EMESRT

Earth Moving Equipment Safety Round Table

2021

Activity Report

Working with industry since 2006

Acronyms

ACARP	The Australian Coal Industry's Research Program
BI	Business Inputs
CAS	Collision Avoidance System
CFM	Credible Failure Modes
CFw	Control Framework
DP	Design Philosophy
EAG	EMESRT Advisory Group
EDEEP	EMESRT Design Evaluation for EME Procurement
EMESRT	Earth Moving Equipment Safety Round Table
HFDD	Human Factors Design Diversity
ICMM	International Council on Mining and Metals
ICSV	Innovation for Cleaner Safer Vehicles
MEI	Mobile Equipment Interaction
OEM	Original Equipment Manufacturer
OMAT	Operability and Maintainability Analysis Technique
PDS	Proximity Detection Systems
PDT	Proximity Detection Technology
PR	Performance Requirement
ROS	Required Operating States
SARG	Self-Assessment Review Guide
TWG	Technical Working Group
UQ	University of Queensland
VI	Vehicle Interaction
WAT	Workflow Analysis Tool

Contents

EMESRT

EMESRT is a global 'safety by design' initiative established in 2006 by mining companies to fill the functional performance expectations gap between earth moving equipment users and equipment designers.

Vision

A mining industry free of fatalities, injuries and occupational illnesses associated with operating and maintaining earth moving equipment.

Purpose

Accelerate development and adoption of leading practice designs to minimise the risk to health and safety through a process of Original Equipment Manufacturer, contractor and user engagement.

Acknowledgement

The EMESRT Advisory Group acknowledges and greatly appreciates the individual contributions of member company representatives and others from the broader EMESRT community of: Mine Operators, Original Equipment Manufacturers (OEM), third party equipment suppliers, Researchers, Industry Groups and others.

Since 2006, their contributions at meetings, workshops, webinars and other activities have directly supported the delivery of the EMESRT vision and they are part of the EMESRT success story.

Overview

This 2021 Activity Report summarises the work on EMESRTs planned industry projects. It provides highlights from 2021, key focus area milestones, next steps and information about how EMESRT operates.

This report provides updates on EMESRTs four current industry projects:

1. Vehicle Interaction
2. Tyres and Rims Management
3. Mobile Equipment Fires Management
4. Human Factors Design Diversity.

Its intended audience is:

- EMESRT member companies, both specialists and senior leaders
- Original Equipment Manufacturers (OEMs) and third-party providers
- EMESRT Technical Working Groups (TWGs)
- Industry organisations with complementary missions and memberships (e.g., the ICMM ICSV working groups)
- Non-EMESRT member mining companies and contract mining organisations
- Researchers
- Other related industry parties.

The EMESRT Advisory Group hope you find the report informative, readily useable and relevant.

Members for 2021

Alcoa

AngloAmerican

BHP

GLENCORE

RioTinto

Teck

EMESRT Advisory Group Introduction

Mining companies need earth moving equipment that is designed to be operated and maintained under all site conditions without causing harm to people. EMESRT is a mining company led organisation that is responding to this challenge.

EMESRT was formed in 2006 to influence OEMs by establishing a ‘common voice’ on health and safety issues to enable delivery of practical outcomes to long-standing industry design related problems.

In 2021, six major mining companies – Alcoa, AngloAmerican, BHP, Glencore, Rio Tinto and Teck Resources were members of EMESRT. This member-based partnership embraces EMESRTs purpose, to: *Accelerate development and adoption of leading practice designs to minimise the risk to health and safety through a process of Original Equipment Manufacturer, contractor and user engagement.*

EMESRTs six member companies operate a significant percentage of the industry and are committed to working together to achieve a collective influence to improve health and safety outcomes.

EMESRT operates as a high-influence global organisation. Its effectiveness in delivering industry-level change rests on its membership credibility, trust with OEMs and active industry stakeholder engagement.

Therefore, a key part of a consistent and reliable solution to mining health and safety is to focus at the design stage. This is where Health and Safety solutions can be incorporated into the standard factory design by OEMs, thus fully integrated for the users.

Ultimately the key to improvement is recognising that OEMs know how to design and EMESRT knows how to operate, therefore collaboration to develop effective designs is essential. This is facilitated by users clearly providing an aligned common understanding of the problems to be addressed and the designers recognising this collective input is necessary for inclusion early in their design development process.

Designing beyond standards

OEM mining equipment design development processes are underpinned by international standards and guidelines, which are useful in ensuring consistency and embedding innovation in design change once it has occurred. However, standards and guidelines generally do not create the change. EMESRT engages and works with industry to address equipment design inadequacies in ways that improve safe operability and maintainability beyond standards.

Figure 1 on page 3 summarises EMESRTs approach.

As the illustration below suggests, EMESRT believes that standards – including both technical and process standards don't necessarily move the wheel up the hill. Rather, the standards and guidelines provide the wedge that defines minimum design requirements; they underpin the changes in the minimum expectations in equipment designs.

Moving the wheel up the improvement hill requires new ways of defining and thinking about equipment health and safety related exposures. EMESRTs programs and initiatives contribute to new thinking and focus on clearly defining the problem to be addressed by designers in improving equipment design.

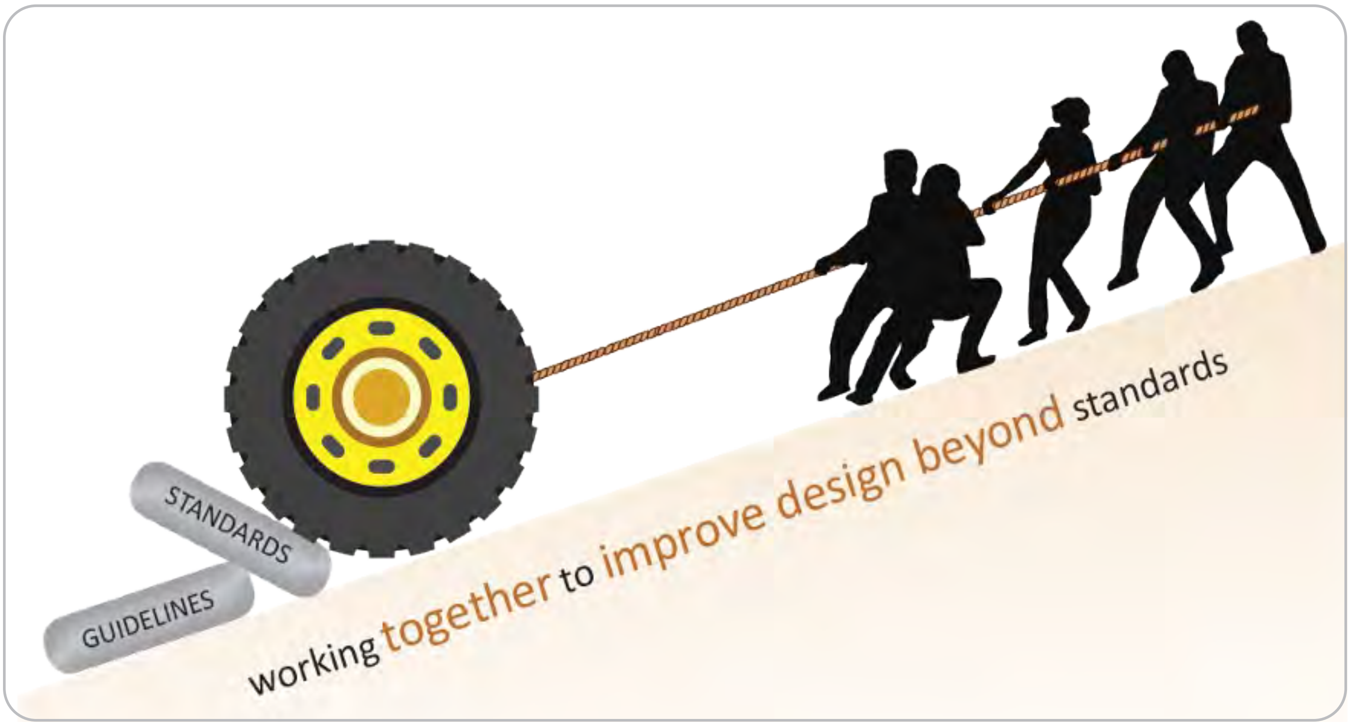
The breadth that equipment standards often seek to cover can create a degree of generality that makes them broadly applicable across the multiple design settings. This can mean that improved standards and guidelines may not necessarily address problems in a specific situation.

