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ADVANCING RAILWAY DEPENDABILITY: A CASE STUDY ON ETCS LEVEL 2 MAINTAINABILITY DEMONSTRATION

BY
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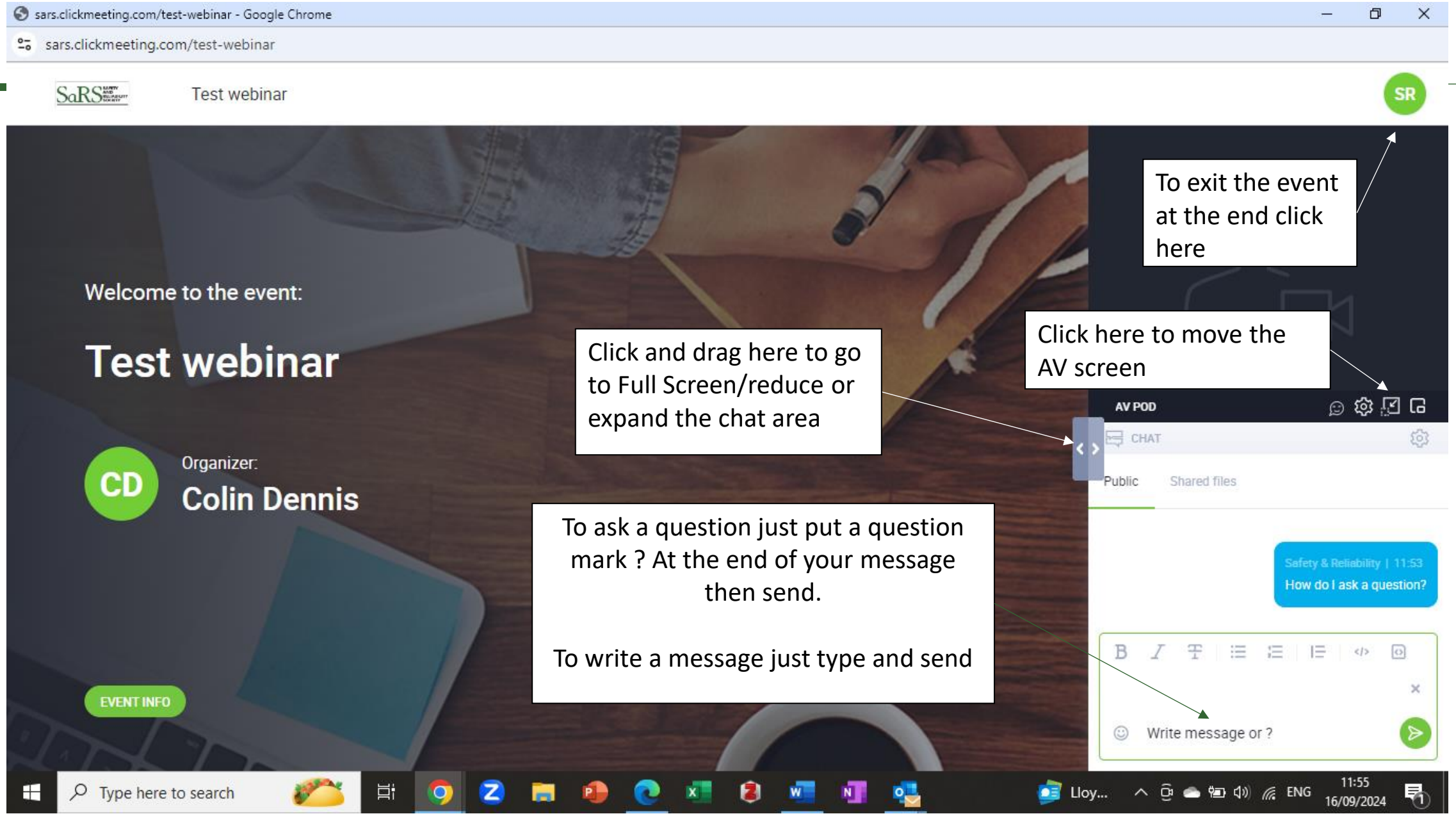

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Advancing Railway Dependability: A Case Study on ETCS Level 2 Maintainability Demonstration

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Maintainability

- Maintainability vs maintenance
- Maintainability measures
- Maintenance levels

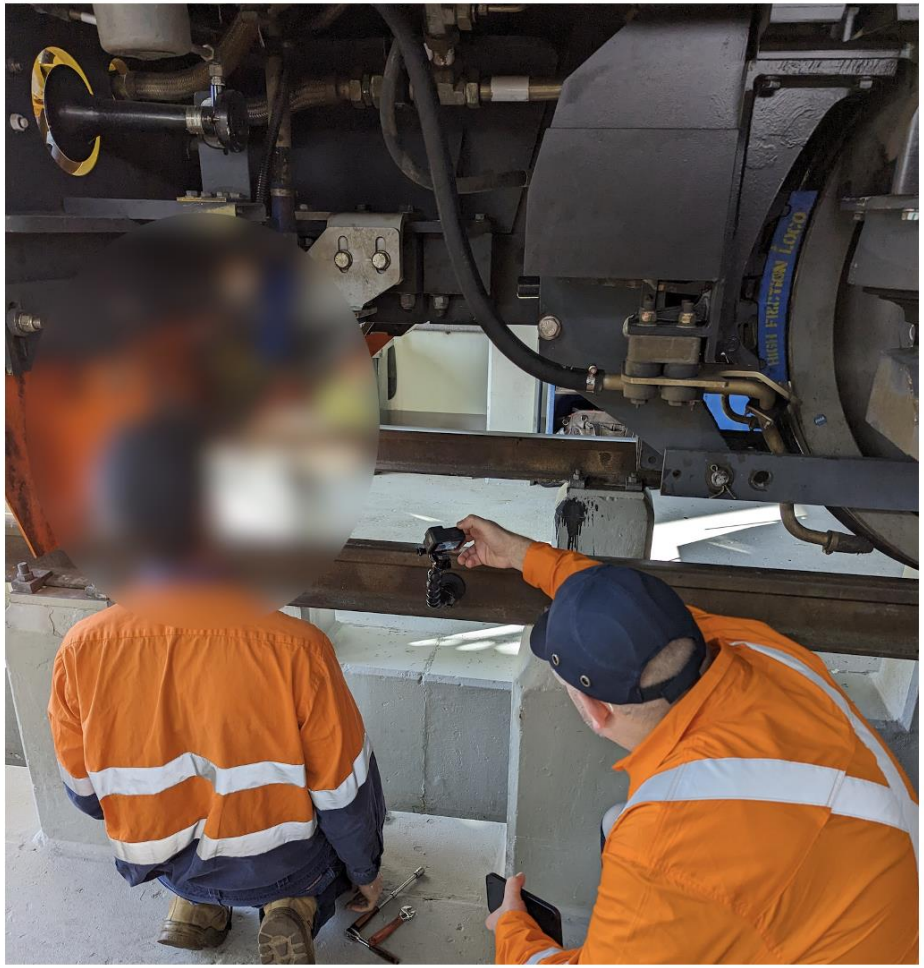
Maintainability

Maintainability vs Maintenance

- Maintainability is a characteristic of design and installation. It measures the ability of an item to be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels and using prescribed procedures and resources at each prescribed level of repair.
- Maintenance is essentially the response to the maintainability program, i.e., the series of actions necessary to retain material in or restore it to a serviceable condition.
- Two types of maintenance actions:
  - **1. Corrective Maintenance** - An action required when equipment fails or malfunctions.
  - **2. Preventive Maintenance** – An action required to maintain equipment in an operable condition through periodic servicing and/or replacement of components at specified intervals.

