MINING ELECTRICAL SAFETY 2017 CONFERENCE

Safe Autonomous Production

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MESA
MINE ELECTRICAL SAFETY ASSOCIATION INC.

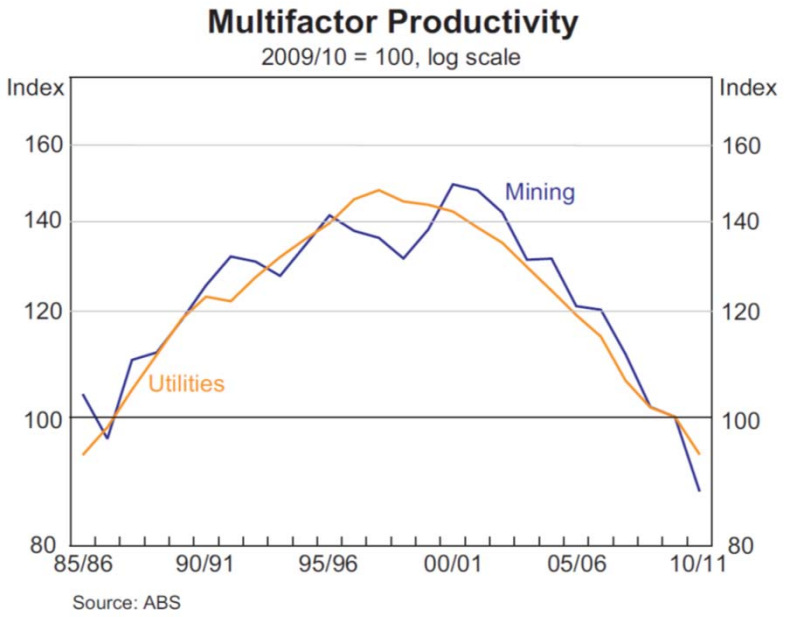
Overview

Why? ... are we even considering this?
What? - Autonomous operation concepts.
Who? - Case Study – Automated Block Cave Copper / Gold Mine.
How? - Safety approach.
But? - Challenges for underground coal and surface mines.
Then? - Lessons learned.

Why? – Mining Industry Productivity

"…the general slowdown in productivity growth cannot be attributed to weak investment, but is likely to be associated with either ***a slowdown in the pace of adoption of productivity-enhancing technological innovations*** *or less rapid improvement in the efficiency with which capital and labour are employed".*

Patrick D'Arcy and Linus Gustafsson, Australia's Productivity Performance and Real Incomes, Reserve Bank Bulletin, June Quarter 2012.



Why? – 12 Disruptive Technologies (McKinsey)

1. Mobile internet.
2. Automation of knowledge work (non-routine, requiring judgement).
3. The internet of things (web-connected low-cost sensors).
4. Cloud technology.
5. Advanced robotics.
6. Autonomous and near-autonomous vehicles.
7. Next generation genomics.
8. Energy storage devices.
9. 3D printing.
10. Advanced materials.
11. Advanced oil / gas exploration & recovery.
12. Renewable energy.

McKinsey & Company - *Disruptive technologies: Advances that will transform life, business, and the global economy*, May 2013.

Why? – Automation ≠ Remote Control

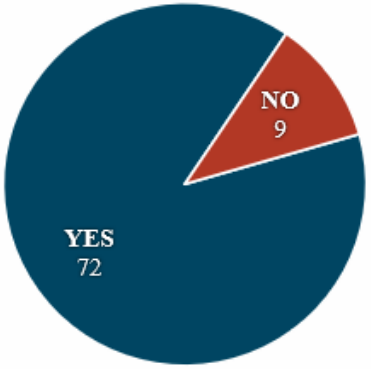
Automation: The use or introduction of automatic equipment in a manufacturing or other process or facility.

