TMM CPS functions

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Make today matter

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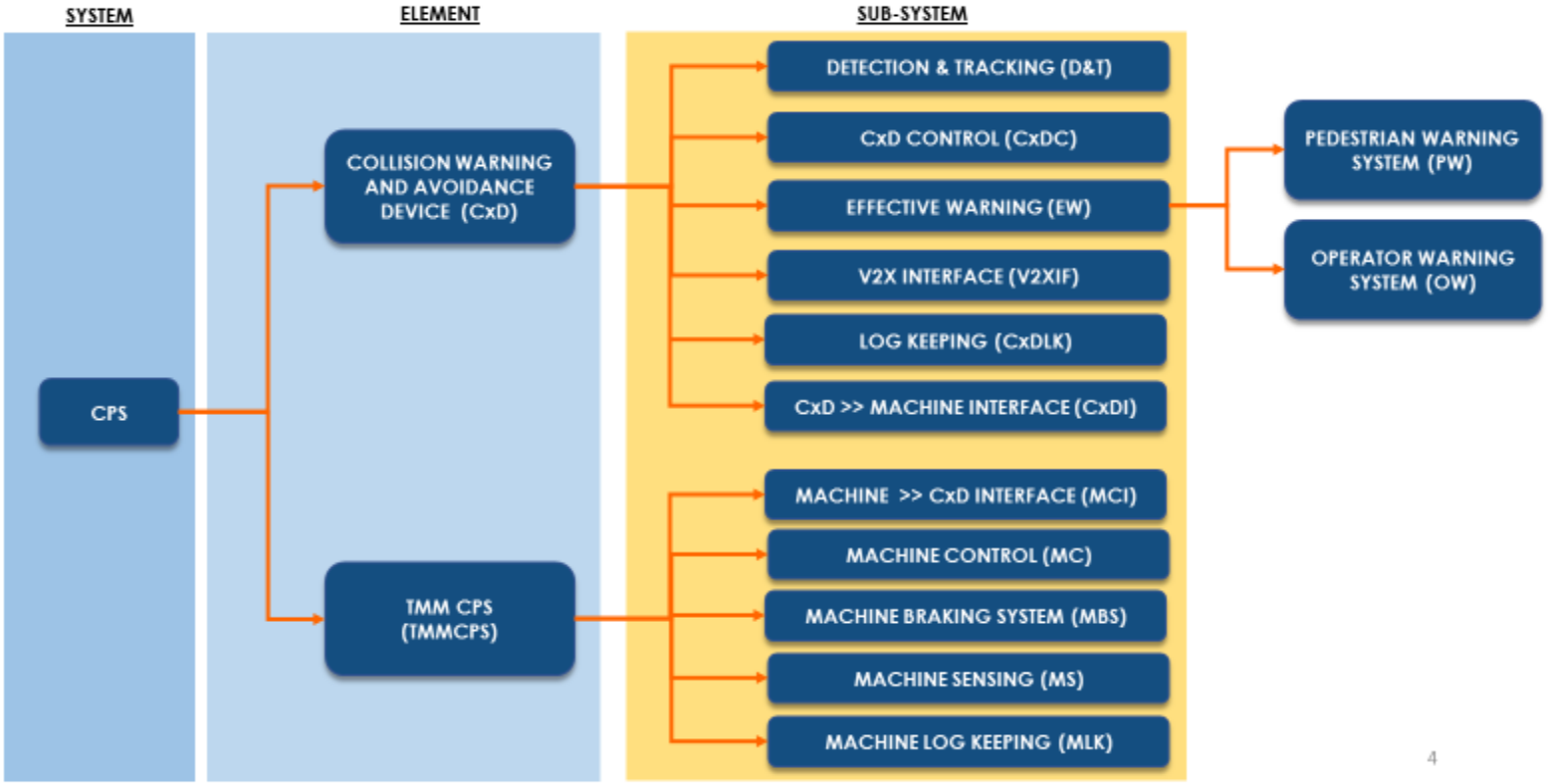
Background