Maintainability

Measures of Maintainability

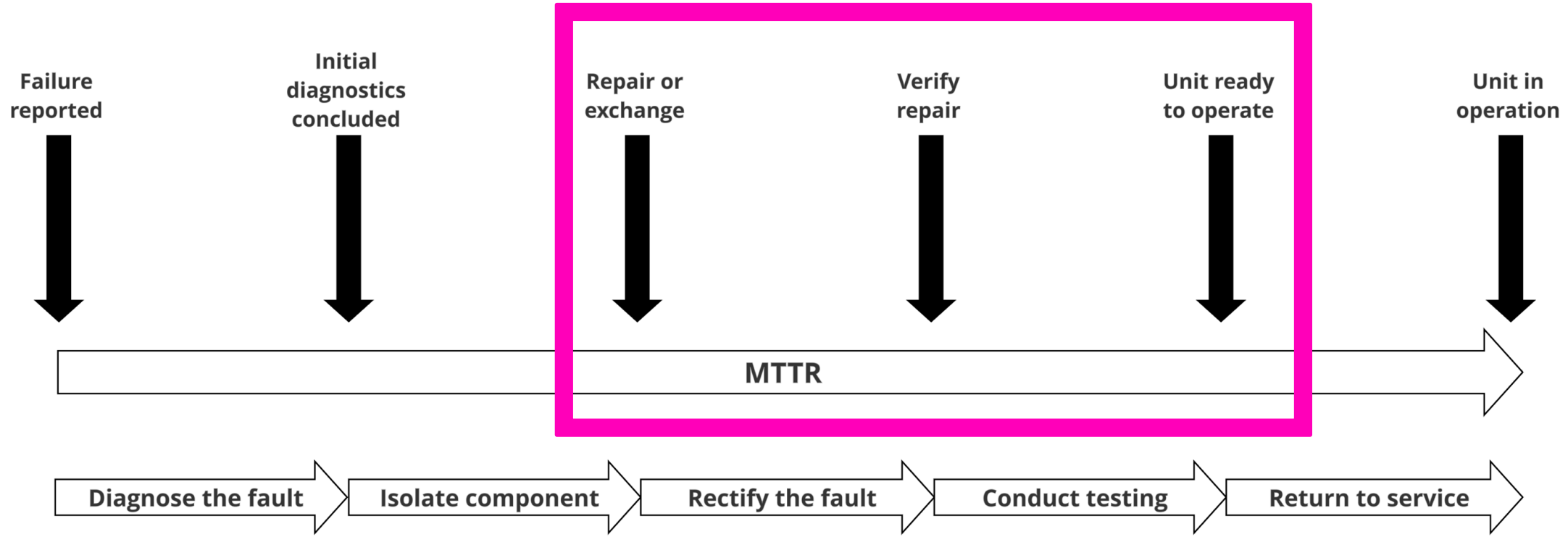


- Characteristics of maintainability are usually expressed quantitatively and not qualitatively.
- A commonly used measurable parameter to quantify the maintainability characteristic, the ease of maintenance, is the maintenance time required to correct equipment performance deviations, such as failure or degradation.
- When maintenance time as a design parameter is measured, active time should only be considered.

Maintainability

Measures of Maintainability

- Mean Time to Repair/Restore (MTTR)
  - MTTR is a key metric used to measure maintainability. It is calculated as:
  - MTTR=Total Downtime/Number of Repairs



Maintainability

Measures of Maintainability

- Mean Time to Repair/Restore (MTTR) Equation (systems and subsystems)

$$MTTR_s = \sum_{i=1}^{n} \left\{ \frac{m_i MTTR_i \lambda_i}{\sum_{i=1}^{n} m_i \lambda_i} \right\}$$

- Where:
  - MTTRs: Mean Time to Repair/Restore of the entire system.
  - n: Number of different subsystems or components within the system.
  - mi: Number of instances of the i-th subsystem/component.
  - MTTRi: Mean Time to Repair/Restore the i-th subsystem/component.
  - λi: The failure rate of the i-th subsystem/component.
- This formula was used to verify the design MTTR and validate MDT MTTR results.

Maintainability

Maintenance Levels

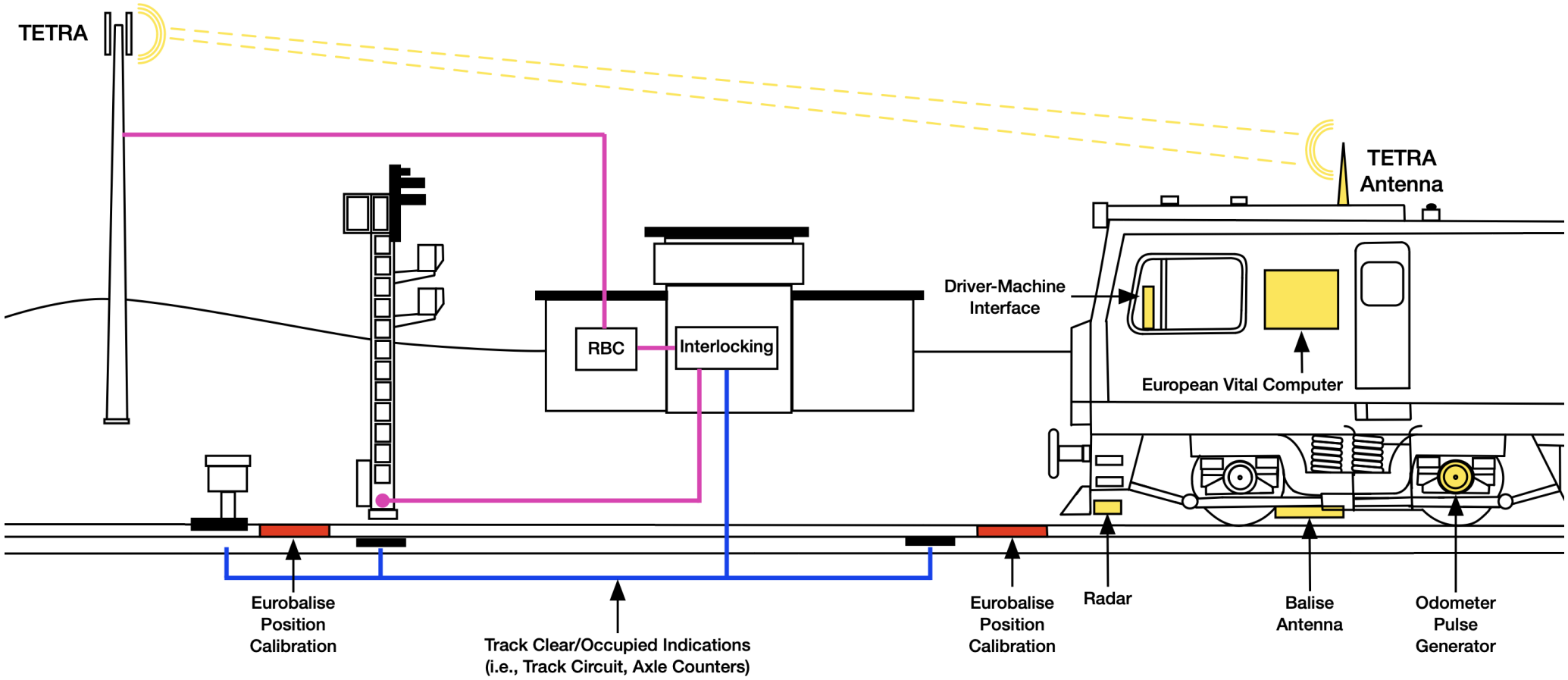
- 1st Line Maintenance (ML1)
  - **Definition:** Basic, routine maintenance tasks performed by the operator to ensure the system or equipment continues to operate effectively on a day-to-day basis.
- 2nd Line Maintenance (ML2)
  - **Definition:** More specialised maintenance tasks conducted by the operator, often involving troubleshooting and minor repairs that require some technical expertise and tools.
- 3rd Line Maintenance (ML3)
  - **Definition:** Advanced maintenance tasks managed by the contractor, involving complex repairs, major overhauls, and deep technical expertise, often requiring specialised facilities and equipment.