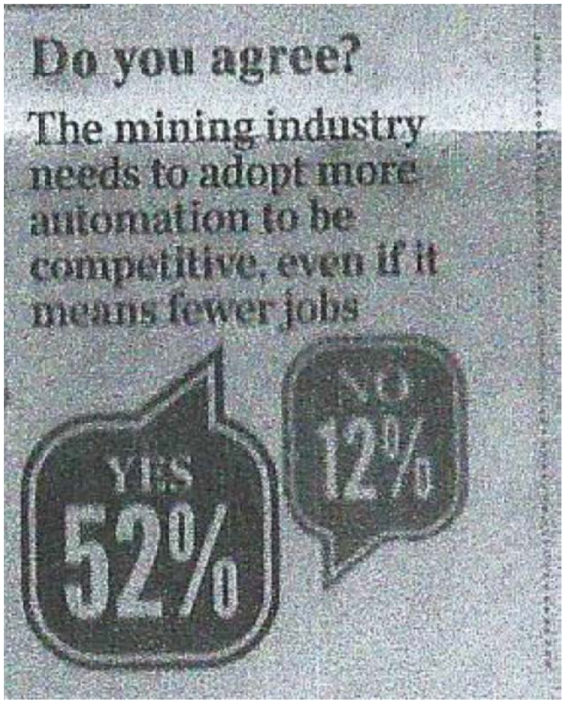
Autonomous: machine that is intended to accomplish its task/s within a set of defined operations without human intervention or direct control.

Semi-autonomous: a machine which requires direct control by a human operator to complete some tasks, while having a portion of its operating cycle not under direct human control.

Why? – Automation = Productivity Driver

To be competitive, the Australian industry needs to adopt greater automation, even if it means fewer jobs.

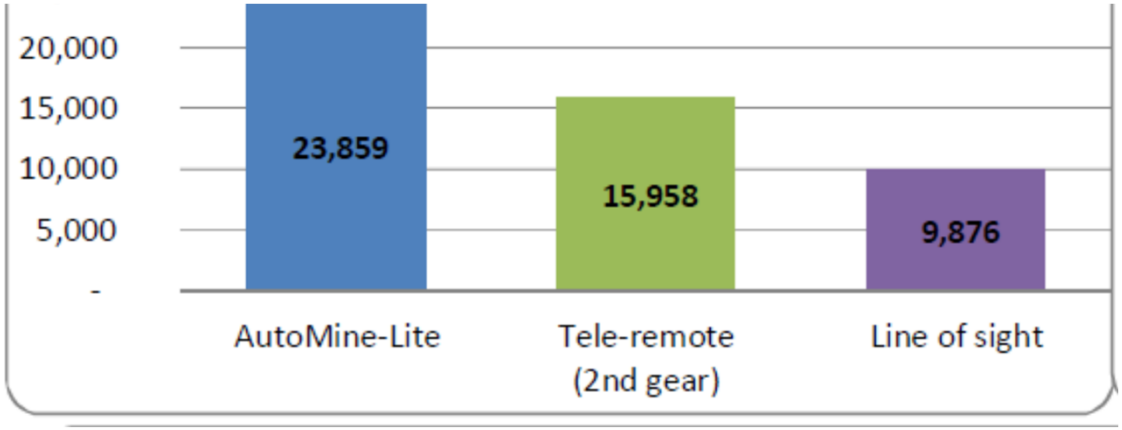




http://www.theaustralian.com.au/business/powering-australia/graph/work

Why? – Automation = Productivity Driver

Autonomous operation is usually initiated as a productivity improvement measure, not usually as a safety improvement measure.
eg. 1.6 times more tonnes / month than tele-remoting.
2.4 times more tonnes / month than LOS remoting.



Source: Sandvik

Improved mine safety is a by-product of automation.

What? – Segregated Autonomous Production

People and autonomous machines are kept separate.

An **Access Control System (ACS)** is placed around the autonomous production zone.

Access Barrier (physical and/or electronic)

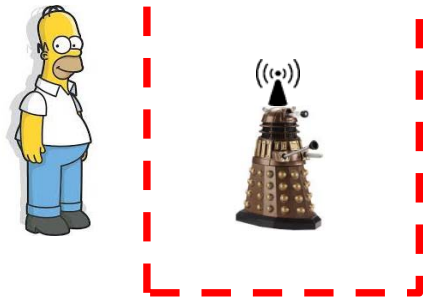
What? – Segregated Autonomous Production

ACS keeps machines in and people out.

- Out-of-control machine - automatically de-energised before it exits the autonomous production zone or reaches another machine.
- Person intrudes into an autonomous production zone - machines in that zone are automatically de-energised.

The ACS is controlling the risk.

- Design ACS to a “sufficient” level of reliability for the risk, and independent of the autonomous control system.

