EMESRT
Earth Moving Equipment Safety Round Table

Published October 2023

EMESRT Vehicle Interaction Control Improvement (VICI) Project Guide

An EMESRT Industry Resource

Working with industry since 2006.

The Earth Moving Equipment Safety Round Table (EMESRT) is a global initiative involving major mining companies. EMESRT engages with key mining industry Original Equipment Manufacturers (OEM's) to advance the design of equipment to improve safe operability and maintainability beyond standards.

The EMESRT vision is a mining industry free of fatalities, injuries and occupational illnesses associated with operating and maintaining earth moving equipment.

Contents

Since 2013, EMESRT has facilitated Vehicle Interaction (VI) Improvement Projects, with the goal of improving the effectiveness and reliability of vehicle interaction controls at a site level.

Guide Objective

This VICI Project Guide has been developed to assist operating sites in the resources industry to deliver successful projects that improve vehicle interaction controls. This resource is based on processes and approaches that have been successfully applied at EMESRT member company and other operations to systematically improve current vehicle interaction controls, while supporting the operational integration of new technology VI controls.

Expected users are site and divisional leaders with the business knowledge and experience to plan and deliver complex business improvement projects.

Background

Following an approach from EMESRT in 2017, the ICMM launched the Innovation for Cleaner, Safer Vehicles (ICSV) programme in 2018.

Bringing together member companies and OEM's, this initiative is building the confidence required to mobilise investment to respond to greenhouse gas emissions, diesel exhaust particulates and unwanted vehicle interactions in a new generation of mining vehicles, while improving existing mining vehicles.

Mobile equipment accidents are the highest fatality category in ICMM member mining companies, and the ICSV ambition is that by 2025 vehicle interaction technology is available that supports industry operational practices. Ongoing collaborations between mine operators, industry associations, researchers, OEM's, and third-party technology providers continue to develop and refine resources that will deliver this outcome. These include practical processes that assist sites to integrate technology while supporting the development of Capable Solutions for global market uptake.

For the next three years, the ICSV will leverage this momentum by asking leading sites to adapt and apply these resources and share lessons learned.

The ICSV Vehicle Interaction Strategy:
Leverage momentum in leading sites to drive the adoption of capable solutions to have them ready for global market uptake by 2025.

- A capable solution delivers better vehicle interaction control performance by improving the quality of decision making, from task execution through to mine operations and design.
- A capable solution considers relevant aspects of the operating environment, production requirements and equipment design.
- Where technology is a part of a capable solution, it is operationally integrated with existing controls.

Conditions of Use

This publication has been written *by practitioners, for practitioners.* While it is informed by research from academics and other industry thought leaders, it is fundamentally a guide of practice over theory. The resources provided are based on approaches that have been successfully applied and reviewed by industry leading mining operations.

This resource was prepared by Risk Mentor with the support of all content contributors. Subject to the EMESRT Permitted User definitions, it is offered as a collaborative and evolving good practice resource that supports the mining industry intent to collaborate and share information that improves vehicle interaction controls. It cannot offer, nor is it intended to offer, a 'one size fits all' approach to vehicle interaction controls. It is expected that users will appropriately adapt the information provided, based on the specifics of their site and operations.

Note: the terms Vehicle Interaction (VI) and Mobile Equipment Interaction (MEI) have the same meaning in this guide. Both terms have been used in a range EMESRT documents and forums, and are interchangeable.

Work Breakdown Structure

"A hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables."[1]

VI Control Improvement Project Structure

To provide structure, VI Control Improvement Projects can be represented as a Work Breakdown Structure (WBS).

The WBS is, first and foremost, a tool to be used by the Project Manager.

Each section of the project is broken into a number of individual Work Packages, which are explored in the next section.

Important note: While the following Work Breakdown Structure (WBS) represents a typical VI Control Improvement Process, it is a starting point only.

The specific project phases, Work Packages, and the order in which the project is completed will be site dependent. It is intended that the WBS, associated Work Packages and other resources will be adapted and applied by each site or company.