Case Study – Aurizon Trainguard Project

- Trainguard Project Overview
- Project maintainability metrics and challenges measuring them
- Maintenance strategy
- Maintainability demonstration test (MDT) process
- MDT walkthrough
- MDT results

Case Study – Aurizon Trainguard Project

Project Overview – ETCS L2



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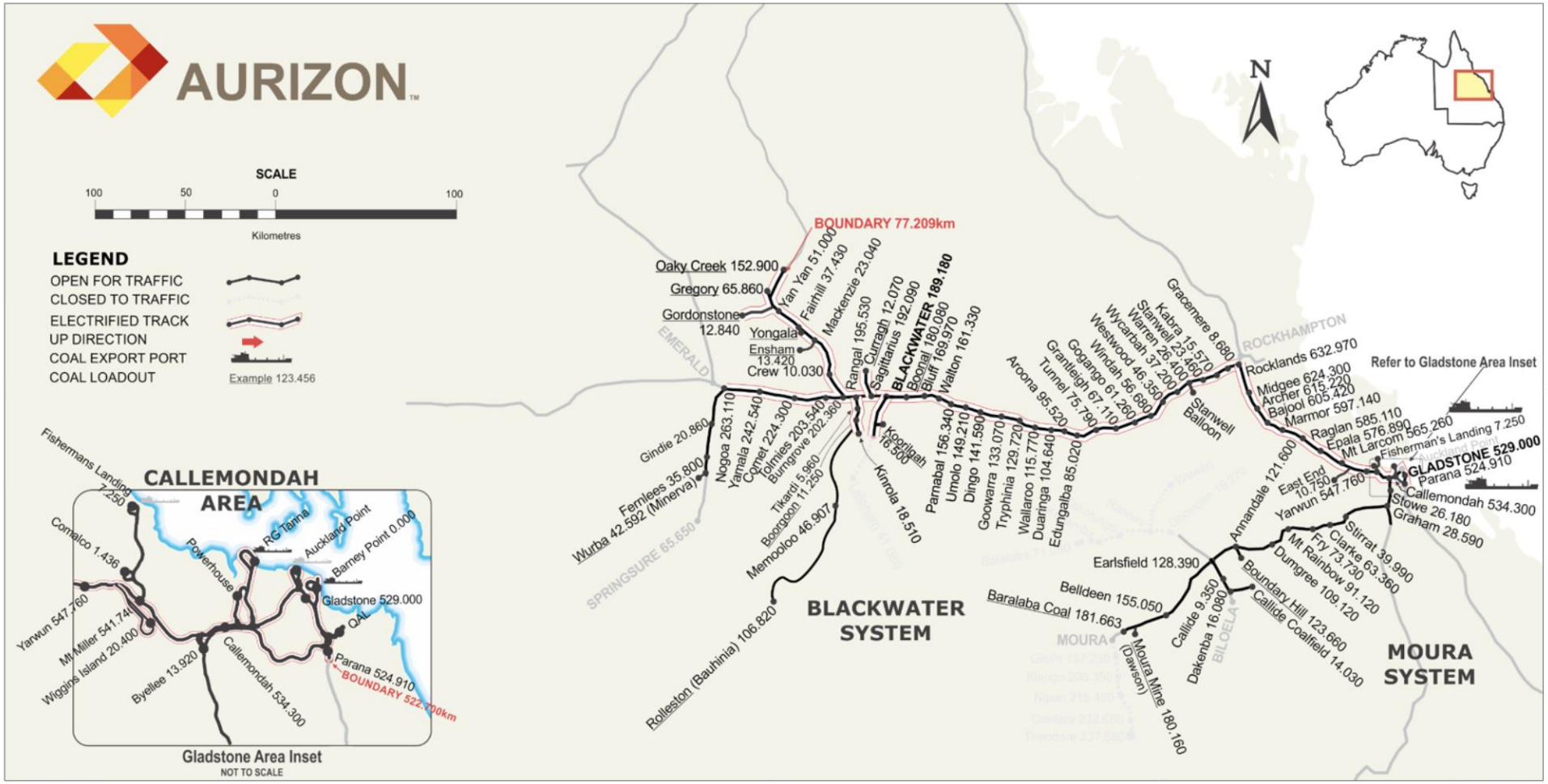
Project Overview – Aurizon Blackwater System, QLD



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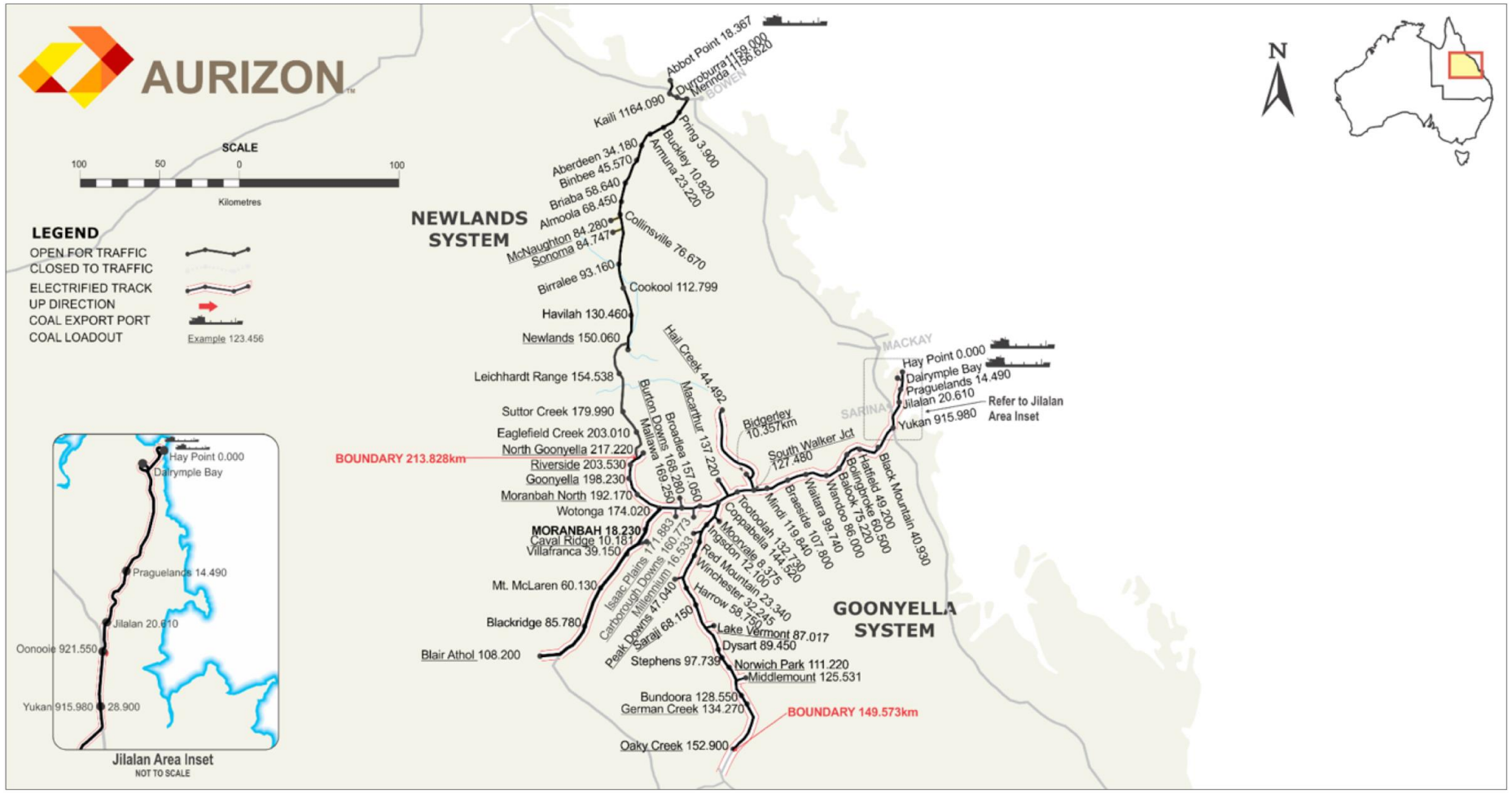
Project Overview – Aurizon Goonyella System, QLD



