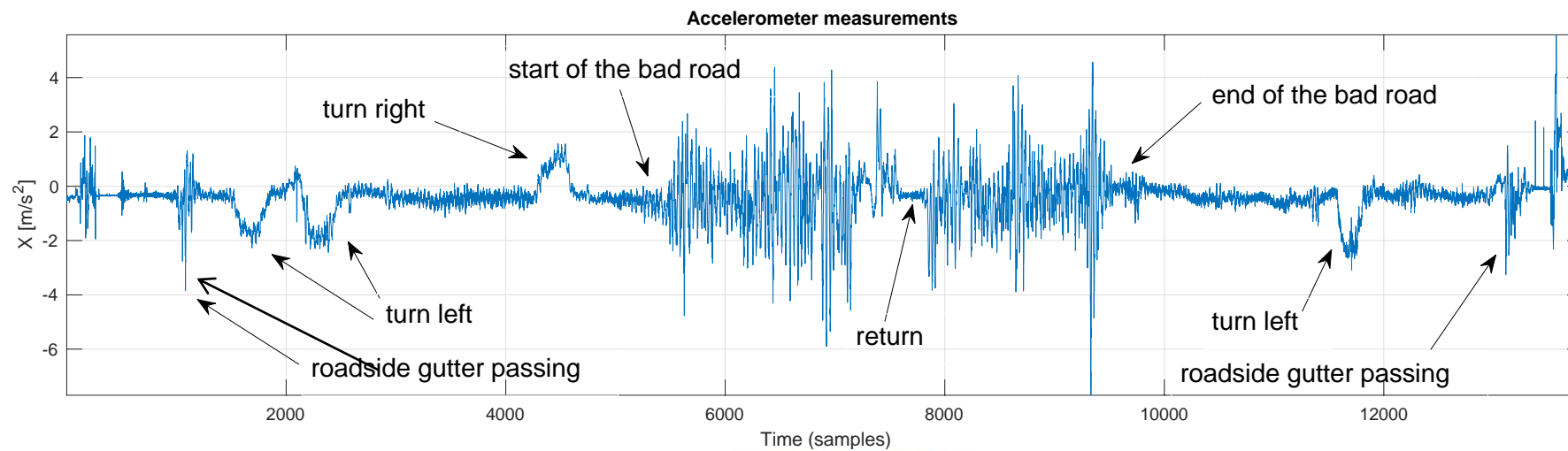
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# Why road quality monitoring is important?



# Preliminary experiments



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rogramme through the ETN  
.955681) by European





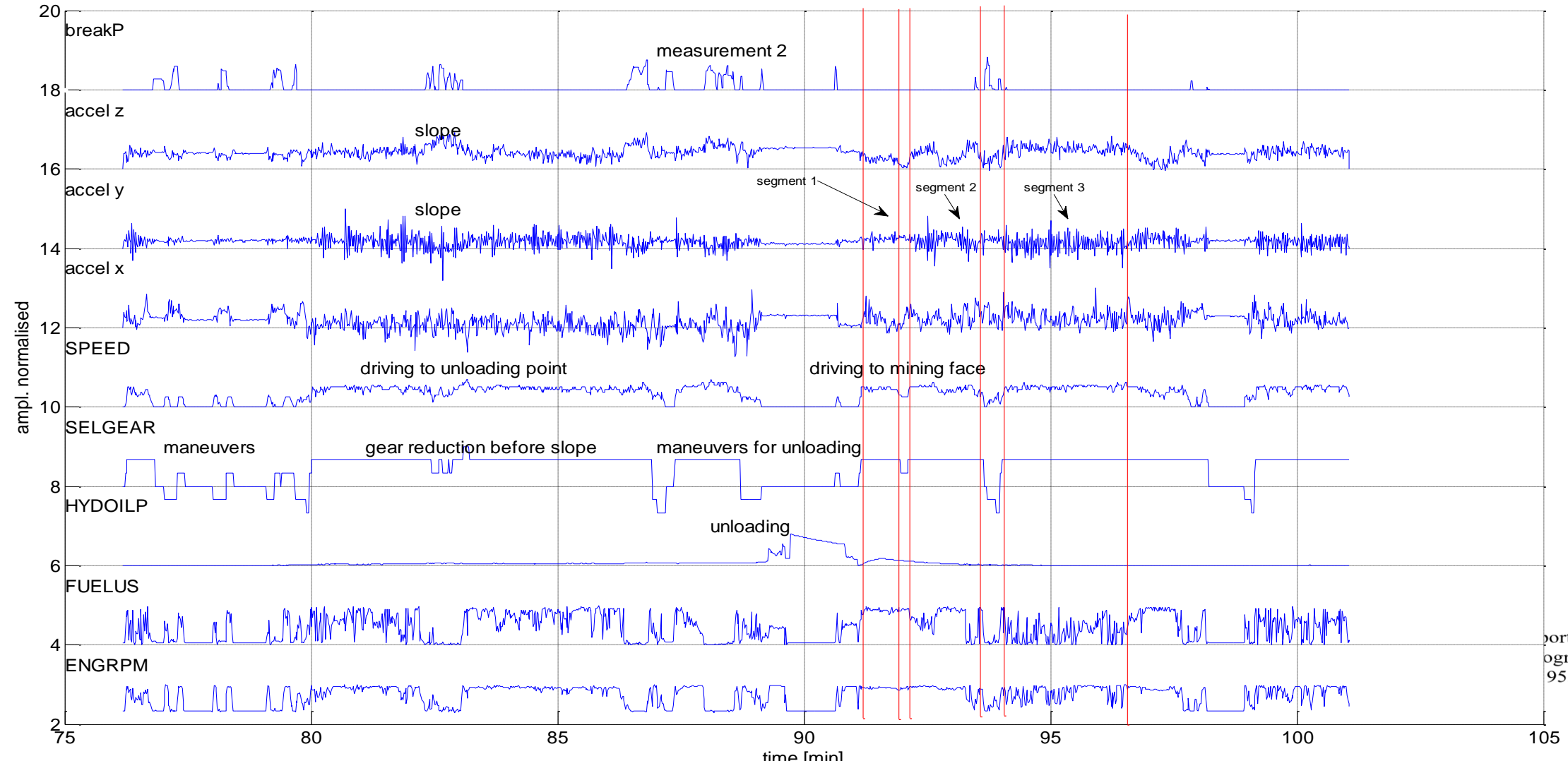
# Underground Manhattan?