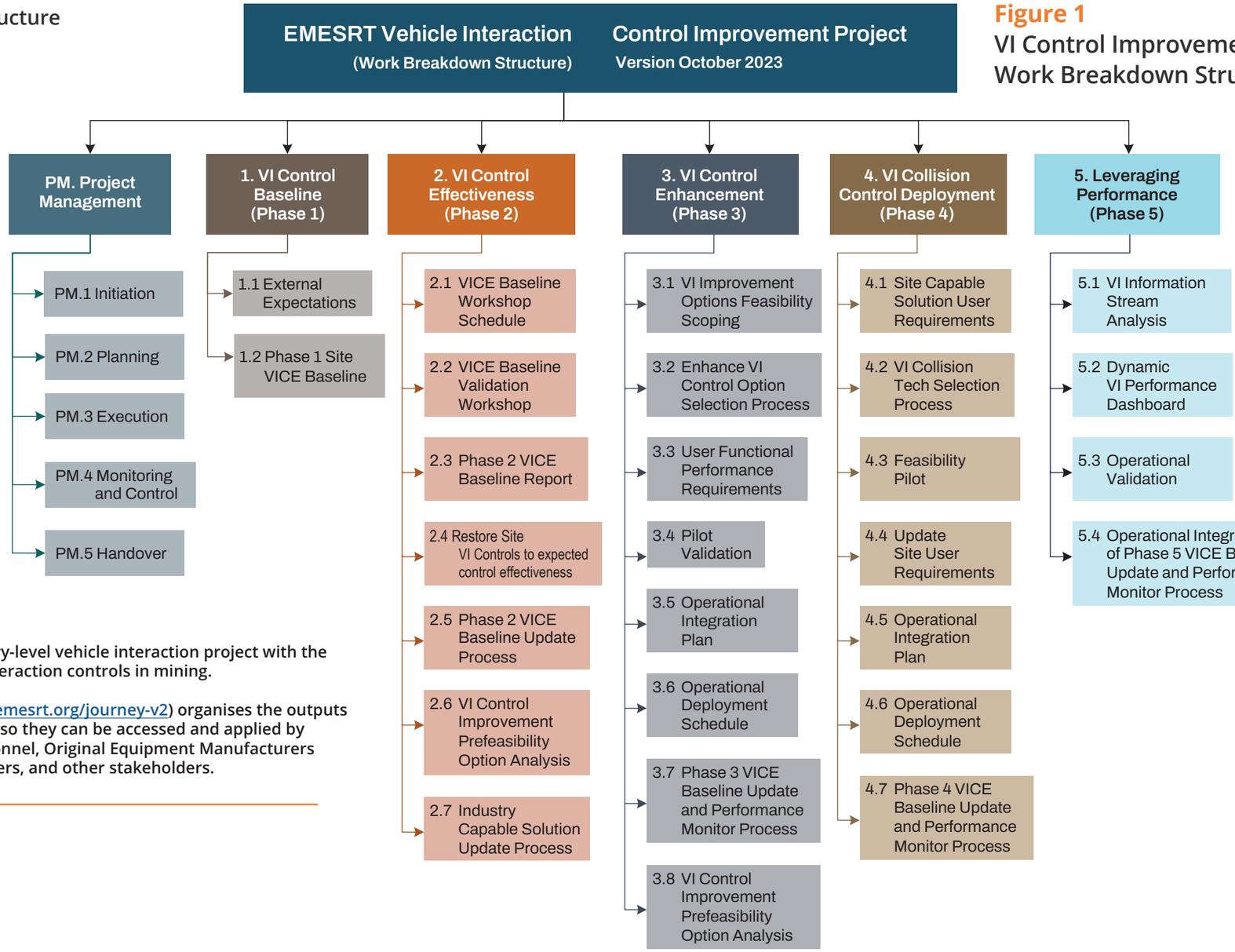


Figure 1
VI Control Improvement Project Work Breakdown Structure (WBS) to results level.

Since 2013, EMESRT has facilitated an industry-level vehicle interaction project with the goal of improving the reliability of vehicle interaction controls in mining.

The EMESRT VI Knowledge Hub (available at emesrt.org/journey-v2) organises the outputs from this work and other useful information so they can be accessed and applied by a range of end users e.g. operating site personnel, Original Equipment Manufacturers (OEM's), Proximity Detection Systems providers, and other stakeholders.

1. PMBOK® Guide (2021), 81.

"Work Breakdown Structure components located at the lowest level in the WBS hierarchy are called Work Packages. At the lowest level, you plan for the work, assign the resources responsible for it, develop the estimates, and monitor and control the work."[2]

Work Packages

Work Packages are the lowest level in a Work Breakdown Structure. They are detailed, prescriptive project components, where discrete blocks of work are planned and allocated to team members.

The Work Packages within every VI Control Improvement Project include scheduled activities and milestones required to complete the Work Package deliverable or project work component.