For this reason, EMESRT believes that equipment design should focus on hazard identification through task-based analysis and process assessment, rather than being based only on compliance with technical standards. This needs to involve valid contributions from the industries users collated in a common format that aligns with the designers own assessment methodology, which is generally FMECA (failure mode, effects and criticality analysis).

EMESRT has been delivering outcomes to complex problems in the mining industry for the last 16 years. EMESRT achieves this by applying five factors for success:

1. Working with an industry-level focus
2. Having a real-world business understanding of financial drivers and leverage
3. Understanding that innovation is market-driven, not pushed by technology
4. Implementing good governance processes to cover structure, funding, management, renewal and continuity
5. Seeking endorsement from senior managers and decision makers.

Figure 1: The designing beyond standards EMESRT approach.



EMESRT Advisory Group

The EMESRT Advisory Group (EAG) includes one representative from each member company. Its role is to identify and agree the priority work areas. The EAG then confirms the project strategy, work plans, budgets, and support. Each member contributes to the EAG based on their diverse experience, skills and availability.

EMESRTs clear purpose and volunteer structure is enabled by effective and efficient project management processes. EMESRT sets an annual membership fee to provide the resources necessary to implement its approved work plans.

EMESRTs work plans follow a simple and effective four-step sequence:

1. Rigorously defining and documenting the problem to be addressed from the perspective of mining equipment users
2. Preparing a draft industry project landscape based on the gap between the current and future required state. It identifies stakeholders, confirms current knowledge and articulates project deliverables
3. Building project communities through subject focused technical working groups
4. Coordinating resources to leverage industry-level innovations and improvements.

EMESRTs projects are selected based on member and industry experience and concern, a compelling case for improvement, and EMESRTs ability to influence change. The EAG members lead and coordinate the TWGs formed for each project.

The EAG acknowledges and thanks all TWG members for their time and commitment to deliver EMESRTs vision and purpose. We look forward to their continued support in 2022.

The EAG acknowledges the direct financial and in-kind support from member companies and their ongoing support for their representatives' contributions.

EMESRT Advisory Group
March 2022

Engaging With Industry During 2021

EMESRT relies on industry engagement to progress its workplan, understand key issues and offer industry-relevant outcomes. Despite some constraints caused by COVID-19, EMESRT continued to engage with industry stakeholders during 2021. This collaborative approach with industry will continue into the future.

Where possible, in-person events continued throughout 2021. However, most events were delivered via webinars and teleconferences – including project updates and knowledge sharing of industry issues.

EMESRT member company representatives actively promote EMESRT at public forums and industry events. During 2021, EMESRT presented updates to several industry bodies, including the Australasian Institute of Mining and Metallurgy (AusIMM), International Council on Mining and Metals (ICMM), the Commissioner for Resources Safety and Health – Queensland and Standards Australia.

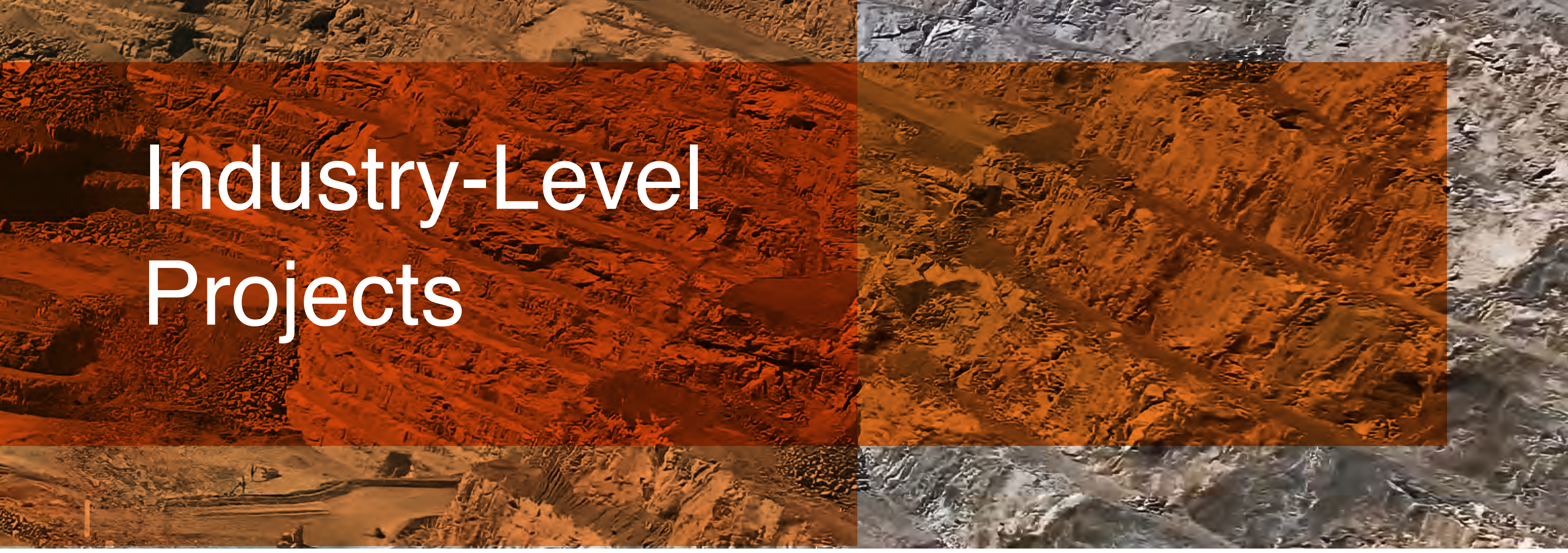
Throughout 2021, EMESRT continued to collaborate with the ICMM Innovation for Cleaner Safer Vehicles Initiative – Vehicle Interaction by both attending and presenting at multiple virtual workshops.

The EMESRT Vehicle Interaction TWG was active in its industry engagement throughout 2021. It provided input to the design and content of the ACARP (Australian Coal Industry Research Program) C26028 PDS Validation Framework Project to confirm a methodology for validating proximity detection technology. This project was a joint effort with Australian and South African researchers. In May 2021, EMESRT hosted industry webinars showcasing the ACARP C26028 project outcomes, attended by 74 people from multiple countries.

The Vehicle Interaction TWG also contributed to several parts of ISO *21815 Earth-moving machinery – Collision warning and avoidance*. In particular, the TWG contributed to Part 2: On-board J1939 communication interface, published by ISO in July 2021.

The EMESRT Mobile Equipment Fires TWG achieved a significant outcome in December 2021, with the launch of Performance Requirement 4 (PR-4) – Mobile Equipment Fire Management. The launch followed extensive industry consultation, involving mining company representatives, OEMs, regulators, fire detection and suppression system providers, fire system designers, academics and researchers. More information about PR-4 is available on page 23.

EMESRT expanded its industry engagement during 2021, with several new organisations contributing to current industry projects. By the end of 2021, EMESRTs TWGs included 222 individuals representing 77 organisations.



Industry-Level Projects

EMESRT brings together some of the world's largest mining companies who represent a significant share of the annual global spend on earth moving equipment. Through EMESRT, these companies address industry issues and work together to avoid project duplication. EMESRT provides an industry-level 'corporate memory' with shared access to resources, experience and expertise.

EMESRT adds value to the industry by facilitating the closing of the design gap between OEMs and equipment users. To do this, EMESRT establishes relationships with OEMs and third-party suppliers, and seeks to influence product design and support appropriate user alignment.

Through EMESRT, OEMs can develop a customer (user) perspective of operational and maintenance problems – making it possible to achieve rapid advances in equipment design, beyond standards. The practical reasons for adopting this approach are:

- The design gap between OEMs and users requires a user-focused perspective (enabling designs to meet users' needs)
- OEMs are the only group that can shrink the design gap (which third-party suppliers typically develop products to fill the gap)
- An industry-wide approach can create a business case for OEMs to invest in research and development which will lead to user problem focused improvement in designs.

In each industry project, EMESRT adopts a formal project management approach to create system-level understanding, engineering logic, wide engagement and a clear focus on delivering practical outcomes for users.

EMESRT is committed to sharing leading practice information that can be adapted to address real-world issues. One example of this is EMESRTs publication Performance Requirement 4 – Mobile Equipment Fires Management (December 2021). For more information about this publication, see page 23.

