Safety in confined underground space – PROXIMITY Detection in No-Go-Zones Status 2017

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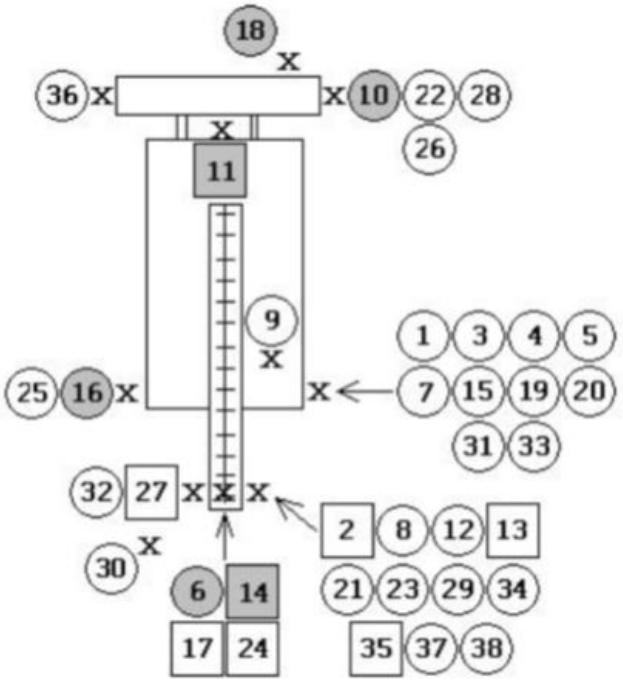
Restricted space underground

Despite work rules and safety training, accidents with collisions between machines and personell are still too frequent in underground operation.

Mine Safety and Health Administration Accident analysis Continuous Miner



Places of fatal accidents arround radio remote controlled continuous miner (Huntley 2014)

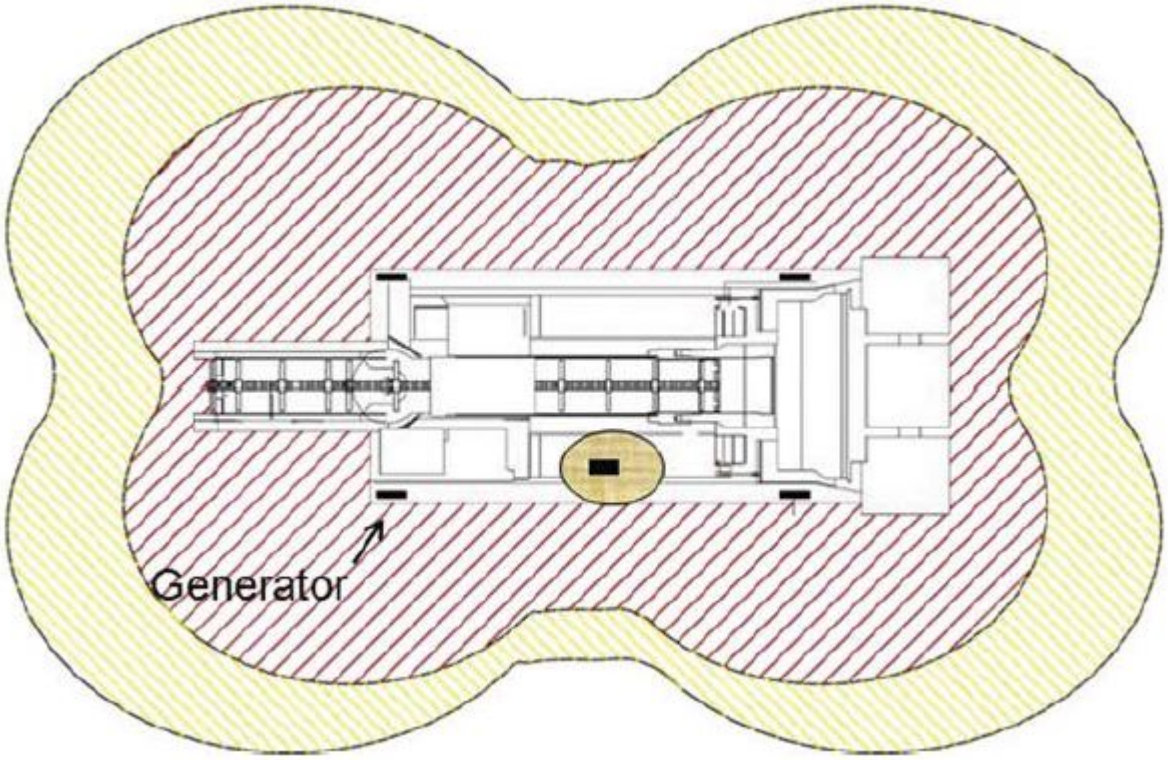
- MSHA analysed the accidents of collisions of machines and personell from October 1984 until September 2014 in US underground coal mining.
- 38 fatalities where identifyed with radio remote controlled continuous miner.
- Reasons where unplanned machine movements and/or positions to close to machines.
- Circles are machine operators, squares are helpers, in grey during maintenance.