Each package combines company experience, knowledge and processes into a standard summary format, which details:

- A WBS hierarchical reference
- Required outcome
- Completion state, i.e. when and how the activity has been completed
- Suggestions for work package owner and participants
- Important references
- Case study information, where relevant, based on EMESRT member company and industry experience
- Notes and advice
- Links to tools, templates and processes that can be adapted for site use.

The Work Packages linked to this EMESRT VICI Project Guide are provided in two formats. The first is in a PDF format with advice, case study information, links to resources and templates etc. The second format is a template that can be adapted and applied. It has limited information that includes reference numbers and completion step.

Note: The Project Management (PM) components of the Work Breakdown Structure are 'level of effort' components, supporting activities that do not produce definitive end products.[3]

2. Duke, R. Provided via workbreakdownstructure.com
3. Buchtik, L. Secrets to Mastering the WBS, Second Edition. PA: Project Management Institute. See page 50.

Phase	Information
Project Management **Conduct project planning** – improving mobile equipment controls at operating sites is best conducted as a **Project**. This requires coordinating multiple related activities such as: • Reviews and assessments of current VI control performance • Supporting experienced personnel to reassess and modify how they carry out their work • Change management • Stakeholder management • Operational validation and integration • New technology assessment and sourcing • Approvals and finance • Data collection and analysis. **Apply existing company project management approaches** to deliver required outcomes, including: • Appointing an appropriately experienced Project Manager • Appointing a Senior Manager Sponsor. **Conduct a review of operating site vehicle interaction control status,** using the ICMM Maturity Framework Assessment tool. The site results from this broad review will assist both the Project Manager and the Senior Manager Sponsor to make the business case, develop the project charter, and manage stakeholders.	**Responsible:** Project Manager supported by Project Sponsor **Resources:** A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Seventh Edition Company Project Management resources and requirements
Results and Work Packages **PM. Project Management** **PM.1 Initiation** PM.1.1 Maturity Framework Assessment PM.1.2 Project Charter PM.1.3 Project Initiation PM.1.4 Stakeholder Management Plan **PM.2 Planning** PM.2.1 Scope and Budget PM.2.2 WBS and Schedule **PM.3 Execution** PM.3.1 Status and Tracking PM.3.2 Quality and Integration **PM.4 Monitoring and Control** **PM.5 Handover**	**For Project Charter:** Company standards relevant to Vehicle Interaction e.g. Fatal Hazard Protocols for Mobile Equipment EMESRT Vehicle Interaction Control Improvement Strategy Template 2020

Phase	Information
VI Control Baseline (Phase 1) **Following the EMESRT Control Framework (CFw) approach, establish a site VI Control Baseline to ensure:** • External expectations of operating site — legal and company — are captured and reviewed • The EMESRT 9-layer Control Effectiveness Model is applied • A project risk and control management process is established, that can be reviewed and updated through each project step and passed on at project handover • A reference and consultation process is established for operational input and validation of key project steps • Effective change management reviews are completed and updated at each step, such as capturing the interactions between new and existing VI controls.	**Responsible:** Project Manager **Notes:** A CFw is a process aligned with both Failure Modes and Effects Analysis and the ICMM Critical Control Methodology. It is useful for identifying VI controls that are dependent or partly dependent on people. **Resources:** EMESRT VICE Baseline Facilitator Guide Version 0.1
Results and Work Packages **1. Vehicle Interaction Control Baseline** **1.1 External Expectations** 1.1.1 Legislative Requirements 1.1.2 Company Standards 1.1.3 Sector Resources 1.1.4 VICE Review Required Operating States **1.2 Phase 1 Site VICE Baseline** 1.2.1 Site Conditions 1.2.2 Site Specific Requirements 1.2.3 Credible Failure Modes 1.2.4 Incident Analysis 1.2.5 BI Role Allocation 1.2.6 BI Map 'Work as Documented' 1.2.6.1 BI Expectation 1.2.6.2 BI Specify 1.2.6.3 BI Implement 1.2.6.4 BI Monitor 1.2.7 Control Management Sheets	

Phase	Information

VI Control Effectiveness (Phase 2)

This phase ensures that existing VI controls are robust, reliable and practical BEFORE investing in enhanced and/or new VI controls.

Conduct validation workshops with experienced and knowledgeable site personnel and other useful contributors:

- Introduce participants to Control Framework thinking
- Harness their experience to review the site VI CFw (Version 1), with the aim of identifying gaps in existing VI Controls, and confirming causes for gaps (e.g. it is difficult to monitor and verify that ME operators always give way).