Since its establishment, EMESRT has disseminated relevant resources to industry – through its website, email list and project-specific online knowledge hubs. Two examples of this are EMESRTs Vehicle Interaction Knowledge Hub (launched as a beta version in 2020) and the Mobile Equipment Fire Management Knowledge Hub (launched as a beta version in 2021). EMESRT expects to deliver further knowledge hub development in 2022.

EMESRTs contribution has been recognised by regulatory and other industry bodies, which have referenced EMESRT resources in guidance material and at industry seminars. These resources are included in EMESRTs knowledge hubs.

Design philosophies: The EMESRT Backbone

EMESRTs approach to the design challenges in large surface earth moving equipment is based on eight design philosophies. These design philosophies were initially developed in 2007 to present EMESRTs aligned views on objectives, general design outcomes, hazards to be mitigated and examples of industry attempts to mitigate unwanted events.

Through the design philosophies, EMESRT presents an aligned industry voice that helps OEMs design equipment that reduces the exposure to unwanted events to an acceptable level (including foreseeable human error).

EMESRTs design philosophies are not technically prescriptive. They are intended to support OEM equipment design processes in considering issues and identifying design controls or features that effectively address unacceptable exposure to users.

EMESRTs eight priority design philosophies focus on issues where improved human factors design could reduce unwanted events associated with equipment operation or maintenance.

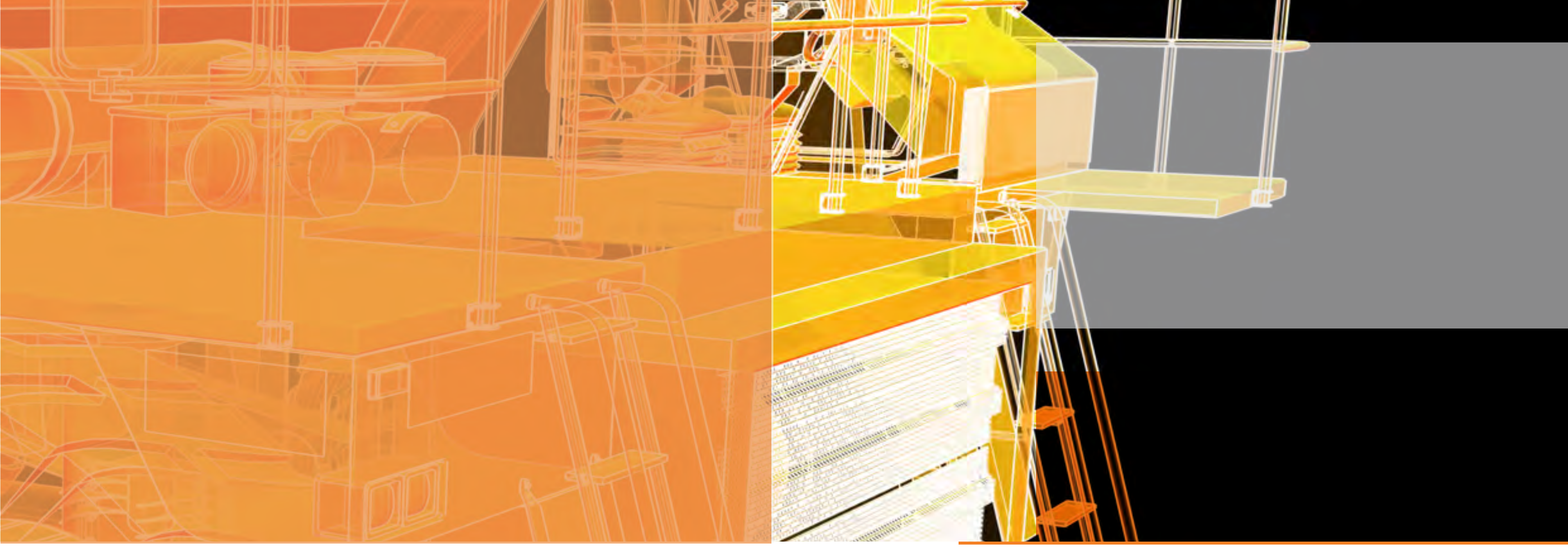
EMESRTs eight design philosophies are:

1. Access and working at heights

The objective is to prevent harm related to access and working at heights (where there is a risk of falling at least 6’ (1.8m) or if serious injury may result) on equipment; to prevent slip/trips, sprains/strains, falls from height and failure to egress in emergency events to as low as reasonably practical, including consideration in design for foreseeable human error. *For example, injury during access to equipment and its routine service and inspection points, work platforms and operator workstations due to poor location of service and inspection points, lack of fall-from-height protection, premature failure of components due to corrosion, slippery surfaces, accumulation of dirt or other material, or poorly lit environments.*

2. Tyres and rims

Prevent harm related to tyre and rim events to as low as reasonably practical, including consideration in design for foreseeable human error and material failures. *For example, harm due to uncontrolled release of pressure from the tyre and rim assembly during operation and maintenance.*



3. Exposure to harmful energies

Prevent harm related to exposure to moving machine parts, failure of hydraulic equipment or systems, or other energy sources, such as compressed air, heat, electricity and gravity to as low as reasonably practical, including consideration in design for foreseeable human error. *For example, harm from exposure to energies such as heat, electricity, radiation, compressed air, high pressure fluids (including hydraulic fluids) and falling objects.*

4. Fire

Prevent harm related to equipment fires to as low as reasonably practical, including consideration in design for foreseeable human error. *For example, harm from fire arising from damage (including heating, melting and chaffing) to electrical cables and components, hydraulic hoses and fuel lines due to design inadequacies including poor location, inadequate separation of fuel and ignition sources, and flaws in clamping or restraints.*

5. Machine operation and control

Prevent harm, during machine operation and control, to as low as reasonably practical, including consideration in design for foreseeable human error. *For example, musculoskeletal injury or illness due to workstation design (including seat and seatbelt design, openings and cab height) that promotes biomechanically compromised postures for the 5th percentile female to 95th percentile male body dimensions.*

6. Health impacting factors

Prevent harm from exposure to health impacting factors to as low as reasonably practical, including consideration in design for foreseeable human error. *For example, harm from exposure to health hazards such as extreme temperatures, excessive vibration and noise levels, particulates, gases and vapours within the operating workspace; and musculoskeletal factors due to poor ergonomic design of equipment and controls.*

7. Manual tasks

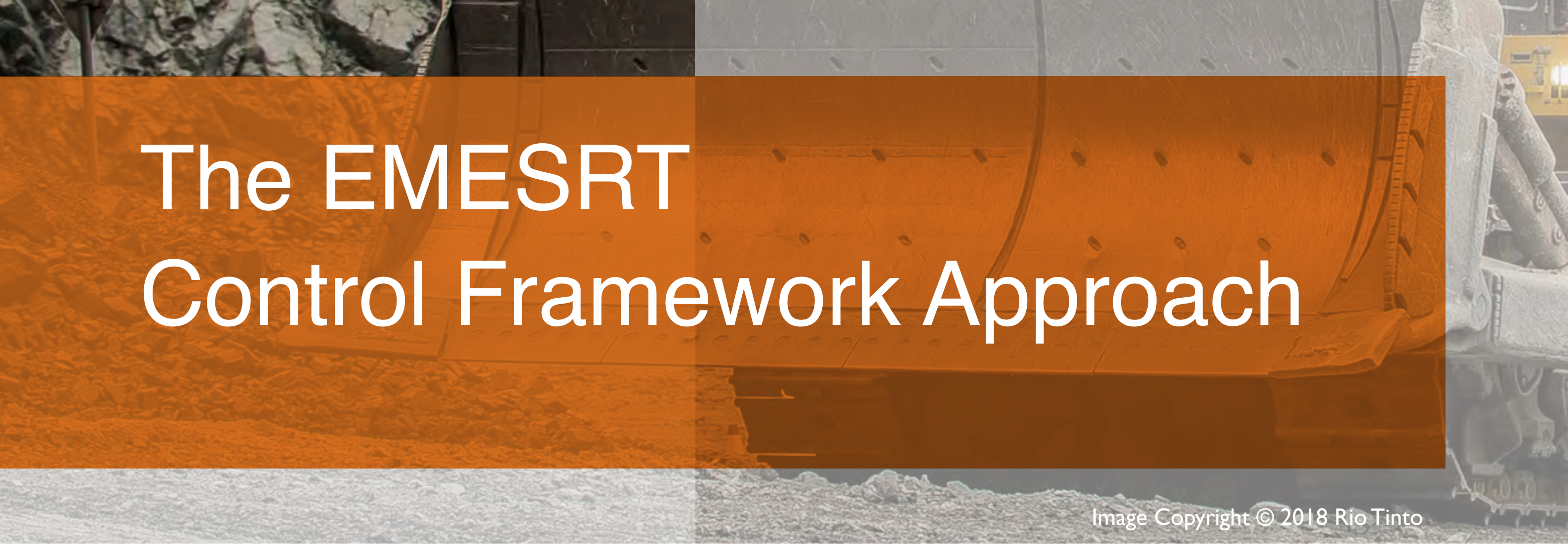
Prevent harm due to manual tasks during installation, maintenance and operations of equipment, to as low as reasonably practical, including consideration in design for foreseeable human error. *For example, musculoskeletal injury from exposure to risk factors such as forceful exertion, awkward or static posture, repetition or prolonged duration, and hand-arm and/or whole-body vibration due to manual tasks associated with installing, operating and maintaining the equipment.*

8. Confined spaces and restricted work areas

Prevent harm to people working in confined spaces and restricted work areas to as low as reasonably practical, including consideration in design for foreseeable human error. *For example, asphyxiation from irrespirable atmosphere due to lack of adequate ventilation.*

Further information about EMESRTs design philosophies is available on the EMESRT website: emesrt.org.