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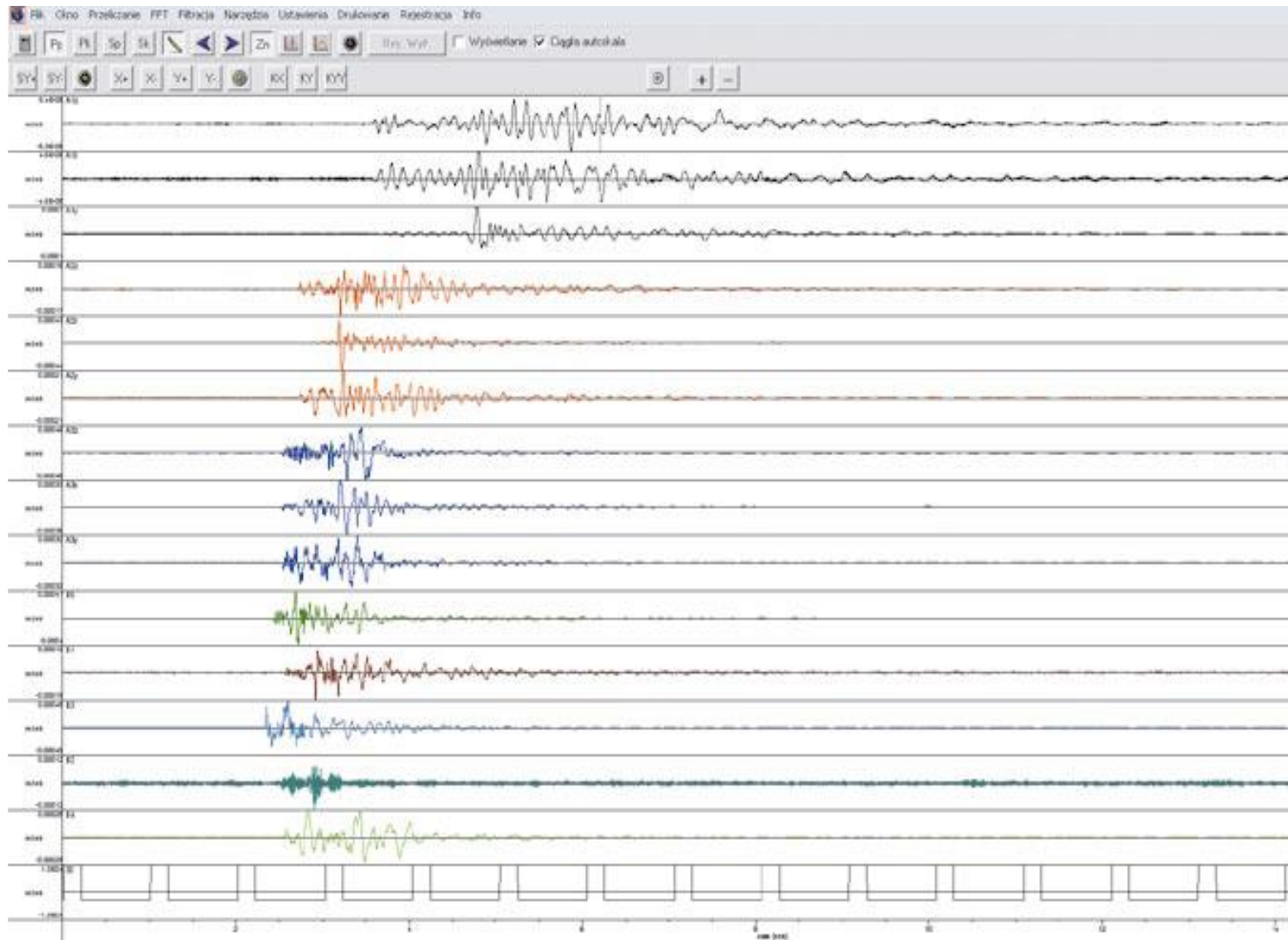