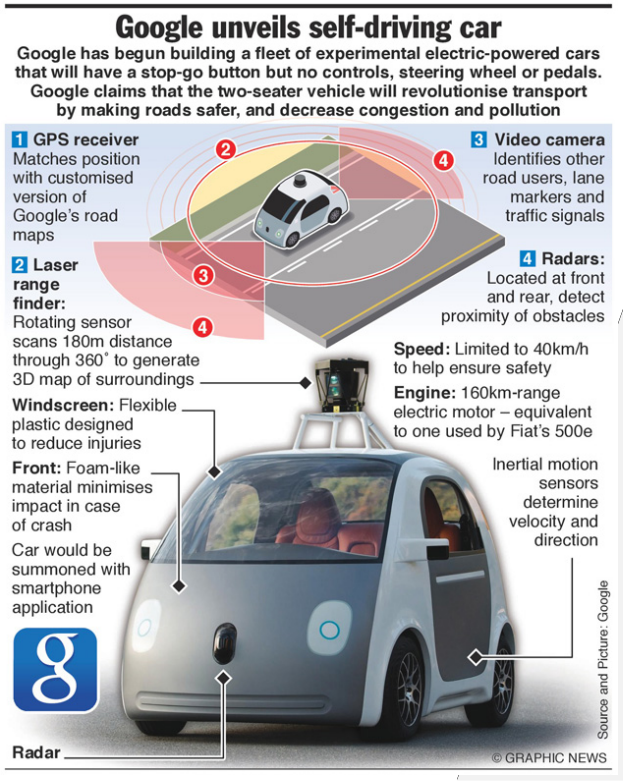


What? – Non-segregated Autonomous Production

People and autonomous machines mingle in the autonomous production zone.

A **Proximity Detection / Collision Avoidance System (PD/CAS)** protects all entities.

No Access Barrier !



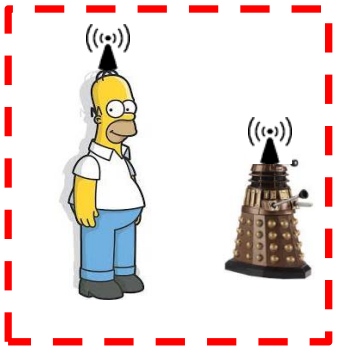
What? – Non-segregated Autonomous Production

PD/CAS keeps machines and people separated.

- Out-of-control machine - automatically de-energised before it reaches another person or machine.
- Person too close to an autonomous machine - machine automatically de-energised.

The PD/CAS is controlling the risk.

- Design PD/CAS to an “sufficient” level of reliability and independent of the autonomous control system.



What? – Less Safe Autonomous Production

- Either autonomous control system, PD/CAS or ACS is not designed to a “sufficient” level of reliability – **at least one should be.**
- PD/CAS or ACS not independent of the autonomous control system – **should be.**
  eg. same GPS unit used for autonomous guidance and also for PD/CAS.
  ie. if GPS provides incorrect or inaccurate positioning, this can affect both the autonomous guidance and the PD/CAS at the same time.
  Also: difficult to maintain safety integrity of PD/CAS or ACS due to continual development / optimisation of the automation control system.

Who? – Northparkes Mines

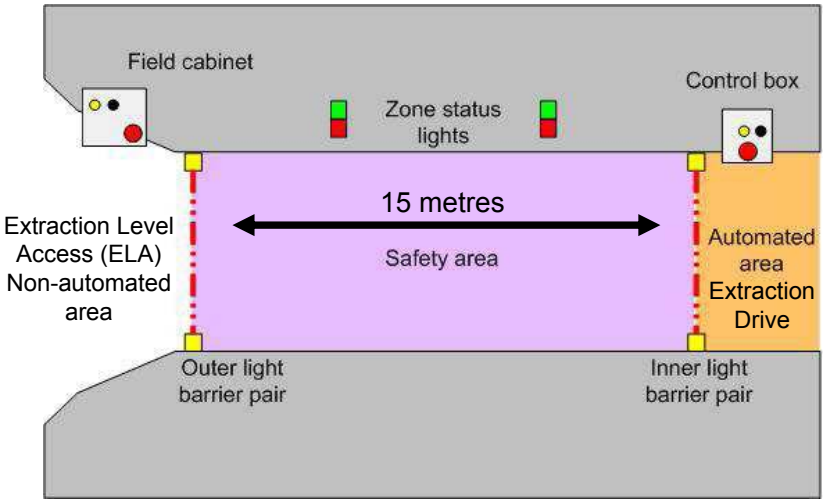
- Segregated (Semi)Autonomous Production.
- SIL2 Access Control System (ACS) – independent of autonomous control.