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ETCS maintainability metrics and challenges measuring them

ID	Example Requirement Text	Example Acceptance Method
Onboard Req1	The first-line maintenance Mean Time to Repair (MTTR) for the Onboard subsystem on each train shall be no greater than 0.3 hours.	Design Phase: Onboard RAM Analysis Report. Delivery Phase: Subsystem RAM KPI Report.
Onboard Req2	The second-line maintenance Mean Time to Repair (MTTR) for the Onboard subsystem on each train shall be no greater than 3.0 hours.	Design Phase: Onboard RAM Analysis Report. Delivery Phase: Subsystem RAM KPI Report.
Centralised Req1	Mean Time to Repair (MTTR) or reconfigure the Centralised subsystem shall be no greater than 1.0 hours.	Design Phase: Centralised RAM Analysis Report. Delivery Phase: Subsystem RAM KPI Report.

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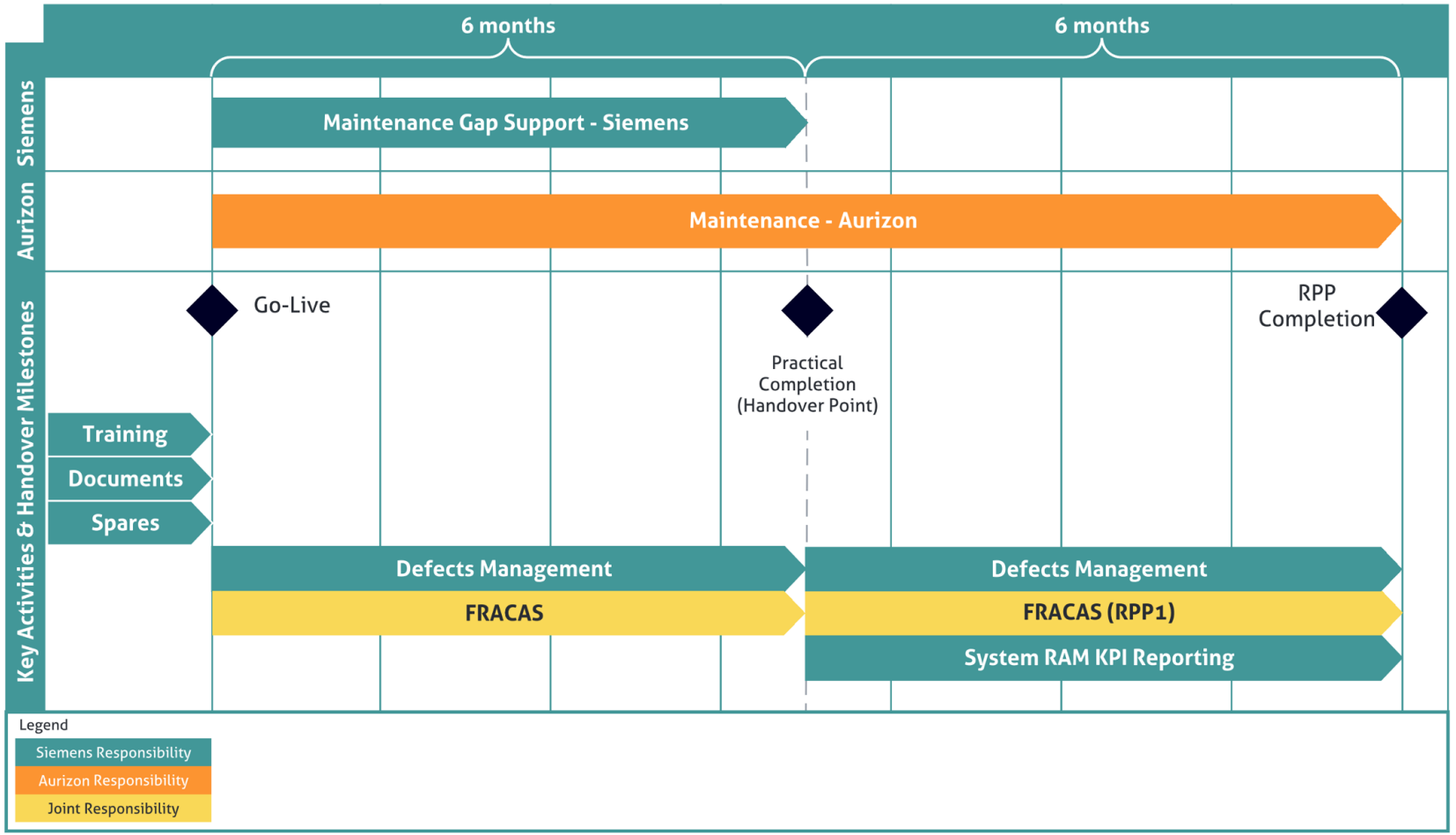
Project Maintenance Strategy for Phase 2