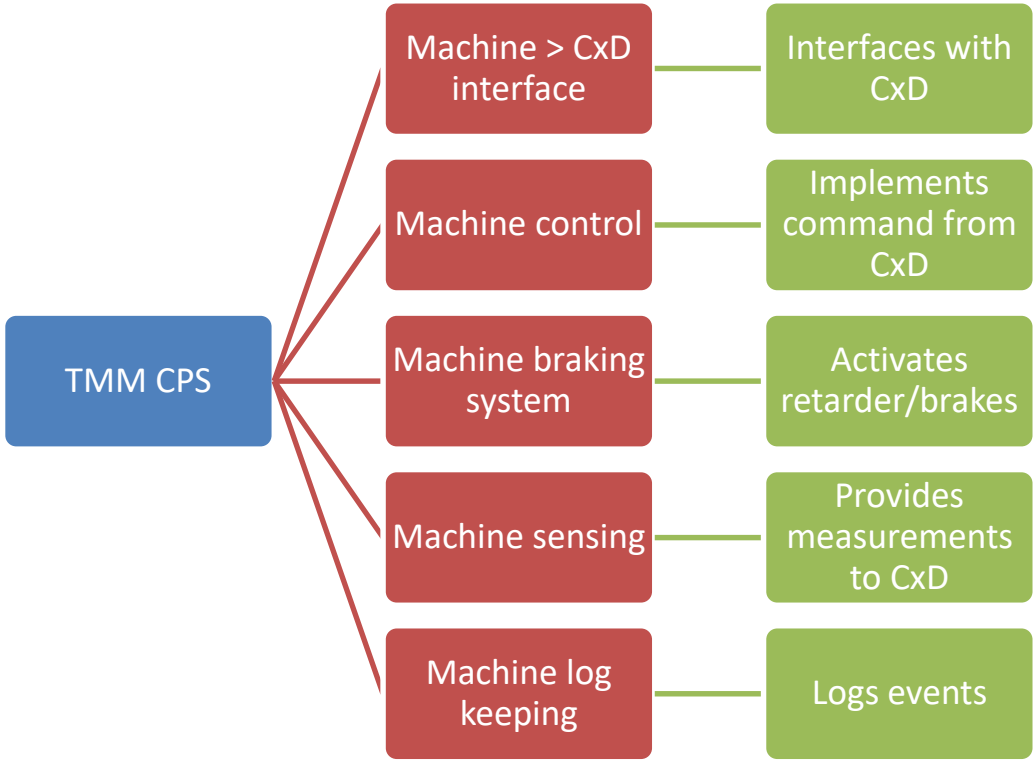
- CPS is a system
  - Currently not available as an ‘off-the-shelf’, ‘all-in-one’, ‘one-size-fits-all’ product
  - Two/three providers integrating
    - CxD
    - TMM OEM
    - Interface supplier (if needed)
  - Safety system requires clearly defined functionality (responsibilities)
    - Liability and accountability if something goes wrong
- We have made significant progress with CxD providers
- Unfortunately not the case with TMM OEMs