Development of Protection Systems

- Based on the high incident rate the National Institute for Occupational Safety and Health (NIOSH) started in 1998 the development of a proximity detection system for persons to close to mining machinery.
- Task: Detect people in „No-Go Zones“
- Patent US 5.939.986
- Since 2009 such systems based on the patent became operational.

- Technical Methods:
- Electromagnetic field measurement
- - RADAR
- - Radio Frequency Identification (RFID)
- - Optical video systems (3D-Vision)
- - Thermo imaging
- - acoustic travel time measurement
- - Time-of-Flight systems with radio frequencies

Electromagnetic Field

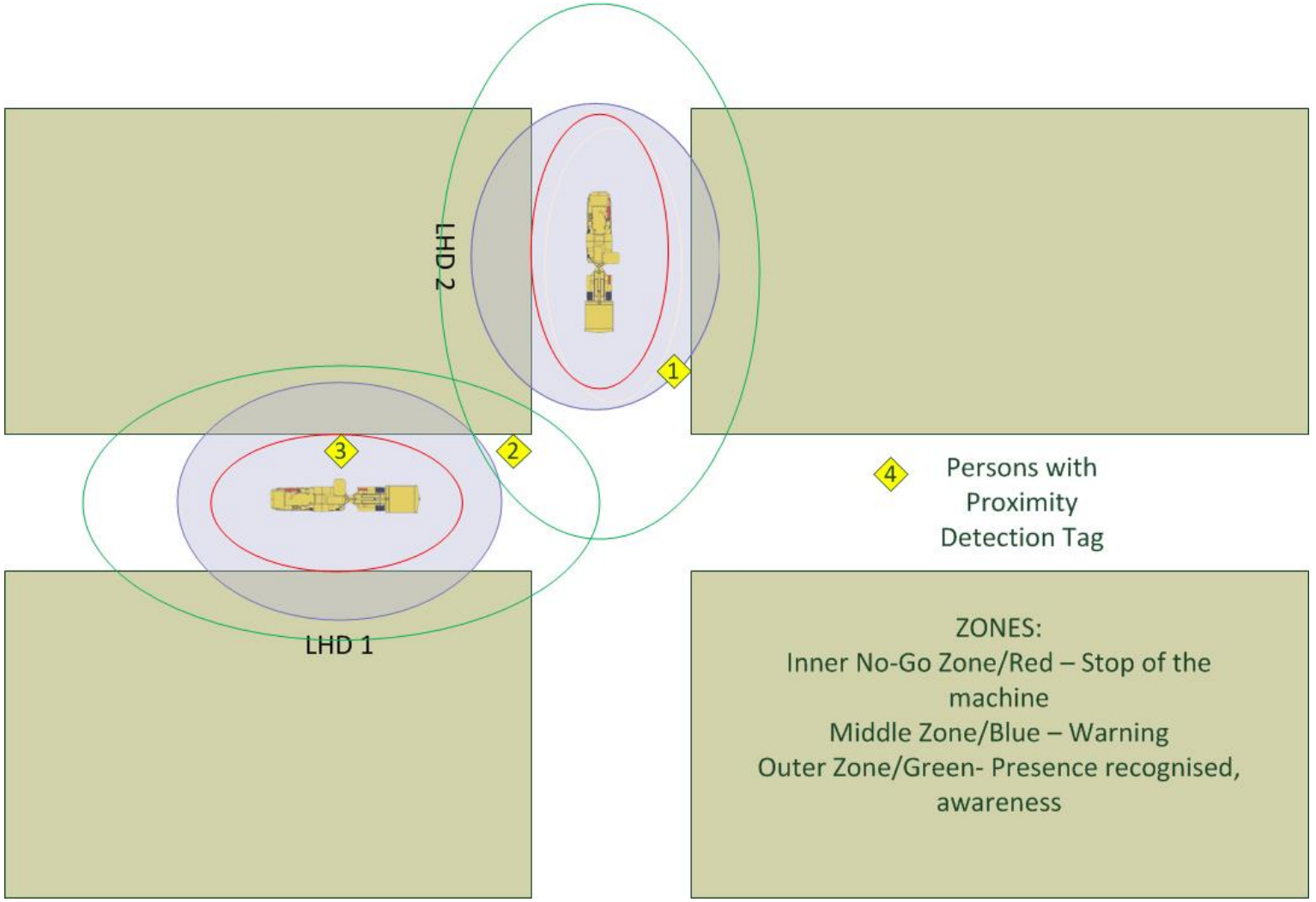


Four field generators onboard a continuous miner produces the low frequency electromagnetic field. The field forms a 3-dimensional bubble around the machine. (Source: NIOSH)