Update the site VI CFw map (Version 2) and use it to:

- Prepare and implement a plan that will improve the reliability of existing VI controls
- Confirm inputs required to maintain adequate performance of VI controls
- Prepare site functional and performance requirements for enhancing existing VI controls (EMESRT Levels 1–7)
- Prepare a site Use Case profile for mobile equipment that captures the full range of machine tasks and current vehicle interaction controls.
- Prepare site functional, performance and technical requirements for new VI controls (EMESRT Levels 8–9).

Responsible:

Project Manager

Resources:

VI risk analysis resources
e.g. bow ties

CFw – Validation Workshop Control Sheets

EMESRT VICE Baseline Facilitator Guide Version 0.1

VI Control Restore Plan Template

EMESRT PR – 5A Vehicle Interaction Systems 2019

Results and Work Packages

2. VI Control Effectiveness

2.1 VICE Baseline Workshop Schedule
2.2 VICE Baseline Validation Workshop
2.2.1 Participant CFw Briefing
2.2.2 'Work as Done' Validation with CMS
2.2.3 Intro to Functional Performance Scenarios
2.3 Phase 2 VICE Baseline Report
2.3.1 Sorting Opportunities for Improvement (OFI)
2.3.2 Site External Expectation Alignment
2.3.3 Action Plan with Management Approval
2.4 Restore Site VI Controls to Expected Control Effectiveness
2.4.1 Progress Tracking Process
2.5 Phase 2 VICE Baseline Update Process
2.6 VI Control Improvement Prefeasibility Option Analysis 2.7 Industry Capable Solution Update Process
2.7.1 Site Feedback to Company
2.7.2 Company Feedback to Industry

Phase	Information

VI Control Enhancement (Phase 3)

When existing VI controls (EMESRT Levels 1-7) are operating as expected, then options for enhancement can be considered.

List opportunities for enhancement using the VI Control Improvement Prefeasibility Option Analysis from Step 3. Examples include: using cameras to improve mobile equipment operator awareness; separating pedestrians from mobile equipment underground; monitoring and analysing work practices.

Select options based on:

- Cost
- Ease of implementation
- Relevance to future new control implementation
- Inputs required to maintain adequate performance of enhanced VI controls.

Validate and update enhancements to existing controls, in consultation with experienced site personnel and other useful contributors, using the VI CFw.

Where practical, conduct a pilot of the VI control enhancement, and engage the broader workforce before operational deployment.

Responsible:

Project Manager

Resources:

ICMM – Case Studies

Vehicle Interaction Use Case Analysis Resource (VI-UCAR) Version 1.0

Results and Work Packages

3. VI Control Enhancement

3.1 VI Improvement Options Feasibility Scoping
3.1.1 **Design** Option Scope
3.1.2 **Operate** Option Scope
3.1.3 **React** Option Scope
3.2 Enhance VI Control Option Selection Process
3.2.1 Option User Requirement Analysis
3.2.2 Option Cost Benefit Analysis
3.3 User Functional Performance Requirements
3.3.1 Enhance Control Use Case (Functional Requirements)
3.3.2 Site Performance Requirements Enhance Control
3.3.3 Site Technology and Infrastructure Requirements
3.4 Pilot Validation
3.4.1 Pilot with Feedback Process
3.4.2 Calibration for Operational Deployment
3.5 Operational Integration Plan
3.5.1 Logistics and Infrastructure Plan
3.5.2 Training and Awareness Plan
3.5.3 Workforce Feedback Process
3.6 Operational Deployment Schedule
3.6.1 Deployment Plan
3.6.2 Maintain and Leverage Plan
3.7 Phase 3 VICE Baseline Update & Performance Monitor Process
3.8 VI Control Improvement Prefeasibility Option Analysis
3.8.1 Further VI Control Enhance Options Analysis
3.8.2 Collision Technology Options Analysis