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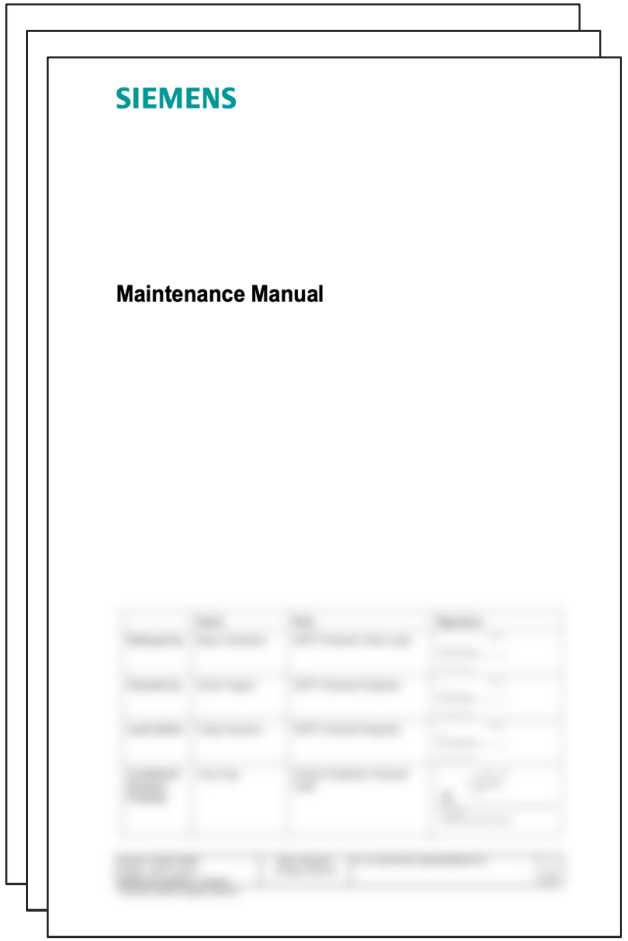
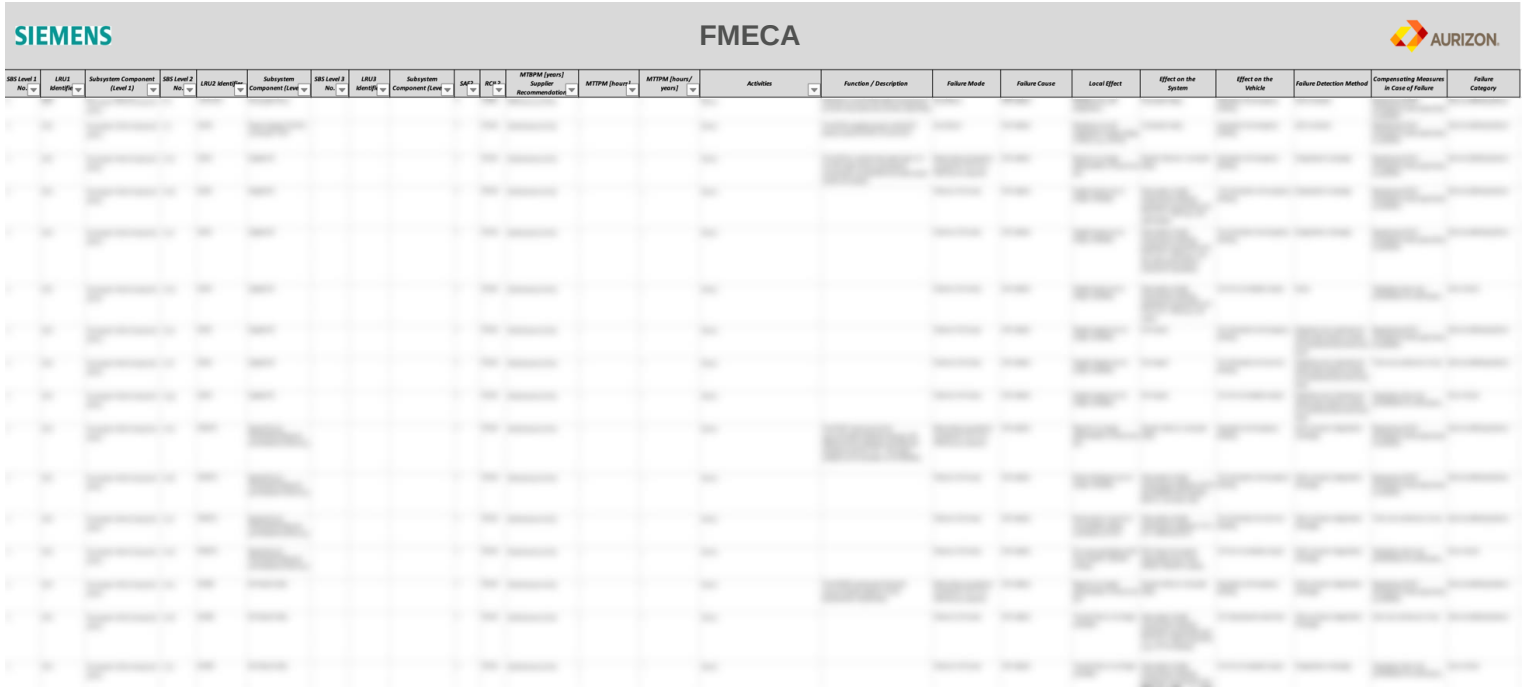
Maintainability demonstration test (MDT) process

1. Select Preventive and Corrective Maintenance Tasks

Case Study – Aurizon Trainguard Project

1. Select Preventive and Corrective Maintenance Tasks





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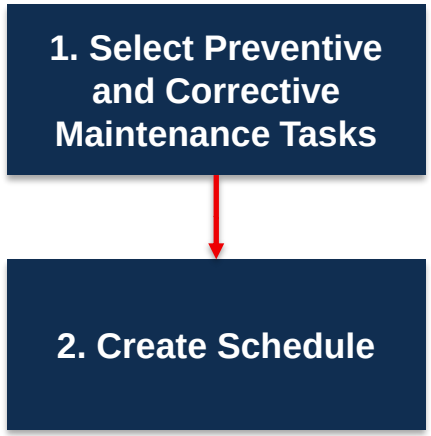
Maintainability demonstration test (MDT) process



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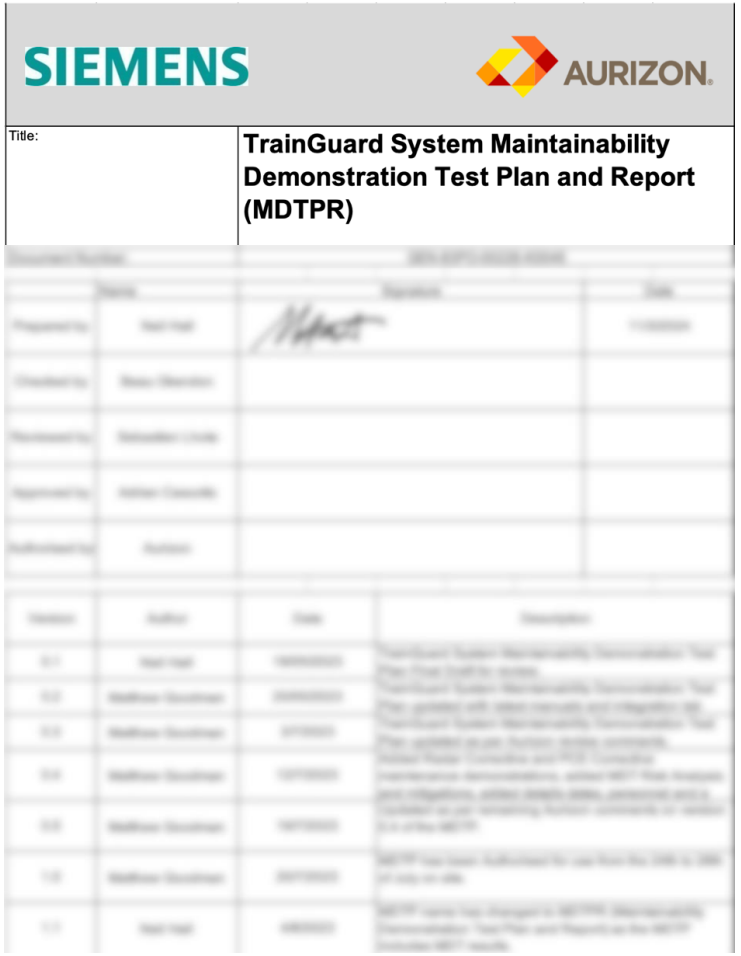
2. Maintainability demonstration test (MDT) scheduling



SIEMENS AURIZON

Title:	TrainGuard System Maintainability Demonstration Test Plan and Report (MDTPR)

- **MDT schedule information:**
  - Test Number
  - MDT subsystem
  - MDT Task Title and Description
  - MDT Maintenance Level
  - MDT Location
  - MDT Date
  - Required Tools and Equipment
  - Applicable Maintenance Manuals
  - Nominated Maintainers (Aurizon)
  - MDT Witness
  - Technical Support (Siemens)

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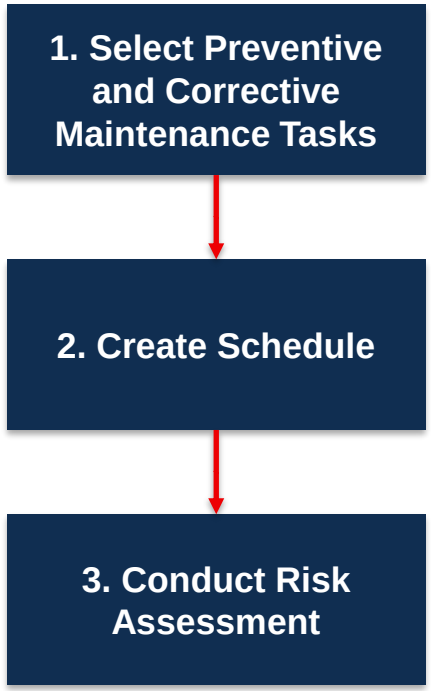
Maintainability demonstration test (MDT) process



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3. MDT risk assessment

- **MDT task risk assessment:**
  - Performed during commissioning shutdowns.
  - Each MDT was risk assessed separately.
  - Assessment results were used to estimate test time contingency.
  - Prioritisation of MDTs.
  - MDT grouping.