The EMESRT Control Framework Approach



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Since 2017, EMESRT has developed and refined its Control Framework (CFw) approach, which is now a core operational process used for all industry projects. A CFw is highly iterative and adaptive process that begins with asking:

'What has to be in place for work to go right?'

It uses these organising questions to organise the knowledge and experience of contributors:

1. What is the business purpose?
2. What safe and productive operating states are required to deliver the business purpose?
3. What can cause failure?
4. What are the business inputs that prevent or mitigate failure?
5. What is the expectation of these business inputs and how are they?
    - Specified
    - Implemented, and
    - Monitored

The CFw approach is aligned with Failure Modes and Effects Analysis, Human Factors, and the 'new control' definition elements of the ICMM Critical Control Methodology. It allows real-world inputs and experience to be mapped to the safe and productive operating states required to deliver business purpose.

The mapping step uses these interlinked hierarchical components to develop a deep understanding of complicated problems:

- **Required operating states** (ROS) that deliver business purpose
- **Credible failure modes** (CFM) that can compromise ROS – these are also validated by incident experience
- **Business inputs** (BI) that support the establishment and maintenance of the ROS by preventing or mitigating the CFMs – these are mapped into the CFw from operational practice.

Each BI has a clear title, an expectation it should deliver upon, a specification, a description of how it is implemented, and details of how its status is monitored and verified.

The CFw approach establishes both a whole-of-system overview and a structure linked to detailed operational practice. Working this way provides information and insights about the dynamic connections between personnel, equipment, work environment, workgroups carrying out different tasks, and overall coordination. This promotes the systematic identification of improvement opportunities.

The CFw approach is flexible, allowing updating of all CFw component descriptions, content and links as new information becomes available and new insights develop.

Applying the CFw approach produces the networked and hierarchical structure represented in Figure 2 opposite.

The EMESRT Control Framework approach is based on a pivot from risk to controls where:

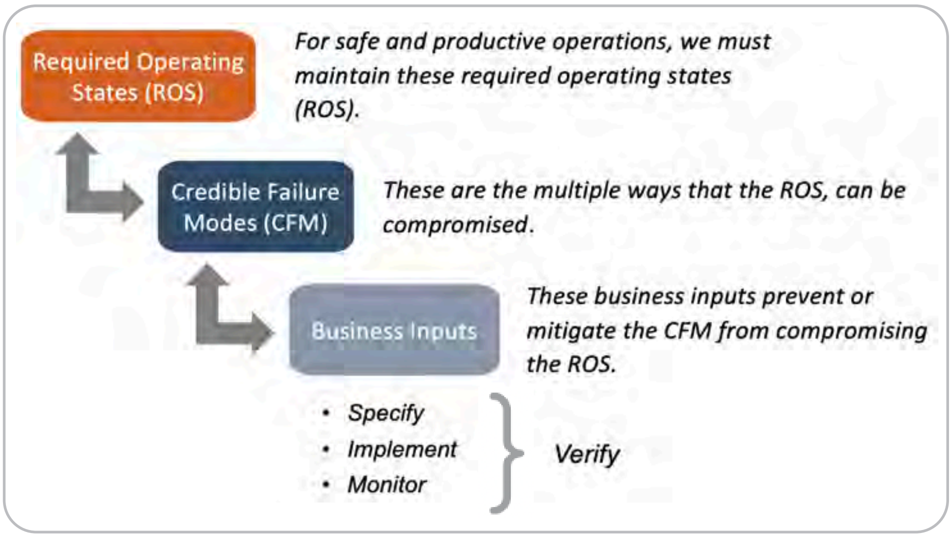
- Controls prevent or mitigate something bad from happening
- Controls are specifiable, measurable and can be verified
- Understanding how they fail – design issues, poor implementation, non-compliance, etc., is essential to improve their reliability.

This 'new control' thinking is widely accepted and supported. Multiple resource companies are attempting to make it work and it is influencing regulators across multiple jurisdictions.

Developing a CFw requires the systematic review and assessment of the robustness and reliability of business inputs. It follows these steps:

1. Confirm the safe and productive outcomes relevant at an enterprise level, these Required Operating States (ROS) are the basis of CFw organisation, e.g., Operators give way
2. Identify and catalogue the credible failure modes that can compromise each required operating state
3. Based on each credible failure mode, identify the business inputs that prevent or mitigate the required operating states being compromised
4. Using site documentation and knowledge, map how each business input is specified, implemented, and monitored to prepare CFw Version 1
5. Present CFw Version 1 to knowledgeable employees for review, updating and validation to CFw Version 2 (baseline)
6. From the validation workshop, confirm the opportunities for improvement required to achieve nameplate Mobile Equipment Interaction (MEI) Control Performance and present for senior management review
7. Use the CFw information as a reference when considering further improvements to MEI controls.

Figure 2: The hierarchy and components of a control framework.



Current Industry Projects

At the end of 2021, EMESRT was leading three active industry-level projects, each with an established TWG working on agreed project objectives.

Each project is led by an EAG member who provides strategic project oversight and coordinates project activities.

The four current EMESRT projects focus on:

1. Vehicle Interaction Control Improvement
2. Tyres and Rims Management
3. Mobile Equipment Fire Management
4. Human Factors Design Diversity

This following section provides an overview of each project.

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Industry Project 1: Vehicle Interaction Control Improvement

This industry project is led by Glencore representative Tony Egan and AngloAmerican representative Matthew Clements.

Why focus on vehicle interaction?

A significant mining industry fatality challenge is to systematically and reliably improve controls for managing mobile equipment operation and people and materials transport.

Failures of vehicle interaction controls cause between 30-40% of industry high potential incidents and of these about half involve pedestrians, mostly in underground operations.

Many contributors (early adopters and researchers) have been and are working to develop and implement improved vehicle interaction controls but we need to do more.

Innovations include new technology controls for prompting operators to intervene or in some cases initiating direct machine function intervention.

The EMESRT industry project

Based on *Design Philosophy 5 (DP-5) – Machine Operation and Control*, EMESRT initiated an industry project in 2013 to improve vehicle interaction controls. The drivers for this work were the rapid development and marketing of Proximity Detection Technology (PDT) and Collision Avoidance Systems (CAS).

The first step was to define the problems that the project would address and to illustrate these using operational scenarios. The next step was to build a set of performance requirements for evaluating commercial PDS and CAS technologies.

After two years, the project focus on awareness, advisory and intervention technologies was expanded to include mine design and operational controls. This was driven by a systems level understanding that vehicle interaction controls are multi-level, interconnected, dynamic and that many are dependent on the decisions and actions of people to sustain control effectiveness.

Extensive research and development of new technology **react controls** that alert and alarm operators (Level 8) and intervene independently of the operator (Level 9) has been undertaken over the last decade. While these **react control** developments are progressing, there are limited examples of effective commercially ready level operational deployments.

EMESRT member company and industry experience is that scoping, implementing, integrating and maintaining collision avoidance systems is complex because:

- During operations, there is an ongoing dynamic interdependence between **design**, **operate** and **react controls** (reference EMESRT Level 1-9 Model)
- The successful implementation and integration of react controls requires a comprehensive baseline understanding of **design** and **operate** controls and their failure modes
- The potential for error due to the lack of human factors considerations at all control levels

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- Established risk assessment and safety management approaches are inadequate for developing a baseline understanding suitable for complex socio-technology projects
- Success requires precisely understanding what technology does and does not do, taking a project approach
- There are already legislative requirements for the introduction of new technology intervention controls in some jurisdictions.