Phase	Information
VI Collision Control Deployment (Phase 4) The successful implementation and use of new VI intervention controls (EMESRT Levels 8–9) requires the integration of all levels and support processes of VI controls for a 'whole of system' improvement. **Confirm site-relevant options as follows:** • Update and confirm site functional, performance and technical requirements for new technology controls • Identify relevant company VI requirements for new technology controls (EMESRT Level 8 and 9) based on operation type (e.g. underground coal mining, underground hard rock mining, open cut mining, refinery) • Compare site and company VI requirements and identify any differences, e.g. additional site-specific requirements such as machine swing interlocks, and/or restrictions such as an ore body precluding the use of magnetic field PDS • Prepare a site functional and performance specification, and review it against technology performance summaries of preferred PDS suppliers • Select the best fit from PDS technology suppliers, and request they complete a summary of their product performance against site functional and performance requirements • Ensure that technology options meet minimum set requirements based on ACARP PDS validation framework (draft ISO standard) • Confirm site infrastructure requirements for each technology option • Summarise capability, installation and maintenance costs, upgrade potential, data management and fit with future mine digitisation plans and other relevant information for each option. **Validate the shortlisted options with knowledgeable site personnel** — include some who have been involved with Steps 2–4 and all others required for successful implementation of new technology controls (e.g. IT, finance, training, technical, mine planning, senior managers, site infrastructure). **Based on site validation, select the best-fit new VI control option** and confirm the commercial and logistics of technology delivery and installation.	**Responsible:** Project Manager **Notes:** A capable solution delivers better vehicle interaction control performance by improving the quality of decision-making from task execution through to mine operations and design. A capable solution considers relevant aspects of the operating environment, production requirements and equipment design. Where technology is a part of a capable solution, it is operationally integrated with existing controls. **Resources:** Industry VI Intervention Technology Case Studies see ICMM and EMESRT Knowledge Hubs ACARP Project C26028 PDS Validation Framework Mining3 PDS Toolkit (pdstoolkit.com) Mining3 PDS Sensing Capability Assessment document. As documented by Dr Herman Hamersma from The University of Pretoria

Phase	Information
Conduct a pilot implementation: • Brief broader workforce and train all involved in pilot • Complete field trials to confirm functional performance requirements are met • **Phase 1** – deploy for data gathering with an operational PDS, with intervention controls bypassed • **Phase 2** – full pilot deployment in a controlled area to assess actual operational performance. **Review pilot outcomes,** capturing: • Acceptance within the workforce • Technology performance • Changes in mobile equipment reliability, e.g. excessive brake wear • Changes in VI operator and coworker behaviour • 'Point of truth reference' – based on data measures of the effectiveness of current control performance (EMESRT Level 1–7), e.g. pedestrian clearance from underground mining equipment, speed, give-way discipline • How performance data can be used to improve operational controls • Opportunities to extend the application of the new technology, e.g. pedestrian able to slow or stop mobile equipment, swing interlocks, seatbelt and door interlocks, general equipment performance data gathering and analysis • Opportunities to improve design and operate controls BEFORE full deployment of intervention controls • Infrastructure requirements for full deployment. **Prepare a plan** as part of operational deployment, to cover: • Routine incorporation of control effectiveness data into work planning, e.g. separating underground mining activities • Use of control effectiveness data for monitoring and verifying the effectiveness of operational controls • Analysis and performance feedback for supervisors, workgroups and individuals • Minimum equipment and maintenance requirements, e.g. PDS faults that require mobile equipment shutdown • Ongoing technology maintenance.	

Phase	Information
Results and Work Packages	
4. VI Collision Control Deployment	
4.1 Capable Solution User Requirements	
4.1.1 Use Cases – Tech Functional Requirements	
4.1.2 Use Cases – Tech Performance Requirements	
4.1.3 Site Technology Infrastructure Requirements	
4.2 VI Collision Technology Selection Process	
4.2.1 Technology Provider RFP	
4.2.2 Option Functional Performance Analysis	
4.2.3 Option Cost Benefit Analysis	
4.2.4 Technology Shortlisting	
4.3 Feasibility Pilot	
4.3.1 Technology Requirements for Pilot	
4.3.2 Pilot with Feedback Process	
4.3.3 Calibration for Operational Deployment	
4.4 Updated Site User Requirements	
4.4.1 Site Functional Requirements	
4.4.2 Site Performance Requirements	
4.4.3 Site Technology and Infrastructure Requirements	
4.5 Operational Integration Plan	
4.5.1 Logistics and Infrastructure	
4.5.2 Training and Awareness	
4.5.3 Workforce Feedback Process	
4.5.4 Cold Commissioning	
4.5.5 Digital Point of Truth Integration	
4.6 Operational Deployment Schedule	
4.6.1 Deployment Plan	
4.6.2 Technology Criticality and Maintenance Strategy	
4.6.3 Decision Information Integration Plan	
4.6.4 Design and Operate Review Process	
4.6.5 Event Analysis and Configuration Improvement	
4.7 Phase 4 VICE Baseline Update and Performance Monitor Process	