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Maintainability demonstration test (MDT) process

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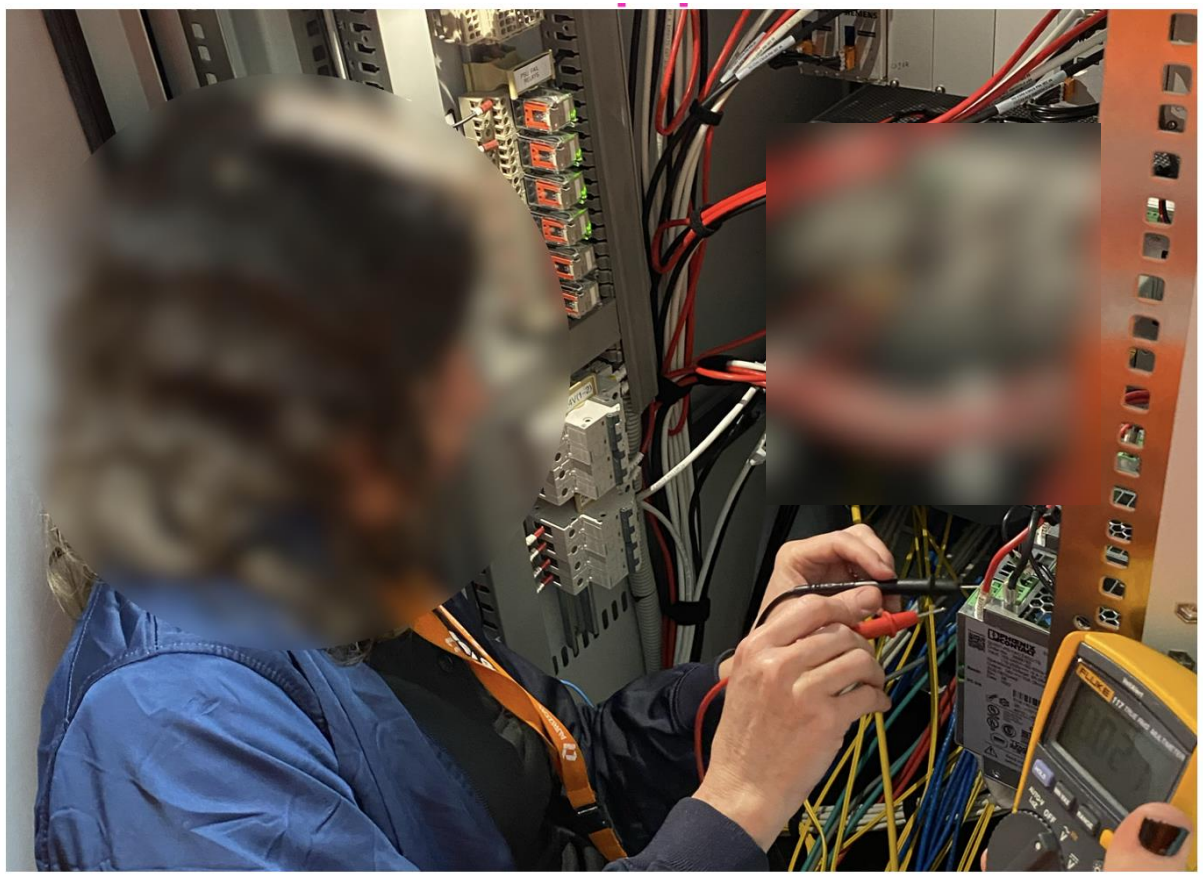
4. Personnel, Training, Documents, Spares, Software, Tools and Equipment



- **Personnel**
  - The skills, experience, and availability of maintenance personnel and technical support
- **Training**
  - Ensured personnel know the systems they maintain and the procedures they must follow. Also, the necessary training is needed to access MDT sites.
- **Documentation**
  - Maintenance documents, such as manuals and procedures.
- **Spares**
  - Ensure spare parts are available to perform maintenance tasks promptly.
- **Software**
  - Software necessary for diagnostics, monitoring, and managing maintenance activities.
- **Tools and Equipment**
  - Tools and equipment necessary to perform maintenance tasks efficiently and safely.
- **Maintenance Environment**
  - A well-organised and safe maintenance environment minimises the risk of errors, accidents, and inefficiencies.

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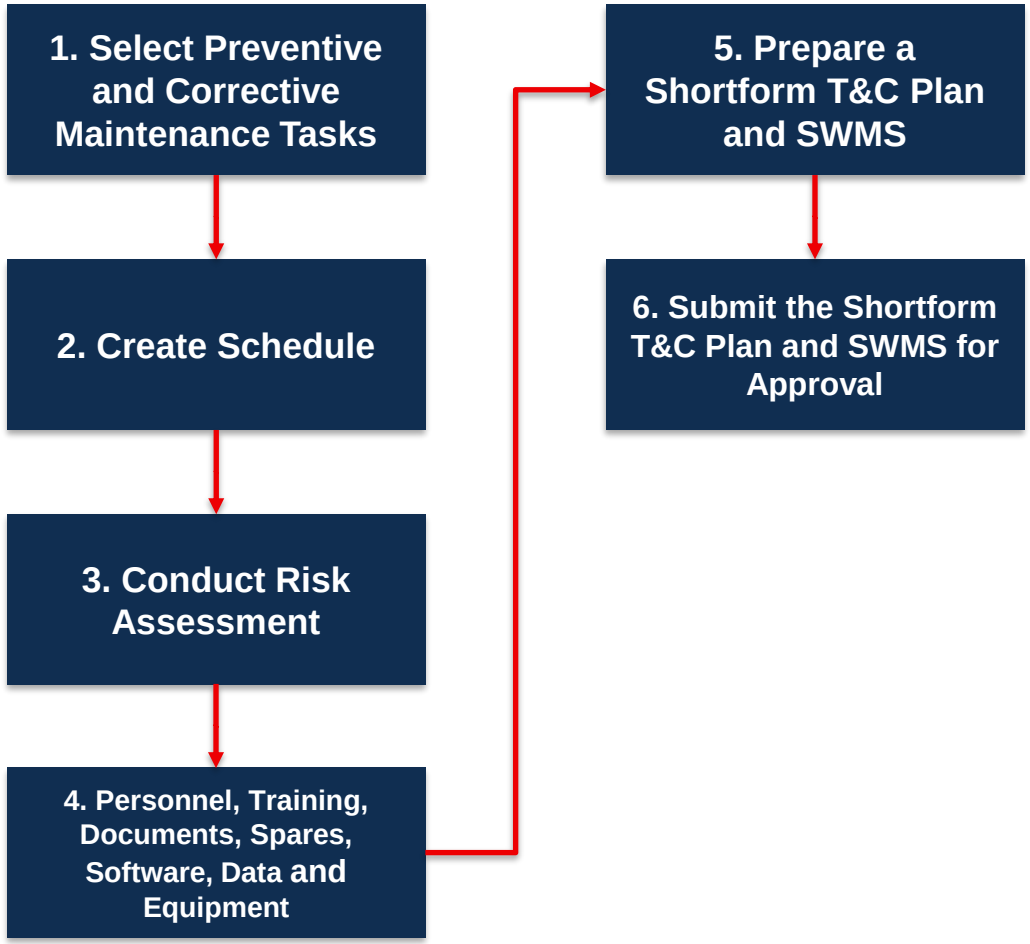
Maintainability demonstration test (MDT) process