To further assist the industry, EMESRT embellished the functional scenarios depicted in Performance Requirement 5A and developed a series of VI storyboards for its VI Knowledge Hub. The storyboard approach was developed by an EMESRT member company to detail the functional performance requirements of specific scenarios, recognising that the interactions are time phased not static. The functional performance storyboards provide a visual and dynamic reference for equipment operators, PDS suppliers and VI control improvement project managers.

As part of the VI Control Improvement Project, EMESRT led and participated in industry-level initiatives focused on improving the reliability of VI controls in mining. Core to this work has been engaging with the International Council for Mining and Metals (ICMM) to leverage their peak industry association with 27 global mining companies. EMESRT is a strategic partner and directly contributes to the ICMM Initiative for Cleaner Safer Vehicles.

Contributors from EMESRT member companies have applied engineering approaches and logic to develop resources that include comprehensive and adaptable project plans, tools and processes that consider human factors and prepare operations for vehicle interaction technology implementations.

This wide range of information and experience is now available for industry use in a VI Knowledge Hub launched in 2020 and available via the EMESRT website – emesrt.org.

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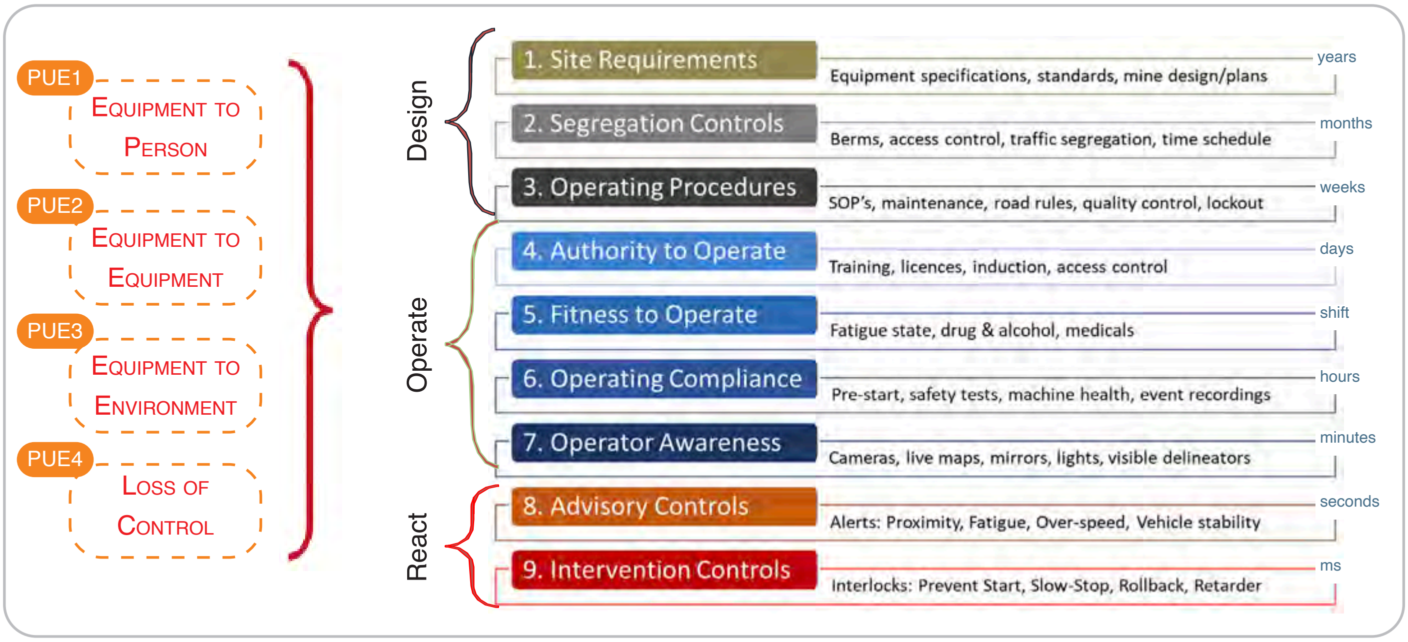
Figure 3: The EMESRT 9-layer model of control effectiveness.



During 2021, project outcomes included:

- Published the EMESRT Vehicle Interaction Control Improvement Guide, available on the EMESRT VI Knowledge Hub
- Further developed and applied the EMESRT VI control baseline mapping approach in member companies – before assessing the need for new technology and other innovations
- Conducted a baseline mapping trial site in the United States to prove up the remote capability for conducting baseline control assessments
- Engaged with the Minerals Council in South Africa to better understand their VI improvement project initiated by the legislative requirements for Level 9 machine intervention. EMESRT and ICMM are exploring ways to understand their approach and align where all parties are aligned
- Contributed to the ISO Technical Committee TC 127 (Earth-moving machinery), Subcommittee SC 2 (Safety, ergonomics and general requirements), and Working Groups 22 and 28 (Collision awareness and avoidance)
- Began drafting the VI underground functional performance storyboards
- Collated and uploaded relevant reference material to the VI Knowledge Hub
- Contributed to ISO 21815 Part 2 (effort rewarded when Part 2 was published in July 2021)
- Contributed to ACARP C26028 PDS Validation Framework Project (with ACARP monitors accepting the final report)
- Conducted successful ACARP C26028 PDS Validation Framework Project industry webinars with 74 participants attending from around the globe
- Established a PDS Validation Framework working group to prepare an industry guideline for users and that may also be accepted by ISO for inclusion in ISO 21815
- Delivered several industry webinars on running a major VI project
- Delivered an ICMM webinar on a leading practice operator fatigue monitoring implementation project.

The EMESRT VI community is supported by monthly webinars and as-required face-to-face workshops. Currently the community includes a broad range of industry stakeholders, with 163 participants representing 57 organisations.

Project next steps

In 2022, the EMESRT VI Control Improvement Project will:

- Continue the delivery phase of the VI improvement strategy
- Broaden industry communication of the VI improvement strategy materials and guidance
- With ICMM, deliver regular topic-specific webinars to industry, e.g., developing/understanding your baseline (maturity framework)
- Publish the VI Control Framework and associated baseline assessment process, including the Self-Assessment Review Guideline
- Review feedback from their practical application and update the surface functional performance scenario storyboards
- Develop, seek broader input and publish underground functional performance storyboards
- Continue engagement with the Minerals Council in South Africa on their project plan
- Develop and publish PDS Validation Framework Guideline
- Review and update the work breakdown structure based on recent projects and experience in the field
- Through the formal liaison status EMESRT has been granted, engage with the ISO Technical Committee TC 127 (Earth-moving machinery), Subcommittee SC 2 (Safety, ergonomics and general requirements), and Working Groups 22 and 28 (Collision awareness and avoidance)
- Develop and publish the EMESRT Vehicle Interaction Project development journey 2013–2021.

For more information about this industry project, please visit the EMESRT website - emesrt.org.

Industry Project 2: Tyres and Rims Management

This industry project commenced in 2018 and is led by EMESRT representative Tony Egan from Glencore and Iain Curran from BHP.

Why the focus on tyres and rims?

Incidents related to tyres and rims occur regularly, in some cases resulting in serious injuries or fatalities. Most tyre-related incidents involve stored energy release, catastrophic disassembly of wheel assemblies, tyre fires or explosions from pyrolysis, or crush injuries when moving tyres and wheels or working with mobile equipment.

Tyre and rim events:

- Present significant fatality hazards for tyre maintenance technicians, mobile equipment operators, mobile equipment maintainers and emergency responders
- Incur considerable costs (e.g., repair or replacement of damaged tyres, unavailability of equipment)
- Are influenced by inadequate maintenance and operational practices
- Are formally reported in most mining jurisdictions; event patterns and prevalence have been extensively analysed and reviewed
- Causal factors need to be better understood – regulators expect mine operators to improve tyre management performance.

In 2018, EMESRT noted that the level and consistency of tyre and rim-related incidents remained concerning and recognised the mining industry needed a ‘step change’ in thinking to improve its performance in tyre and rim management.

In 2018, EAG members agreed to facilitate an industry project to improve tyre and rim management.