# True data from underground measurement





# Seismic data



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# Air quality in the mine

1. The big impact of technological processes: blasting, air conditioning, ventilation, exhaust gases, from LHD engines (CO)
2. Gas release by the rock mass ( $H_2S$ )
3. Geometry of mine corridors

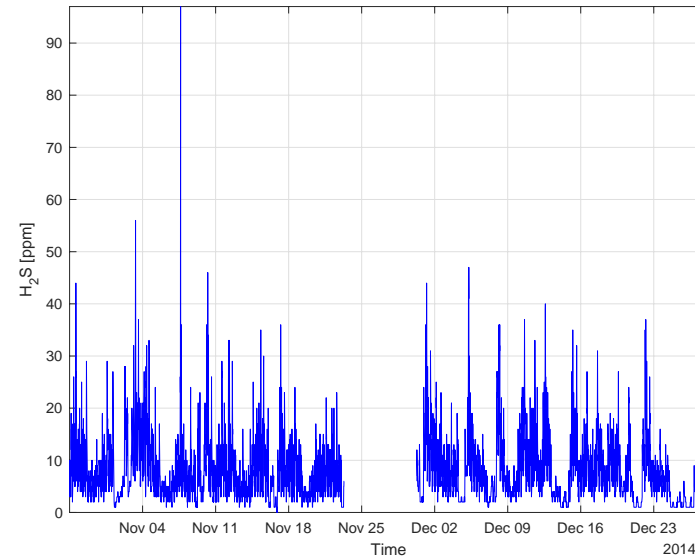
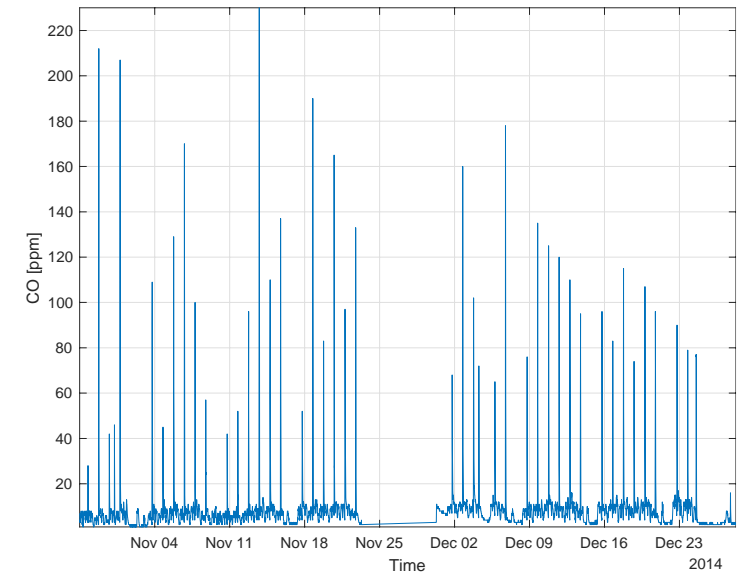
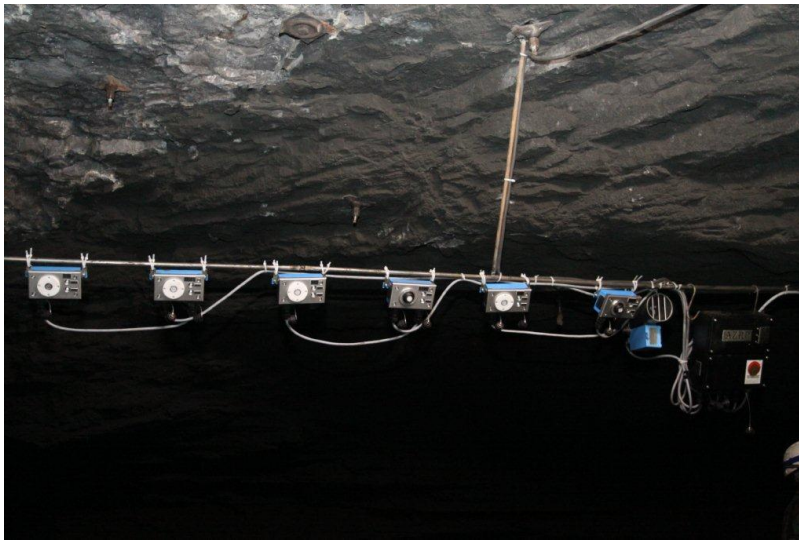
Quality of the air – crucial to allow miners to start their work