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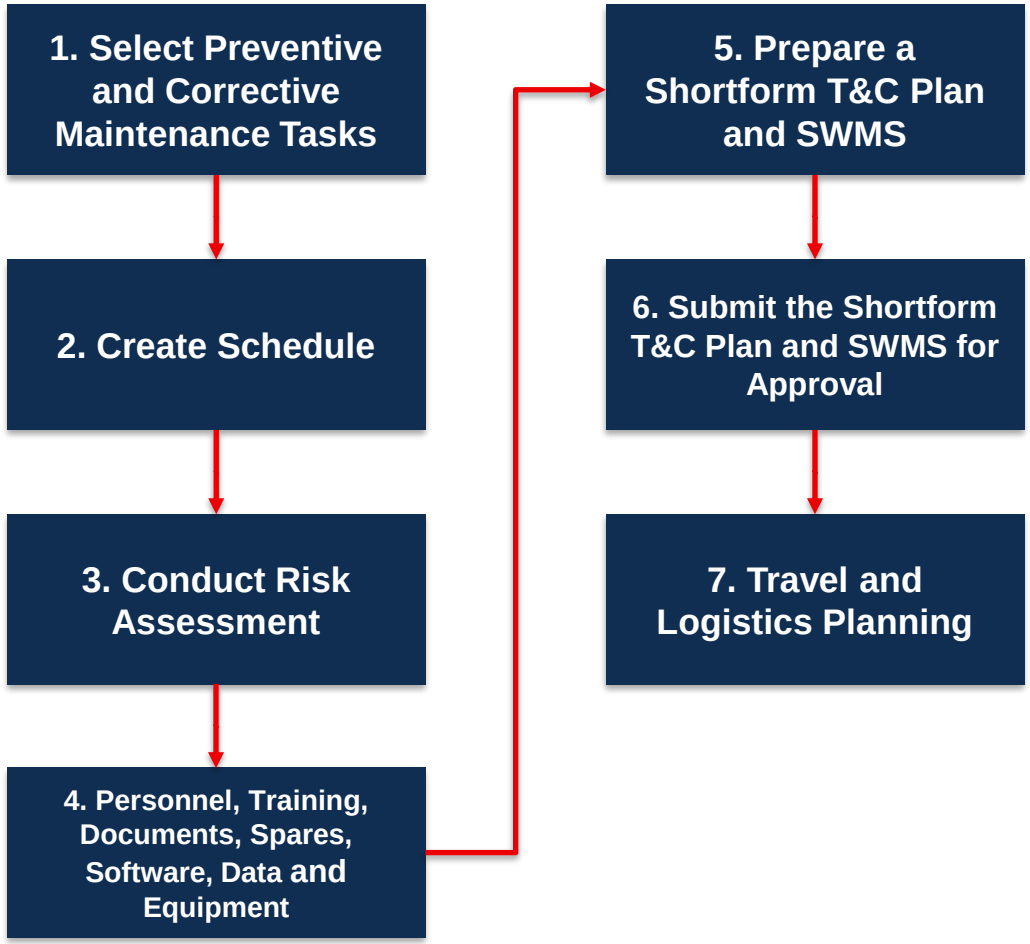
Maintainability demonstration test (MDT) process



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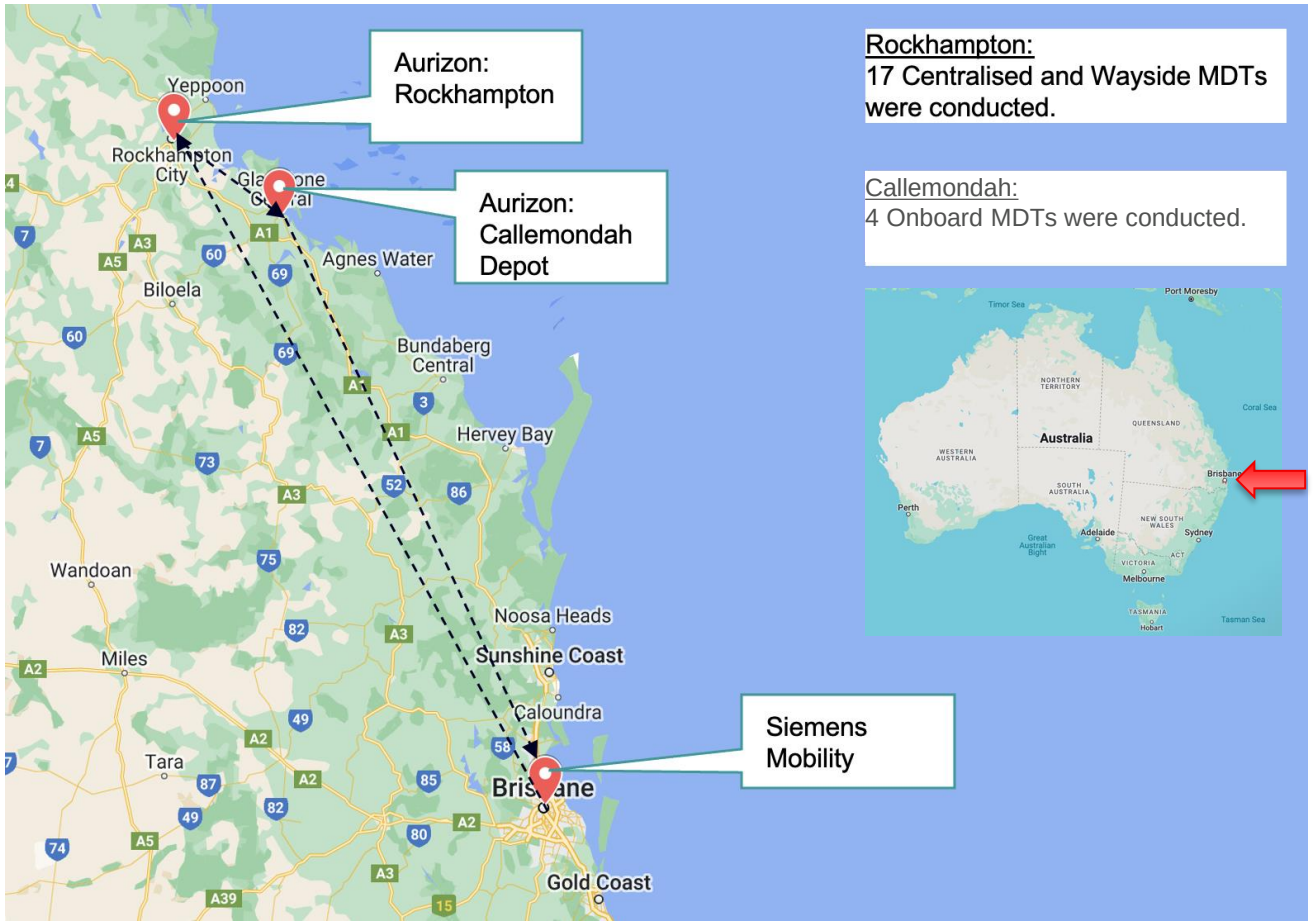
7. Travel and Logistics Planning



- **MDT Part 1 and 2**
- **Travel and accommodation**
  - Coordinating travel and accommodation was crucial to ensure that all necessary personnel were present at the test site on time and well-rested.
- **Availability of personnel**
  - Ensuring that the right personnel, including skilled technicians and support staff, were available was critical for
- **Availability of locomotives**
  - The availability of locomotives was essential for practical onboard equipment testing.
- **Availability of technical support**
  - Technical support, on-site and on-call, was vital for addressing unforeseen issues during the tests.
- **Tools, equipment, software**
  - Fundamental for performing the maintenance tasks involved in the tests.
- **Time constraints**
  - Adhering to time constraints was critical to avoid disruptions to the overall schedule and service.