Background

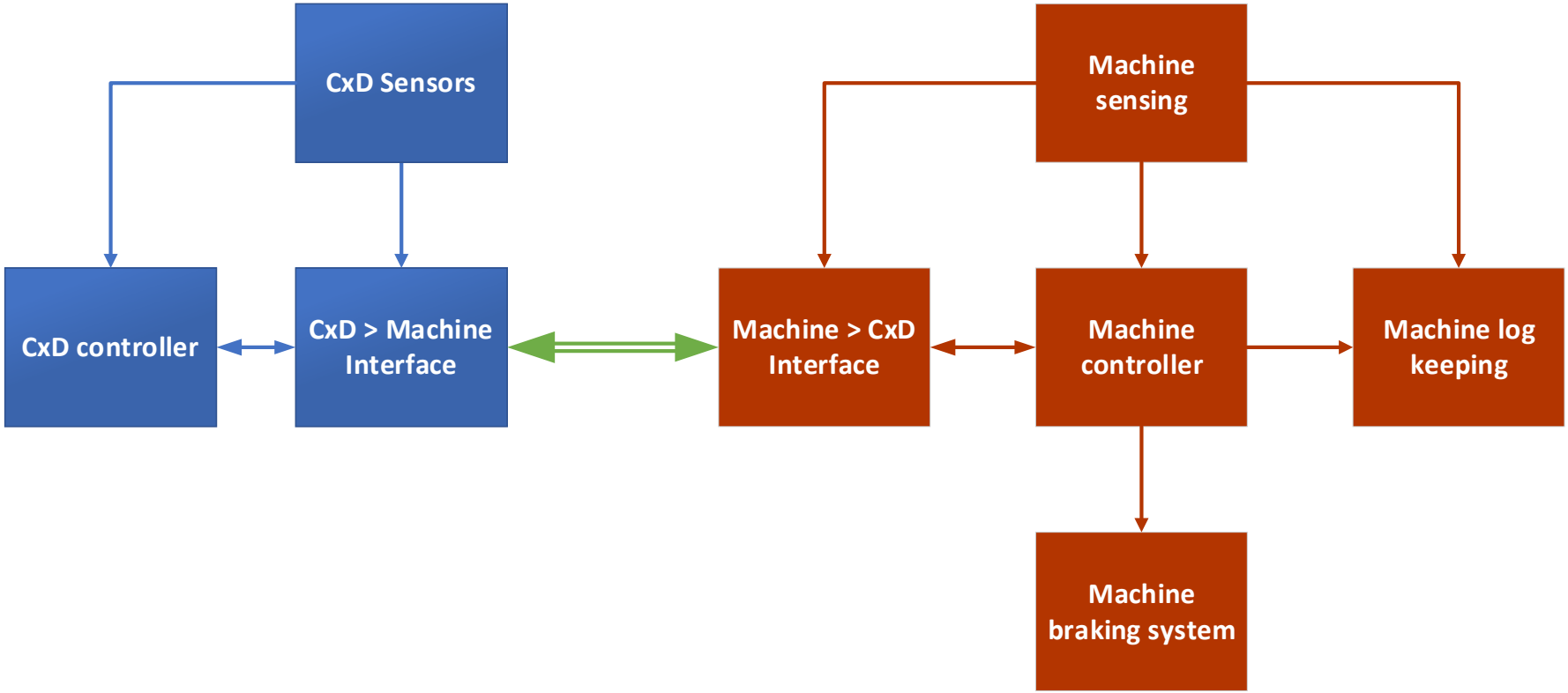
CPS functional breakdown



TMM CPS functionality



TMM CPS functionality



TMM CPS functionality

Machine > CxD interface

- Communication medium between machine and CxD
  - Typically CAN interface
  - Complies with ISO 21815-2:2021
- Functionality
  - Negotiation between CxD and TMM at start-up or if something changes
  - Instructions (commands) from CxD sent to TMM
  - Response from TMM on all messages sent from CxD (heartbeat)
  - Machine data (obtained from Machine Sensing sub-system)

TMM CPS functionality

Machine controller

- Controls all aspects of TMM, but focus is on implementing CxD commands
- ISO 21815-2:2021 defines eight commands (functionalities):
  - Normal operation – keep going, produce!
  - Emergency stop – collision cannot be avoided, try to mitigate the consequences
  - Controlled stop – stop machine in a conventional manner
  - Slow down – reduce speed to avoid collision (e.g. dovetail scenario)
  - Stand down – limited functionality, desired state is stationary (e.g. failure present)
  - Bypass – CxD functions overridden by authorized person
  - Apply setpoints – maximum speed (if speed is exceeded, TMM to reduce speed)
  - Motion inhibit – prevent engagement of propulsion system, remain stationary

TMM CPS functionality

Machine controller

- While a CxD may decide to make use of all these commands, the TMM OEM needs to define which commands are permissible.
  - Clearly communicate this strategy with CxD, CxD must adapt to TMM
- Factors that affect the permissible commands:
  - Brake system type
  - Current machine speed/gear selection
  - Machine status (e.g. boom extended, tray up, bucket raised)
- What are operators allowed to do? What are they trained to do?
  - TMM OEM needs to define expected ‘operator’ behaviour
- Provides fail–to-safe functionality
  - E.g. if communication with CxD is lost, machine must fail to safe condition

TMM CPS functionality

Machine sensing

- Information readily available on machine provided to CxD as defined in ISO 21815-2:2021
  - Machine speed
  - Direction of travel
  - Gear selection
  - Payload status
  - Pitch angle, etc.
- Other information not provided to CxD, but used by Machine Controller to make decisions
  - Articulation angle/steering input
  - Engine management systems
  - Brake wear
  - Fuel & other fluid levels & pressures

TMM CPS functionality

Machine braking system

- The physical braking system, consisting of (as applicable)
  - Friction brakes
  - Retarder
  - Engine braking
  - Hydrostatic drive
  - Electric regenerative brakes
  - Park brake
  - All peripherals, such as valves, harnesses, control electronics, actuators, etc.

TMM CPS functionality

Machine log keeping system

- Keeps an auditable record of CPS events
  - Replies and data messages sent via CAN bus
  - Messages received via CAN bus
- Verifies that TMM received instructions from CxD
- Used for:
  - Incident investigation
  - Performance improvement

Current industry status

- Limited TMM OEM functionality made accessible to CxD suppliers
  - Mines still need to be compliant, so they have to fill the gap
    - Results in aftermarket modifications to braking systems
    - Introduces business risks (e.g. warranty void), safety risk (e.g. FMECA incomplete)
- CxD suppliers are more agile than large, multi-national OEMs, hence they try to accommodate uncooperative TMM OEMs
  - Significant variation within brand, model, serial number ranges
  - Onerous development ask of CxD suppliers, introduces safety and compliance risk
  - ±15 CxD suppliers in the market, vs. 100+ TMM OEMs
- TMM OEMs need to make more progress, quickly

Recommendation

- MOSH requirements clearly define functionality and responsible parties
  - We need buy-in from major OEMs
  - Expectation is:
    - TMM OEM to clearly develop machine control strategies for commands as defined in ISO 21815-2:2021
    - Where some commands are infeasible/impractical, that these be clearly stated
    - TMM OEM to provide brake performance information that is valid under clearly defined conditions (e.g. ISO 3450:2016 test conditions)
    - TMM OEMs to support the South African Mining Industry as the global leaders of TMM safety technology adoption

Thank You