The EMESRT industry project

EMESRTs *Design Philosophy 2 (DP-2) – Tyres and Rims* was published in 2007 and provides visual operational scenario information for the designers of wheel assembly components and mining operators. The objective of the design philosophy is: *to prevent harm related to tyre and rim events to as low as reasonably practical, including design consideration foreseeable human error.*

This project is an extension of the original work of developing DP-2. It was triggered by an EAG internal review of all DPs, which identified that the guidance in DP-2, and other DPs, needed further supporting detail.

This EMESRT project was based on four drivers:

1. Significant fatalities amongst tyre maintenance technicians, mobile equipment operators, mobile equipment maintainers and emergency responders
2. Inadequate maintenance and operational practices that contribute to early service failures
3. Increasing expectations from regulators that mine operators can improve performance
4. The range and complex interdependency of the business inputs necessary for safe and productive operations using rubber tyre earth moving equipment.

EMESRT established a TWG in 2018 representing a broad range of industry stakeholders. The 41-member group (representing 21 organisations) meets regularly to further progress this industry project.

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It was recognised that further problem definition work on this complex and broad reaching issue was required. This was the catalyst behind several rounds of funding for two ACARP (Australian Coal Industry's Research Program) Projects. ACARP is a unique and highly successful mining research program that has been running in Australia since 1992. The projects are:

1. C33005: Human Factors Aspects of Tyre Handling Equipment Design and Operation Examined within an EMESRT Control Framework Approach
2. C33007: Real-Time Safety Monitor and Alert System for Tyre Handling.

While both projects have been impacted by COVID-19, which limited collaboration by the industry contributors, steady progress continues to be made.

ACARP Project C33005: The project will involve a detailed human factors analysis of the design and use of tyre handling equipment and contribute to potential design improvements. Outcomes will include a storyboard, instructional videos and animated experiences that provide high-fidelity information and translate real-world equipment applications to inform designers, project partners and operational teams.

The project will continue to demonstrate how human factors approaches can influence design in a useful and meaningful way when incorporated within the control framework. This project will support the ongoing implementation of ACARP Project C33007 which is described below.

ACARP Project C33007: This project will install a real-time tyre and rim maintenance safety monitoring system (the Fingermark EyeCue™ system) that reduces hazardous exposure and eliminates the potential for significant harm. The overall objective is to develop user-driven technology to a commercially viable standard that is readily applicable across the mining industry.

During 2021, EMESRT formed a tyre handler subgroup, which was instrumental in gathering information and categorising tyre handling operational workflows. The group included nine subject-matter experts representing seven entities. They identified 15 workflows and associated tasks, which were mapped against the EMESRT control framework (CFw) process and used to populate the online Tyre Handler Workflow Analysis Tool.

The tyre handler workflow analysis tool is a central depository for workflows, tasks and subtasks of tyre handling equipment operations. Users can view and export workflows to a spreadsheet and use the outputs to review internal tyre handler operations, better understand inherited hazards, and consider operations.

An additional test site for C33007 projects has been identified, and equipment installation commenced. While COVID-19 has so far prevented physical presence on-site the project teams are confident that site-access will be achievable in early 2022.

Project information is being shared with industry in an open and transparent manner. As part of this, EMESRT is developing a baseline controls self-assessment review guide and an online knowledge hub.

Project next steps

In 2022, the EMESRT Tyre and Rim Management Project will:

- Develop, review and validate critical task problem statements
- Develop tyre handler animated functional performance scenario storyboards based on tasks identified
- Conduct on-site user interface testing and identify additional testing sites
- Finalise and launch the online Tyre Handler Workflow Analysis Tool
- Release the first version of a tyre movement guideline (addressing lifting, transporting, fitting and removing, and safety zones)
- Identify and recognise the parameters around each scenario documented by project C33005
- Develop and publish the tyre handler operational warning poster
- Develop the curated online Tyres and Rims Knowledge Hub.

EMESRT is reaching a point where a substantial body of information is going to be available to industry, including an approach to more clearly explain the information to people.

For more information about this industry project, please visit the EMESRT website - emesrt.org.

Industry Project 3: Mobile Equipment Fire Management

This industry project commenced in 2018 and is led by EMESRT representative Mark Geerssen from Rio Tinto and Peter Hasler from Alcoa.

Why the focus on fire?

Despite ongoing improvements, hazards still create exposure for mobile equipment fires in both surface and underground mining if not well controlled through adequate designs and management practices.

Earth moving equipment can have highly combustible components, which are in close proximity to ignition and heat sources. They operate using flammable materials such as hydraulic fluids that, when used under pressure, can easily ignite.

Mobile equipment fire events:

- Present significant fatality exposure for operators, maintainers and emergency responders
- Can be catastrophic in underground operations
- Create wider operational and commercial issues for earth moving equipment owners and operators
- Require mandatory statutory reporting in most mining jurisdictions
- Have been extensively analysed – regulators now expect that mine operators will improve their mobile equipment fire management performance.

In 2018, EMESRT noted that the level and consistency of fire-related incidents remained concerning and recognised the mining industry needed a ‘step change’ to improve its performance in mobile equipment fire management.

The EMESRT Advisory Group members agreed to facilitate an industry project to improve mobile equipment fire management.

The EMESRT industry project

EMESRT first turned its attention to mobile equipment fires in 2007, when it published an initial design philosophy (DP-4) focussing on fire. DP-4 is a high-level overview of problems that can lead to adverse consequences from mobile equipment fire events. It provides visual operational scenario information to assist OEMs in designing equipment to reduce the exposure to and the consequences of unwanted equipment fires.

This project is an extension of the original work of developing DP-4.

This project was triggered by EAG discussions that recognised and identified issues with fundamental original equipment design, e.g., separation of fuel from heat sources and ongoing issues with routine maintenance practices including hot work.

Furthermore, fire detection and suppression systems design and installation are not well coordinated between original equipment manufacturers and third-party suppliers. Maintenance of fire suppression systems once installed can be inconsistent and this can be a challenging issue for remote operations.

The objective of this project is to provide mobile equipment designers and users with structured information that enables the prevention of mobile equipment fires and the mitigation of the consequences of fire events.

EMESRT commissioned development of a draft Equipment Fire Control Framework and invited experienced mining industry stakeholders to join the Mobile Equipment Fire Management Technical Working Group.

In 2021, the TWG included a broad range of industry stakeholders, with 41 members representing 21 organisations. The group has a mandate to:

1. Identify design inadequacies and industry leading practice
2. Review current research and identify gaps to improve understanding
3. Consult widely across the industry and share knowledge
4. Develop and promote documentation to support baseline control effectiveness self-assessment and hazard reduction.

The mobile equipment fire management project focus is on ways to understand and mitigate harm related to equipment fires as much as reasonably practical, including using design to address foreseeable human error.

Using the heat, fuel and oxygen fire triangle, the group discussed and documented fire event areas of influence using the CFw approach. More information on the CFw approach is available on page 9.

The TWG developed the EMESRT Mobile Equipment Fire Event Tree and modelled four areas of influence:

1. Mobile equipment design
2. Mobile equipment maintenance
3. Fire detection and suppression systems
4. Operating company emergency and crisis management.

Based on these areas of influence, the TWG developed the first draft of Performance Requirement 4 (PR-4) – Mobile Equipment Fire Management. PR-4 provides comprehensive information for mobile equipment designers, mining companies, fire detection and suppression system designers, and third-party suppliers and maintainers. PR-4 was developed through several iterations before being distributed to major OEMs for feedback on its delivery format and technical relevance.

In the third quarter of 2021, several one-on-one webinars with OEMs provided an opportunity for detailed discussions about PR-4, including feedback and suggestions for improvement.

The final draft of PR-4 was tabled at the EAG monthly meeting in November 2021 and unanimously approved for publishing.

PR-4 is available for download on the EMESRT website Reading Room.

Project next steps

Publishing PR-4 was major milestone for EMESRT and the project's TWG. In 2022, the Mobile Equipment Fire Management Project will:

- Implement a communication strategy to engage with all relevant industry stakeholders
- Present project outcomes at relevant industry forums
- Analyse new incident reviews to identify elements not already contained in the CFw and update it as required
- Carry out SARG field trials and gain feedback on the range of self-review tools required (e.g., variations for underground, refinery, mine size)
- Launch the online knowledge hub
- Develop project management templates for operating sites (to be included on the knowledge hub)
- Develop and publish the EMESRT Mobile Equipment Fire Management Project Report 2018–2023.

More information about PR-4 is available on page 23.