Continuous Miner with PD-System

JOY Continuous Miner 12CM with a Matrix M3-1000 Proximity Detection System, at Las Vegas Mining Show in September 2012. (Picture: N. Sifferlinger)

Zones of Proximity detection



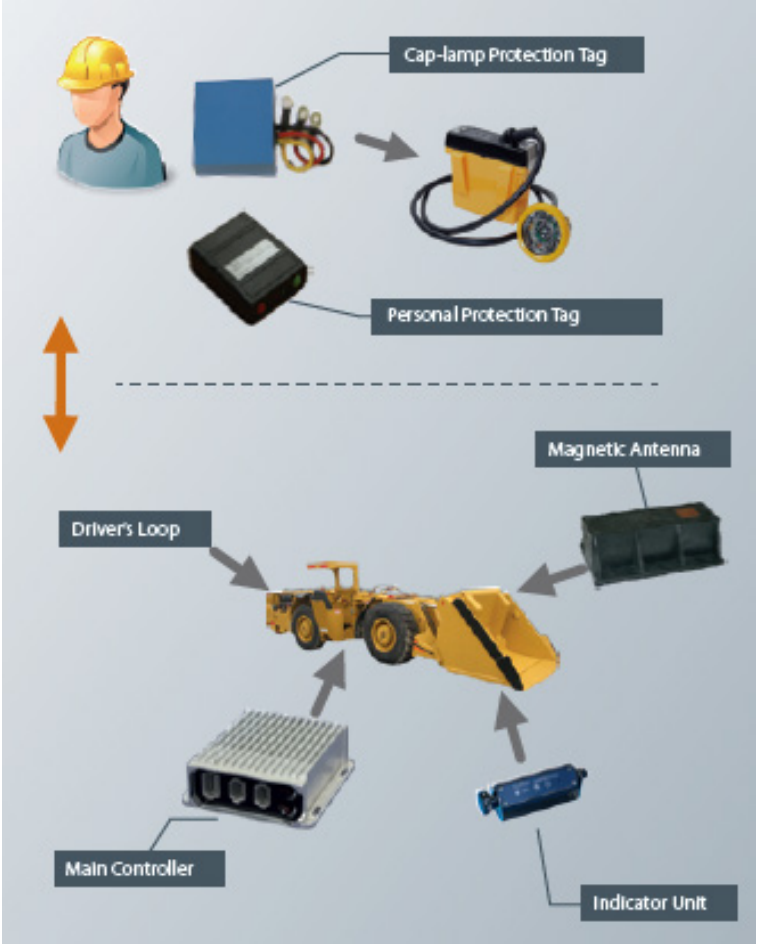
Proximity Detection in coal mining

- Radioremote controlled Continuous Miner with Matrix M3-1000 Proximity Detection System in the USA. (Source: Matrix)

Suppliers of PD-Systems

The major suppliers in 2017 are:

- Strata Mining Products „Hazard Avert®“
- Matrix Design Group M3-1000/Joy Global SmartZone® Gen1
- Matrix Design Group IntelliZone™/Joy Global SmartZone® Gen 2
- Modular Mining Systems
- GE Mining Collision Avoidance System
- Booyco Electronics
- Becker Mining Systems



Components (Infotronix 2013)