One of the most critical parameters of the air quality – CO,  $H_2S$ ,  $CO_2$ ,  $CH_4$  concentration

CO – related to blasting moments

$H_2S$  – natural hazard

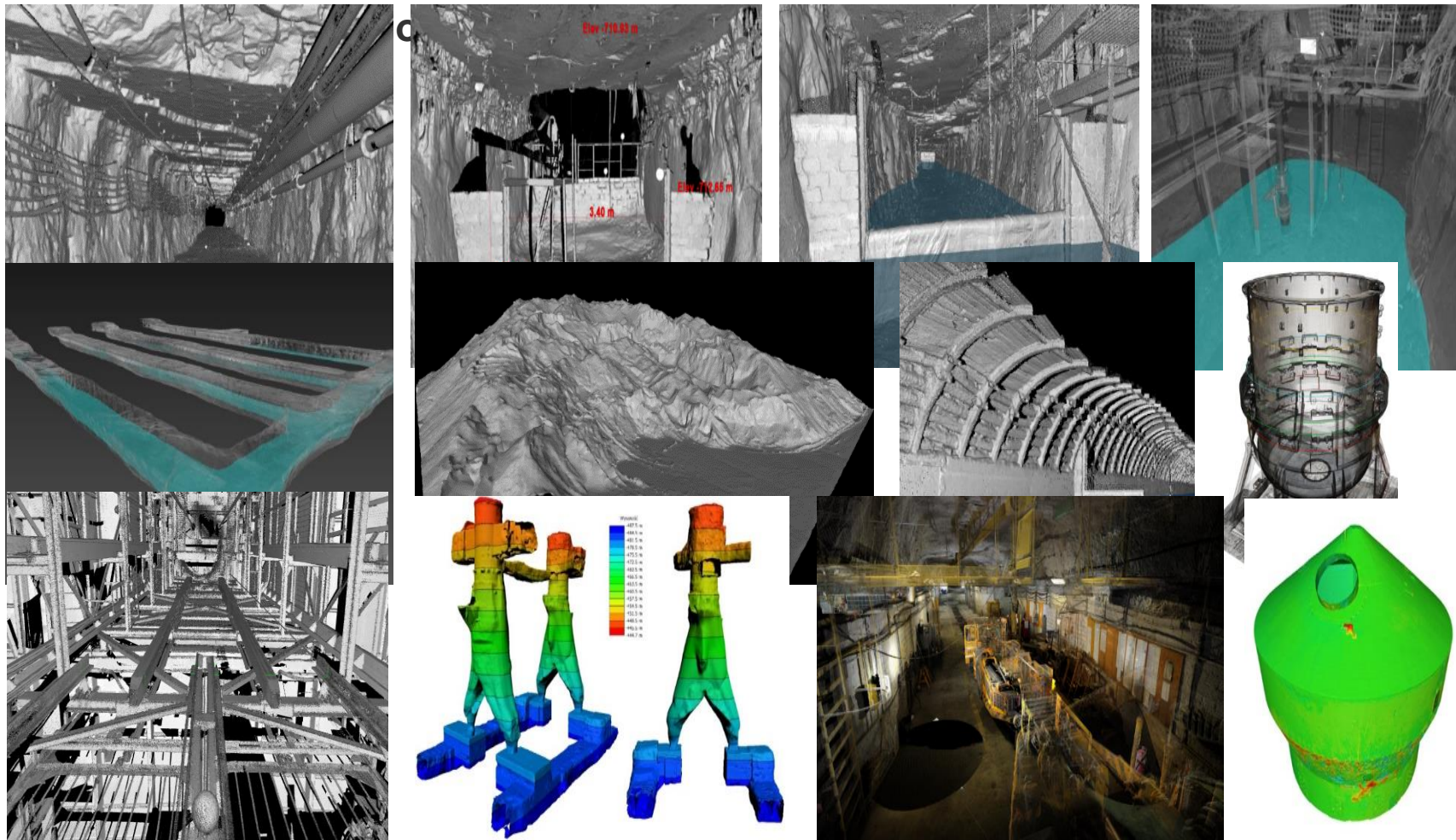
Monitored by specialized equipment long-term data enable to get to know the behaviors of the processes




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# Laser scanning @ KGHM Polska Miedź S.A. O/ZG „Lubin”



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Thank you



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