For more information about this industry project, please visit the EMESRT website - emesrt.org.

Industry Project 4: Human Factors Design Diversity

NOTE: this project is in the development and problem scoping phase to form a formal industry level project.

This industry project commenced in 2018 and is led by EMESRT representative Tony Egan from Glencore and Iain Curran from BHP.

Why the focus on human factors?

Mining companies face a common problem in ensuring that earth moving equipment is designed to be operated and maintained without causing harm to workers. Since EMESRT began in 2006 we have seen an ever-increasing focus on health and safety improvement, and major global mining companies now have reasonably consistent expectations regardless of the mine locations around the world.

Although recognised international standards exist to assist designers in providing equipment that accommodates workforce diversity, designers face significant challenges in applying this information to equipment design. Challenges may restrict potential workers who can operate and maintain the equipment from joining or remaining in the industry.

General ergonomics and human factors approach for improving equipment design are well established. However, understanding how equipment design impacts safe and healthy operation and maintenance is not well understood. This is mainly influenced by the range of anthropometric body variations that diverse workforces present globally.

Anthropometry involves the systematic measurement of the physical properties of the human body, primarily dimensional descriptors of body size and shape.

EMESRT has recognised a potential gap (or 'design vacuum') between OEM designs and user needs because earth moving equipment is designed to meet recognised international standards or guidelines. The open question at this point is do the standards adequately allow for the global anthropometric variations of users.

There are opportunities to improve earth moving equipment design that can remove significant anthropometric impediments or reduce the possibility of cumulative injuries for operators and maintainers.

The EMESRT industry project

In 2018, EMESRT convened a human factors workshop to review the objectives, design outcomes and potential unwanted events across all the design philosophies.

In 2019, EMESRT recognised that further problem definition work on this issue was required, and agreed to facilitate a new industry project focusing on human factors design diversity that could:

- Improve earth moving equipment design by confirming significant anthropometric impediments for operators and maintainers in current equipment
- Adapt and develop human systems integration processes for practical application in the mining industry (e.g., human and equipment interfaces)
- Increase mining industry capability to apply systems and human factors engineering approaches to improve the design and operation of earth moving equipment.

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This EMESRT project was the catalyst for the successful funding of ACARP Project C28034, Mining Equipment Human Factors Design for Workforce Diversity. This project was led by Professor Burgess-Limerick, with research carried out by Dr Danellie Lynas from The University of Queensland.

The project reported that:

- Improving earth moving equipment design can remove significant anthropometric and other work demand impediments for establishing a more diverse mining workforce
- Design improvements can extend the working life of operators and maintainers by lowering the possibility of cumulative injuries through decreasing physical work demands.

To achieve the above requires practical on-the-ground improvement of current operational practice and improvements in equipment design, particularly for maintenance tasks.

The objectives of C28034 were to:

- Identify and describe design issues with current mining equipment that are a barrier to workforce diversity
- Document and evaluate remedial control measures currently undertaken at sites
- Communicate results to equipment designers and mine sites.

In conducting the project, researchers visited seven surface coal mines in Queensland and New South Wales to conduct focus groups and task observations. Additional information was gathered from previously documented assessments of the manual tasks associated with earth moving equipment maintenance.

The project information was used to populate an EMESRT CFw for equipment design for diversity. Two required operating states were defined:

1. Earth moving equipment can be safely and comfortably operated by people across a maximum range of anthropometric diversity
2. Earth moving equipment can be safely and comfortable maintained by people across a maximum range of anthropometric diversity.

The researchers reported considerable consistency across the focus groups and observations, which confirm concerns about the current design of mining equipment. Aspects of earth moving equipment designs may unnecessarily restrict the diversity of potential employees who can operate and maintain the equipment, and in turn create elevated exposure to injury for those who currently undertake tasks associated with operating and maintaining the equipment.

The observations also confirm the concerns are not limited to one particular mine operator, mine site or original equipment manufacturer.

The project team will develop proposed equipment design improvement opportunities, using EMESRTs control framework methodology for identifying end user problems and issues.

Project next steps

In 2022, the Human Factors Design Diversity Project will:

- Review the ACARP Project C28034 outcomes and map an EMESRT industry landscape and work plan
- Based on the research findings, review the EMESRT design philosophies
- Reference research examples of inadequate diversity tolerant designs and engage with OEMs to gain their input to areas that could be in the initial project focus scope
- Gain EMESRT EAG approval for the initial phase of the project scope
- Establish a TWG by engaging with key stakeholders (e.g., OEMs, third-party suppliers, industry experts, researchers and others with relevant expertise)
- Develop a beta version of the Human Factors Design Diversity Knowledge Hub; the hub will provide access to project documents, templates, case studies, presentations, links to websites and other useful reference information.

For more information about this industry project, please visit the EMESRT website - emesrt.org.


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Project Spotlight: Performance Requirement 4 - Mobile Equipment Fire Management

Following extensive industry consultation – with mining company representatives, OEMs, regulators, fire detection and suppression system providers, fire system designers, academics and researchers – EMESRT launched Performance Requirement 4 – Mobile Equipment Fire Management in December 2021.

Performance Requirement 4 – Mobile Equipment Fire Management (PR-4) augments Design Philosophy 4 – Fire published by EMESRT in 2007. The design philosophy provides a high-level overview of problems that can lead to adverse consequences from mobile equipment fire events. See page 24 for DP-4 list of potential unwanted events scenarios.

PR-4 provides structured and comprehensive information that can be applied to reduce the number and consequences of mobile equipment fires in earth moving equipment. It is relevant for designers and OEMs, suppliers of fire detection and suppression systems, and mining users.

PR-4 identifies a sequence for fire prevention and mitigation:

- Fire hazard reviews during factory design of equipment that consider:
  - Prevention of fires – through fuel elimination or segregation design
  - Prevention of fires – through ignition avoidance elimination or segregation design
- Prediction of potential fires with real-time notification to the equipment operator, their supervisor and the site emergency response team
- Early fire detection and local response with suppression and the use of escape devices that allow for safe operator egress
- Early fire detection and local response that extinguishes fire though a combination of fuel elimination, energy isolation, cooling and oxygen deprivation
- Providing, where practical, connectivity points on mobile equipment that increase site emergency capability for extinguishing fire (e.g., through external connections on excavators for adding deluge fluid beyond that stored in onboard deluge systems)
- Providing capability for the operator or site emergency response to isolate fuel and air sources to protect personnel and prevent the fire spreading.

PR-4 uses a Mobile Equipment Fire Event Tree (see Figure 4 on page 25) to define the areas of influence and relevant sub-topics (see Table 1 opposite).

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Table 1: Areas of influence and relevant sub-topics.

Area of influence		Sub-topics
1	Mobile equipment design	1. Liquid containment failures 2. Flammable mobile equipment components 3. External fuel accumulation 4. Inadequate insulation or shielding 5. Error intolerant design 6. New technology fire hazards
2	Mobile equipment maintenance management	1. Component failures that release liquid fuel 2. Compromised thermal protection and solid fuel 3. External fuel is introduced during maintenance 4. Hot work system failures 5. In-service component failures cause an increase in temperature
3	Fire system detection and suppression design	1. Detection and suppression systems fail 2. Interface logic between equipment and fire systems is inadequate 3. Fire detection and suppression system design are inadequate 4. Inadequate installation of fire detection and suppression systems
4	Operating company emergency and crisis management	1. Operating environment 2. Tramming distances 3. Over loading 4. Excessive heat 5. Not able to shut down equipment 6. Fire suppression not activated 7. Fire suppression not sequenced with equipment operation

In developing PR-4, the TWG applied EMESRTs CFw approach. More information on the CFw is available on page 9.

Note: PR-4 does not consider the mobile equipment user emergency management zone.