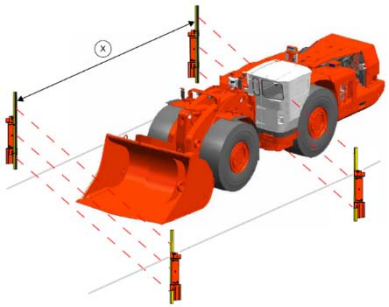
[redacted]

Source: Northparkes Mines

Who? – Sandvik ACS

- Dual light curtains (outer and inner) across entry / exit points to autonomous production zones.
- ACS stop command sent via “wireless” communications.
- SIL2 required. SIL2 capability independently verified.
- Safety area length = comms. delay + braking distance





How? – Control of Automation Risk

- Automation does not eliminate all safety risk.
- It **substitutes** some safety risks. Old risks (of manual operation) are removed. New risks (of autonomous operation) are introduced.
- Care must be taken to control the new risks, so as to ensure a **net safety benefit**.
- New technology → guidelines lag (eg. *ISO/FDIS 17757 (draft) Earth-moving Machinery and Mining— Autonomous and Semi-autonomous Machine System Safety)*.
- The solution is to use a risk management approach
  → **identify** "reasonably foreseeable" hazards / risks
  → **analyse** risks (cause, likelihood, degree of harm, available controls)
  → **treat** (control) risks according to the hierarchy of controls (eliminate, substitute…)
  → satisfy the **"reasonably practicable"** test
  → apply **"functional safety approach"** as necessary (ie. for ACS, PD/CAS of "sufficient" reliability for the risk).
  → **communicate & consult** / **monitor & review** .

How? – Automation Risks

A sample of hazards considered in block-cave LHD automation.
These could also apply to automation in other types of mines.

- Person left in autonomous zone during initialisation.
- Person enters autonomous zone (advertantly or inadvertantly).
- Mine incident (eg. fire) causing person to attempt escape through autonomous zone.
- Autonomous machine malfunctions and tries to leave autonomous zone.
- Roadway / brakes / tyre condition - increased braking distances (affects ability to stop machines within autonomous zone).
- Production control system malfunction - collisions between autonomous machines.
- Unplanned movement during change-over from autonomous mode to manual mode.
- Surface operator - incapacitation / absence / evacuation.
- Human factors - fatigue / boredom / human error.

But? – Automated Surface Haul Trucks

- Roadways regularly changing → change management.
- Segregated or non-segregated?
- Segregated → How to segregate?
- Non-segregated → accuracy & reliability of PD/CAS?
- High kinetic energies & subject to electronic intervention on brakes

  $E = ½ mv^2$

  720 Tonnes @ 60 km/hr = 100,000,000 Joules

  100MJ = 25kg TNT !

But? – Automated Underground Coal Mines

- Mining areas regularly changing → change management.
- Segregated or non-segregated?
- Segregated → How to segregate?
- Non-segregated → accuracy & reliability of PD/CAS?
- Complex system integration - development and long-wall.
- Ex requirements.

Then? – Lessons Learned / Enablers of Success

- Management and workforce **commitment** is non-negotiable.
- **Innovation** culture / mindset.
- A new **skill-set** (management , engineering / technical, operational) is needed.
- Start the system **safety process early**.
- Evolving software-based technology → **expect bugs**.
- Ensure effective **communication, co-operation and consultation** between project, production and vendor teams.
- **Site-based**:
  - project management.
  - technical experts especially during commissioning / early operations.
  - full-time trainers during introduction.
- Robust **service / maintenance contract**.
- **Question everything**!

Final word….the 10 year space gap…

"The world is moving so fast these days that the man who says it can't be done is generally interrupted by someone doing it".

- Elbert Green Hubbard

"If we can send a robot into the Solar System to collect rocks relatively unsupervised, surely we can send one into Australia to do it as well."

– Anon.