Situation USA

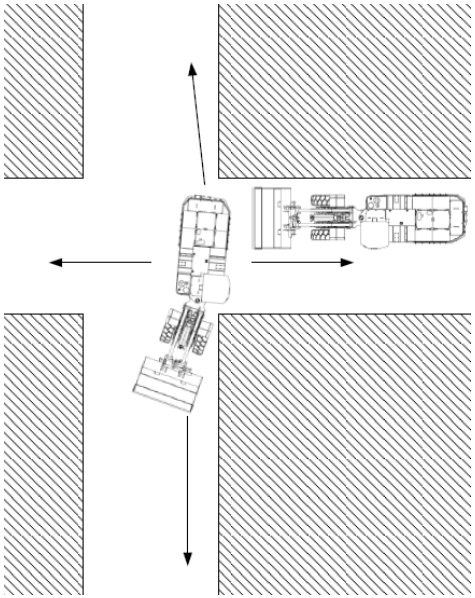
- In March 2015 MSHA made the use of PD systems compulsary for radio remote controlled continuous miner.
- Until March 2018 all effected machines must be retrofitted with PD.
- NIOSH continues testing and drives further development

Source: Matrix

Challenges to existing systems with low frequency magnetic field

The following challenges were identified for this system in underground operation:

- Magnetic Field Generation
- Absorbation or attenuation by rock strata
- Effect of nearby machinery
- Effect of other magnetic field generators in the area (need to tact the different fields)
- Effect of roof structure including strapping and mesh
- Effect of other infrastructure (Pipes, metallic structures and so on)
- RF reflection and multi-pathing
- RF absorbation by rock strata
- Radio noise by other transmitters or electric sparking
- Effect of nearby machinery
- Effect by metallic structures
- Communication problems in “blind corners” (no line of sight)



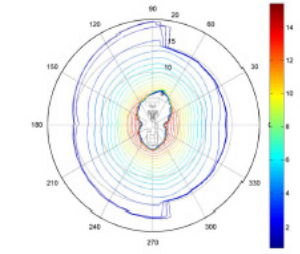


Figure 64 - Full Map, LHD near LHD Results

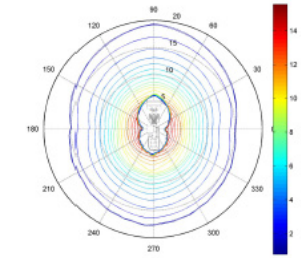
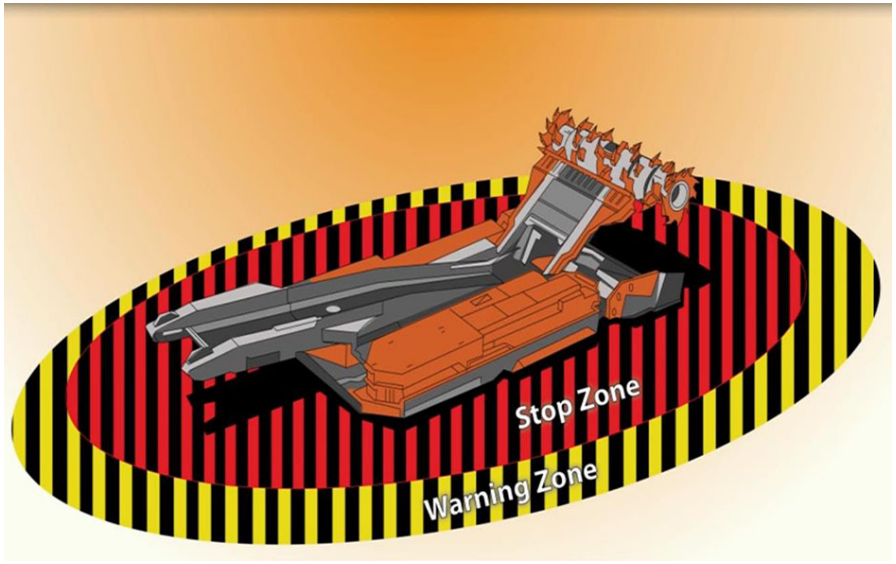