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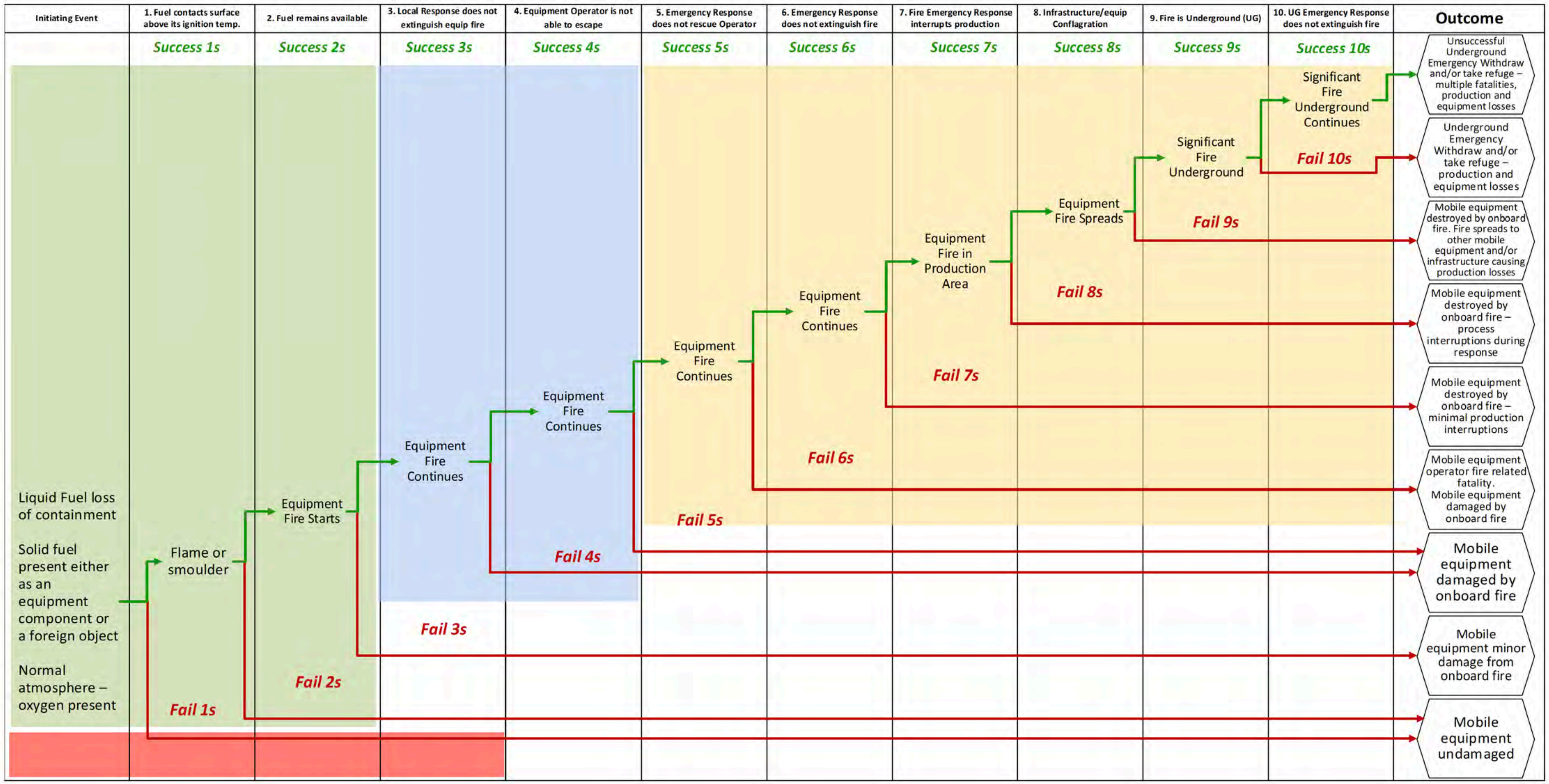
Key

- Mobile Equipment Design
- Mobile Equipment Maintenance Management
- Fire System Detection and Suppression Design
- Asset operation and local and site emergency response - **Out of scope**

Figure 4: Mobile Equipment Fire Event Tree with areas of influence.



How EMESRT Operates

Governance framework

EMESRT aims to deliver practical outcomes at an industry level, with a work program that involves delivering specific projects. EMESRTs Advisory Group (EAG) members, who are senior managers in their respective organisations, make contributions based on their availability, experience and expertise.

Secretariat support is provided on a fee-for-service basis by a third-party provider. Expert consultant support is sourced as required.

Funding

EMESRT membership is open to mining companies and the members provide the direct funding for EMESRT activities through an annual membership fee. The fee is set based on a 24-month rolling activity and project plan, which is reviewed annually.

Significant value is contributed from the in-kind involvement of all stakeholders in the many related project activities. This includes coordinating and connecting work already in progress by other organisations. Indirect funding is accessed via groups such as ACARPs coal industry research, university research, and other technical research and development conducted by other organisations.

The scope of EMESRT activities

EMESRT seeks to foster candid dialogue, transparent industry-level collaboration, open sharing of non-commercial information, and active stakeholder engagement.

The EAG is aware of managing anti-trust issues and clearly communicates EMESRTs scope in all workshops and other industry forums. This process has been in place since OEM engagement work commenced in 2006.

In scope; EMESRT will:

- Focus on the design of earth moving equipment in surface and underground mines
- Provide aligned design expectations based on risk
- Involve interested mining companies in the industry
- Share openly with all interested OEMs and other third-party suppliers
- Listen, consider and value OEM and third-party supplier contributions
- Provide information on leading practice to OEMs and third-party suppliers
- Share leading practice to assist mining equipment users in achieving health, safety and environmental compliance goals.

Out of scope; EMESRT will not:

- Discuss commercial issues or anything of an anti-trust nature
- Provide approval for OEM or third-party designs
- Share OEM confidential information with other OEMs or third-party suppliers
- Impose adoption of solutions on member company sites.

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Annual work plan

The EAG meets annually to discuss the progress of current projects, review and amend the strategic plan and document future focus areas.

The work plan process includes:

- Reviewing the progress of current industry projects (including outstanding activities and the potential end date)
- Identifying prevalent industry issues that members are highlighting
- Structuring responses that are within EMESRTs stated scope of operation
- Appointing project lead(s)
- Confirming the strategy and plans
- Setting timelines and allocate resources
- Allocating budget(s)
- Determining the following year's membership fees based on the identified work plan and allocated budget.

The EAG establishes a TWG for each project. Each TWG includes multiple member representatives, OEMs, third-party suppliers, industry experts and others with relevant expertise. The EAG and TWGs meet regularly to discuss the progress of each industry project.

Continuity and renewal

One of EMESRTs significant strengths is the continuity of its representatives from member organisations. A core group of company representatives were responsible for establishing EMESRT and have remained involved.

Each has made significant contributions to developing the reach and profile of EMESRT and supported the evolving operational processes that can deliver successful industry-level projects. Importantly, they have established and maintained good relationships with senior managers in OEMs and industry third-party supplier organisations.

One of the most important challenges facing EMESRT is capturing the core representatives' decades of effective work so EMESRT can continue beyond its original cohort of pioneers. Meeting this challenge has required formalising and updating EMESRTs operational processes as well as documenting the journey of current and past projects to provide insights into the activities that made a real difference in improving outcomes for users.

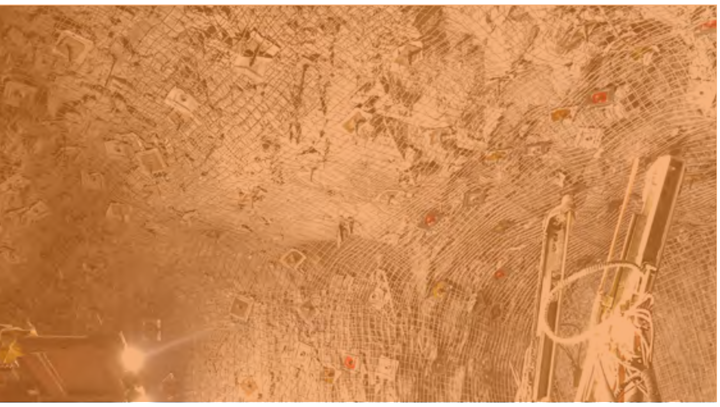
The effectiveness of EMESRTs approach for engaging with and influencing organisational decision-makers is reviewed at each EMESRT strategy and planning review meeting.

While EMESRTs role within the industry is well understood and highly regarded by senior OEM leaders and other industry supplier organisations, it has a lower profile in mining companies, including those that are members. This uneven profile was reconfirmed during ongoing collaboration with the ICMM ICSV program in 2021, where senior OEM manager participants consistently and publicly endorsed EMESRTs successes and ongoing relevance.

This situation reflects EMESRTs underpinning philosophy of focusing on delivering useful outcomes. However, the EAG is working to increase EMESRTs profile and influence with all stakeholders, to increase capacity and support project outcomes.

Relevant stakeholders include research organisations internationally, regulators, industry associations and senior managers in operating mining companies (including EMESRT members).

More information about EMESRT is available on the website - emesrt.org.

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