Phase	Information
Leveraging Performance (Phase 5) While the delivery of future outcomes is beyond the scope of this resource, it is recommended that relevant aspects of plans in this area are considered during project scoping, development and delivery, and after handover. **Consider these aspects:** • Infrastructure on mobile equipment, e.g. beyond delivering new VI controls — can the same equipment gather and transmit equipment location and performance data? • Mine infrastructure, e.g. leaky feeders for use underground, mesh networks, etc. • Dynamic mine planning, including mobile equipment management.	**Responsible:** Project Manager **Resources:** TBC
Results and Work Packages	
5. Leveraging Performance	
5.1 VI Information Stream Analysis	
5.1.1 Asset Performance Data Map	
5.1.2 Dispatch System Logistics Data Map	
5.1.3 Proximity Detection Interaction Map	
5.1.4 Operator Performance Map	
5.1.5 Asset and Personnel Location Data Map	
5.1.6 Output Map of Other Data Streams	
5.1.7 Update of Site FP Scenario Review	
5.1.8 Update Site Analysis and Reporting Requirements	
5.2 Dynamic VI Performance Dashboard	
5.2.1 Decision Maker Information Requirements	
5.2.2 Information Architecture Requirement Analysis	
5.2.3 Decision Making Workflow Digitisation	
5.3 Operational Validation	
5.3.1 Task Level Advice and Performance Feedback	
5.3.2 Supervisory Level Performance Monitoring	
5.3.3 Manager Level Performance Analysis	
5.4 Operational Integration of Phase 5 VICE Baseline Update and Performance Monitor Process	
5.4.1 Data Capture Platforms	
5.4.2 Performance Reporting Platforms	

Glossary of Terms

Term	Description
CFw	The Control Framework approach is aligned with Failure Modes and Effects Analysis, Human Factors and some concepts from the ICMM Critical Control Methodology. It begins with confirming the operational outcomes required to deliver the business purpose by answering ***'what has to be in place for work to go right?'*** It is based on a three-level hierarchical context structure of: • Required Operating State (ROS) • Credible Failure Modes (CFM) • Business Inputs (BI) Applying the CFw approach establishes both a 'whole of system' overview and a structure that is linked to detailed operational practice. For vehicle interaction, this provides information and insights about the dynamic interconnects between personnel, equipment, the work environment, work groups carrying out different tasks, and their overall coordination This promotes the systematic identification of improvement opportunities across these five categories : • **Personnel** – operators and those working around mobile equipment are trained, competent, authorised, informed, alert, and situationally aware. • **Equipment** – Equipment, tools and consumables are available, fit for use, and well maintained. Mobile equipment is fit for use, and key systems are functioning. • **Operating Environment** – The operating environment for mobile equipment is satisfactory. Hazards are identified and managed**.** • **Mobile Equipment** – interfaces with pedestrians and other vehicles are well managed. • **System Optimisation** – there is a whole of system overview of activities that deliver safe and productive outcomes. When necessary, modifications are made.
EMESRT	Earth Moving Equipment Safety Round Table.
ICMM	The International Council on Mining and Metals (ICMM), identified in 2017 as a key stakeholder and EMESRT and actively engaged with them in the formation of the Innovation for Cleaner, Safer Vehicles (ICSV) programme.
ICSV	The Innovation for Cleaner, Safer Vehicles (ICSV) programme. This initiative is building the confidence required to mobilise investment to respond to greenhouse gas emissions, diesel exhaust particulates and unwanted vehicle interactions in a new generation of mining vehicles, while improving existing mining vehicles.
PMBOK	The Project Management Body of Knowledge is a set of standard terminology and guidelines for project management. The body of knowledge evolves over time and is presented in *A Guide to the Project Management Body of Knowledge*, a book whose seventh edition was released in 2021.
OEM	Original Equipment Manufacturers.
MEI	Mobile Equipment Interaction. *Note: Mobile Equipment Interaction (MEI) and Vehicle Interaction (VI) have the same meaning in this procedure. Both terms have been used in EMESRT documents and forums, and are interchangeable.*
PDS	Proximity Detection System
VI	Vehicle Interaction. *Note: Vehicle Interaction (VI) and Mobile Equipment Interaction (MEI) have the same meaning in this procedure. Both terms have been used in EMESRT documents and forums, and are interchangeable.*
WBS	A WBS is a structured breakdown of the total project scope, based on what must be delivered for a successful project. This guidance resource is based on the WBS in Figure 1. It visually defines the scope into manageable parts that a project team can understand. This WBS uses a hierarchy of objective, result and Work Packages.
Work Package	A Work Package is the lowest level component of a Work Breakdown Structure (WBS). It assists work planning, assigning resources, developing estimates, and monitoring and controlling the delivery of required outcomes or products.