Figure 65 - Full Map, Surface Reference

Infotronic 2013

Operational experience in USA and RSA

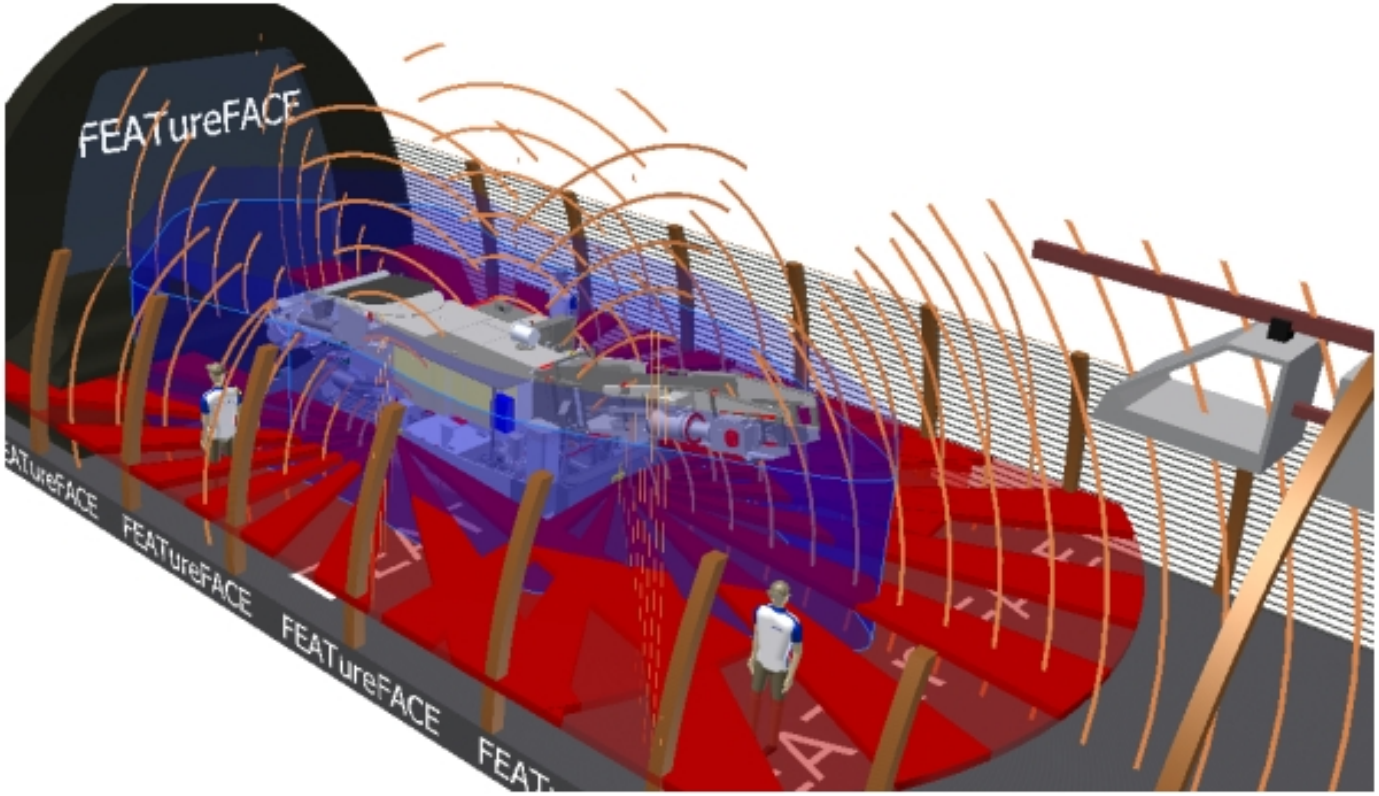
- Presently more than 1500 PD systems are in operation world wide.
- For Proximity Detection Systems of Persons in No-Go-Zones two types of faults are very critical:
- 1) if a person is not detected in the No-Go-Zones, because
  - malfunction of the system
  - no tag at the person under protection
  - the magnetic field gets distorted
- 2) if false alarms shows persons in positions where they are not. If this happens too often the system will be switched off.



Source: MSHA

- NIOSH is working on further develpment of the PD systems and in March 2017 held a public work shop.

Research in Europe: FeatureFace RFCR-CT-2012-00001

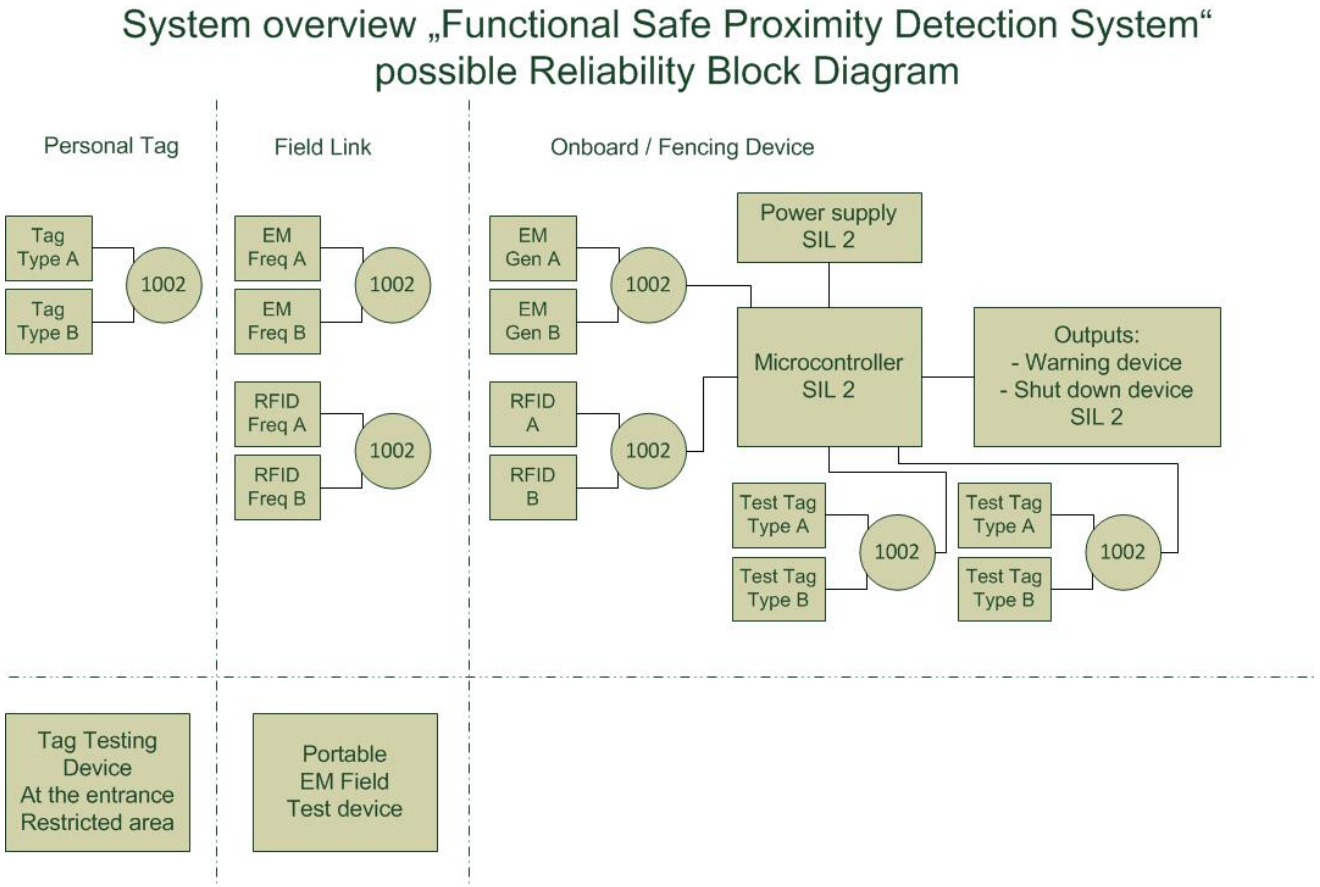


FEATureFACE finished in October 2015 developing and testing concepts (Source: IMR/RWTH Aachen)

Need for functional safety

- Operation has shown that existing PD systems do avoid accidents.
- But system failures are not detected so far in many cases, which creates additional dangerous situations.
- Functional safety offers a solution for this.
- **Functional safety** is the part of the overall safety of a system or piece of equipment that depends on the system or equipment operating correctly in response to its inputs, including the safe management of likely operator errors, hardware failures and environmental changes.

Functional safety concepts



At Montanuniversität Leoben basic research in functional safety is done at the departments of Automation and Mining Engineering.

Functional safe PD systems as enabler in automated zones

Today underground mining areas with autonomous vehicles in operation need total separation from personell.

Functional safe PD systems will enable co-operation in the same area.

Outlook

- In the USA and in South Africa more then 1500 PD systems are in operation.
- The „mining crisis“ 2012-2016 has slowed down further development.
- NIOSH is driving further development in USA, industry will follow.
- Functional safety will become part of future PD systems
- MUL is looking for renewed co-operation with industry to be part of further development.