References

- **EMESRT Design Philosophies**
  https://emesrt.org/design-philosophies/
- **ICMM ICSV Programme Vehicle Interaction Knowledge Hub and Knowledge Base**
  https://www.icmm.com/en-gb/our-work/cleaner-safer-vehicles
- **Mining3 Proximity Detection System Validation Framework**
  https://www.mining3.com/research/proximity-detection-systems/
- **PMBOK Version 7, 2017 Project Management Institute**
  https://www.pmi.org/pmbok-guide-standards/foundational/PMBOK

Note: relevant references are also provided in associated Work Packages.

Document Control and Revision History

Document Control

Approved by:	Document in Draft
Document owner:	EMESRT
Effective draft date:	12 October 2023

Revision History

Version	Reviewed	Nature of Amendment(s)
1-0	October 2020	First version developed
2-0	May 2023	Second version developed
3-0	October 2023	Third version developed

Appendix

Figure 2
VI Control Improvement Project Full Work Breakdown Structure (WBS).

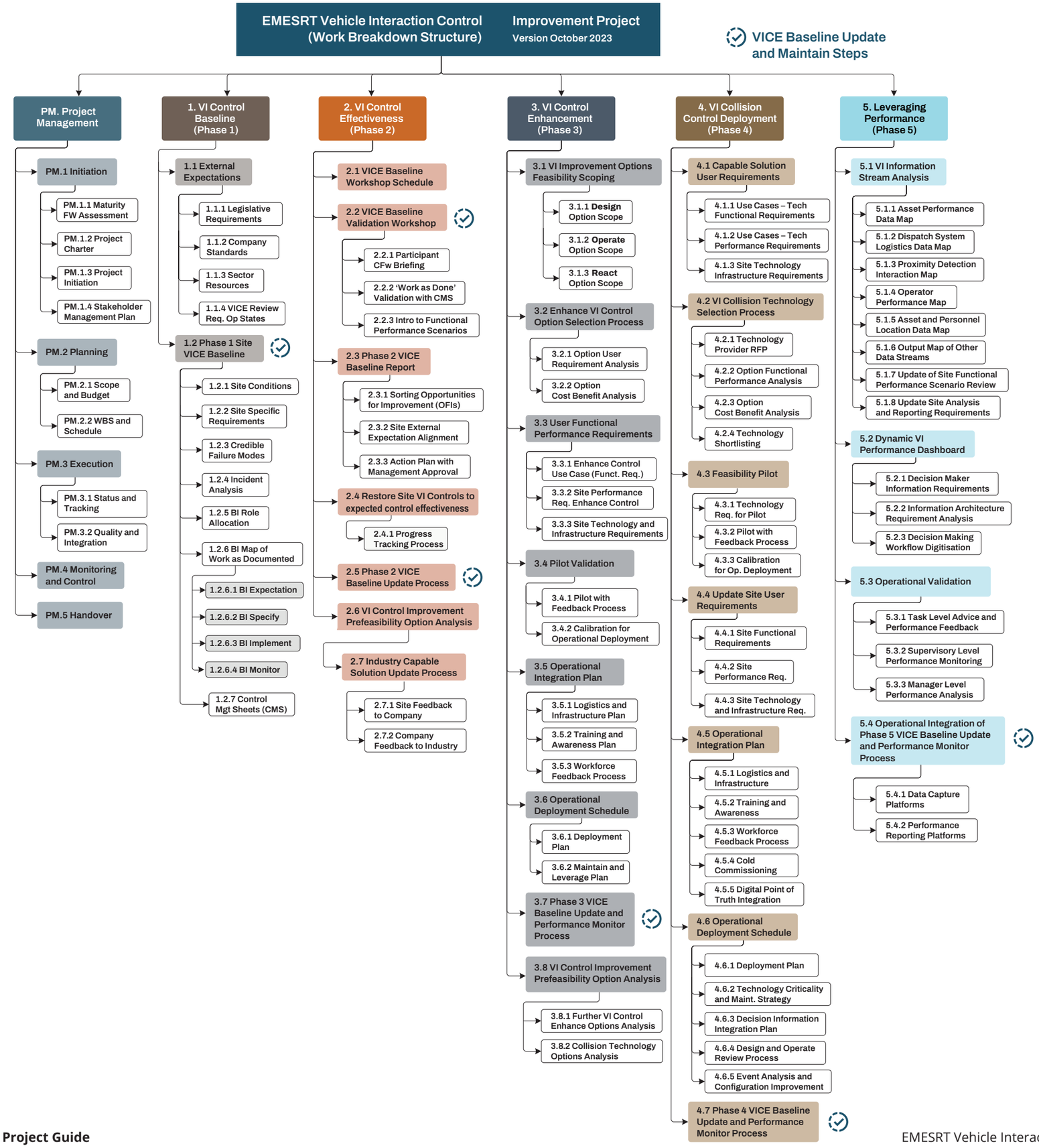
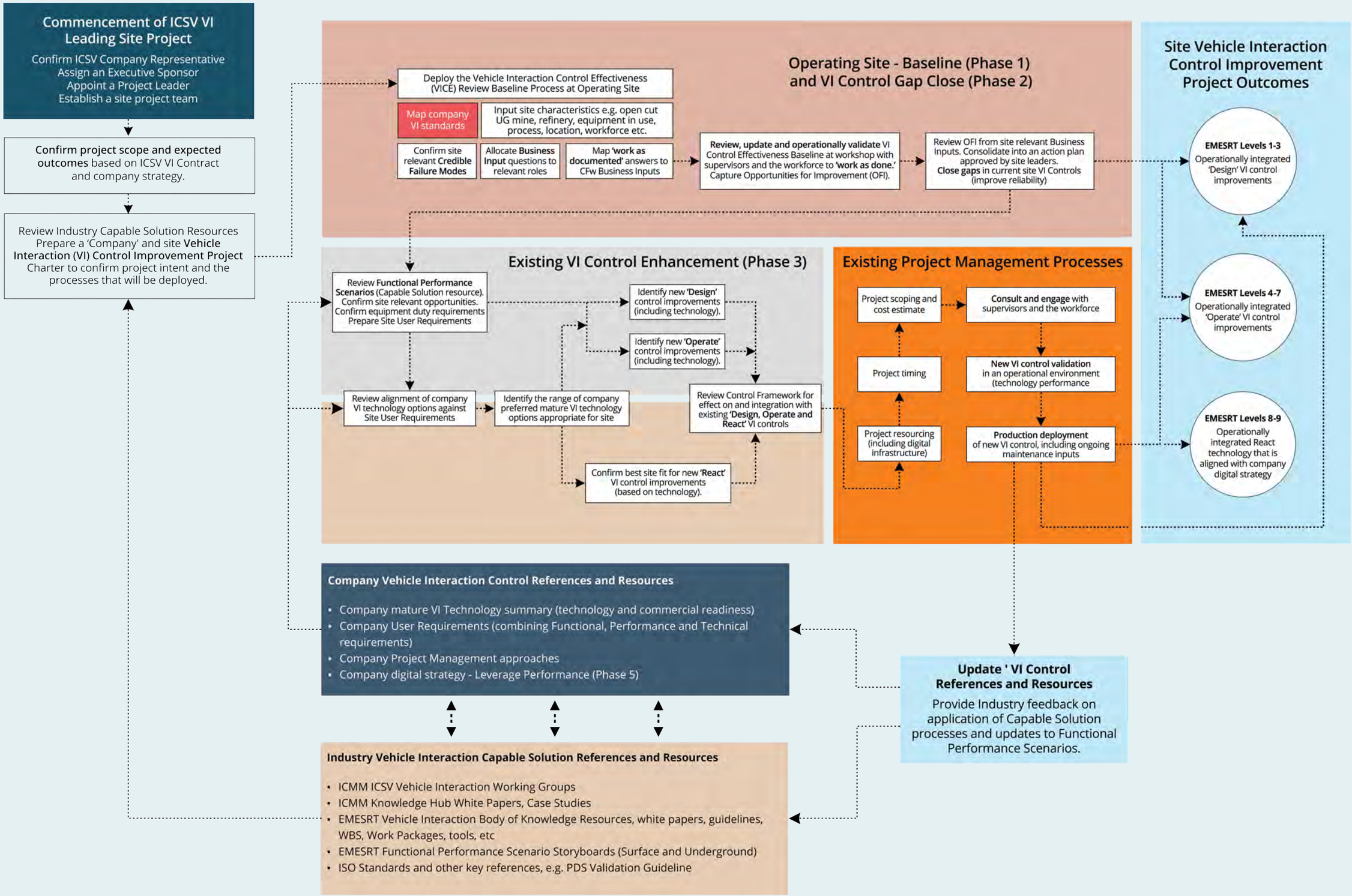


Figure 3 The Vehicle Interaction (VI) Control Improvement Process



Notes

enquiries@emesrt.org

emesrt.org

Follow EMESRT on LinkedIn

EMESRT

Earth Moving Equipment Safety Round Table