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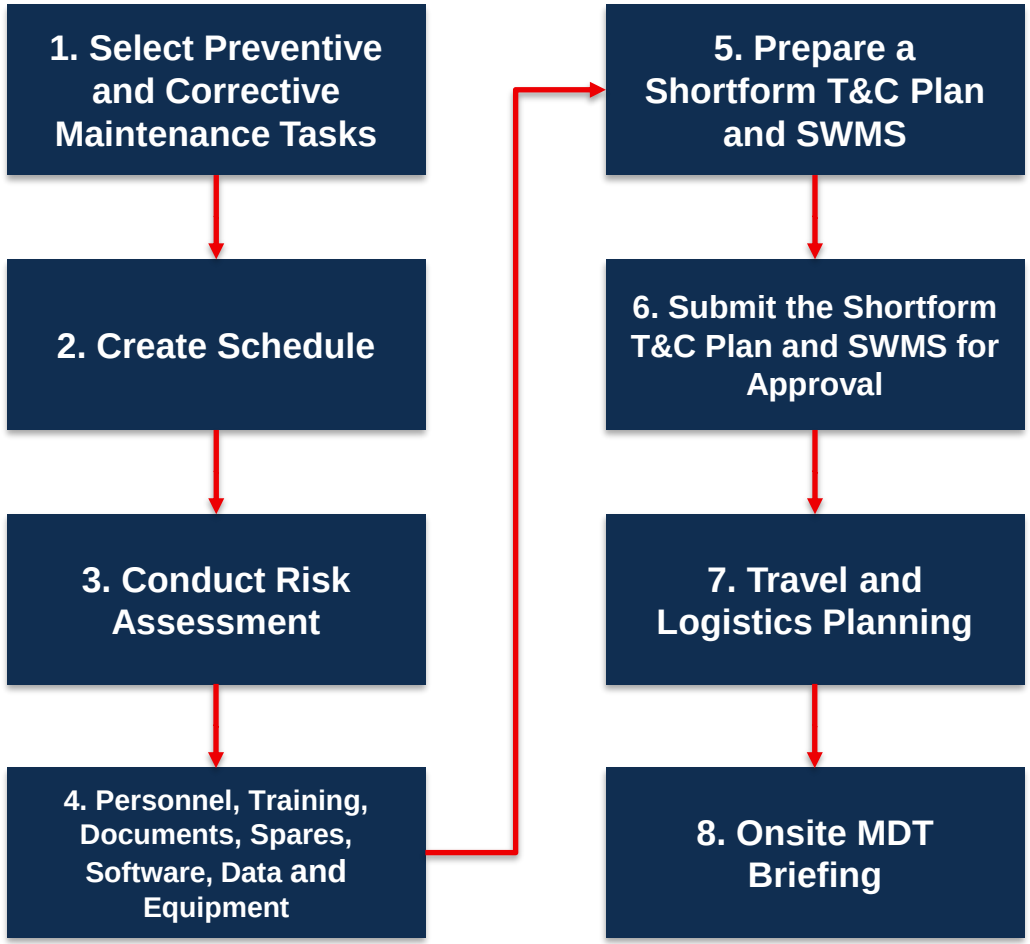
Maintainability demonstration test (MDT) process



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8. Onsite MDT Briefing

- **Before starting the MDTs**
  - Purpose and scope.
  - Number, timings and groupings of MDT.
  - MDT process.
  - Q&A session.
- **During the MDTs**
  - Explain the scope and purpose of each test.
  - Step-by-step walkthrough of MDT procedures.
  - MDT time allowance.
  - Required tools and equipment.
  - Reinforce safety protocols.
  - Q&A.

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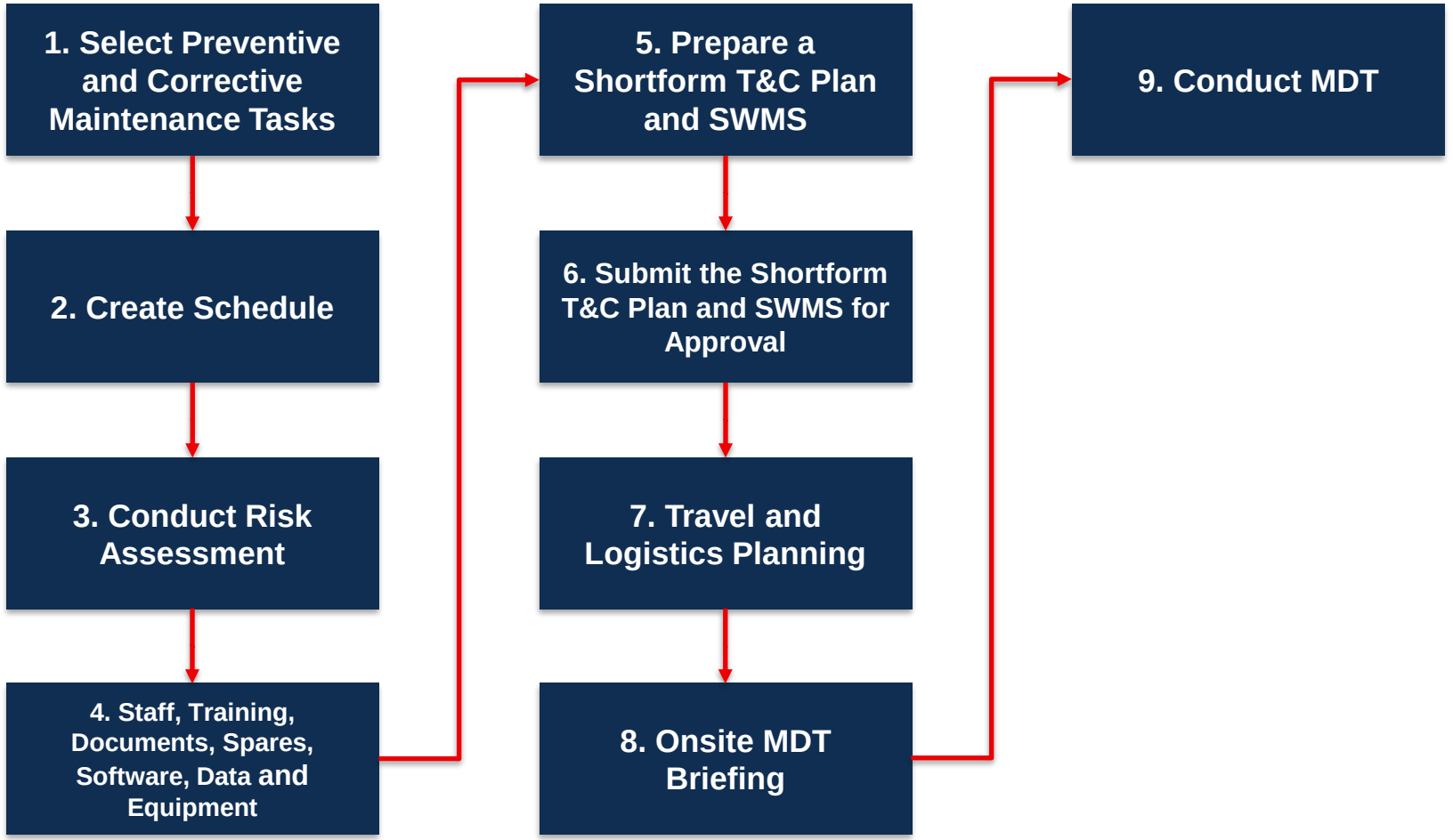
Maintainability demonstration test (MDT) process



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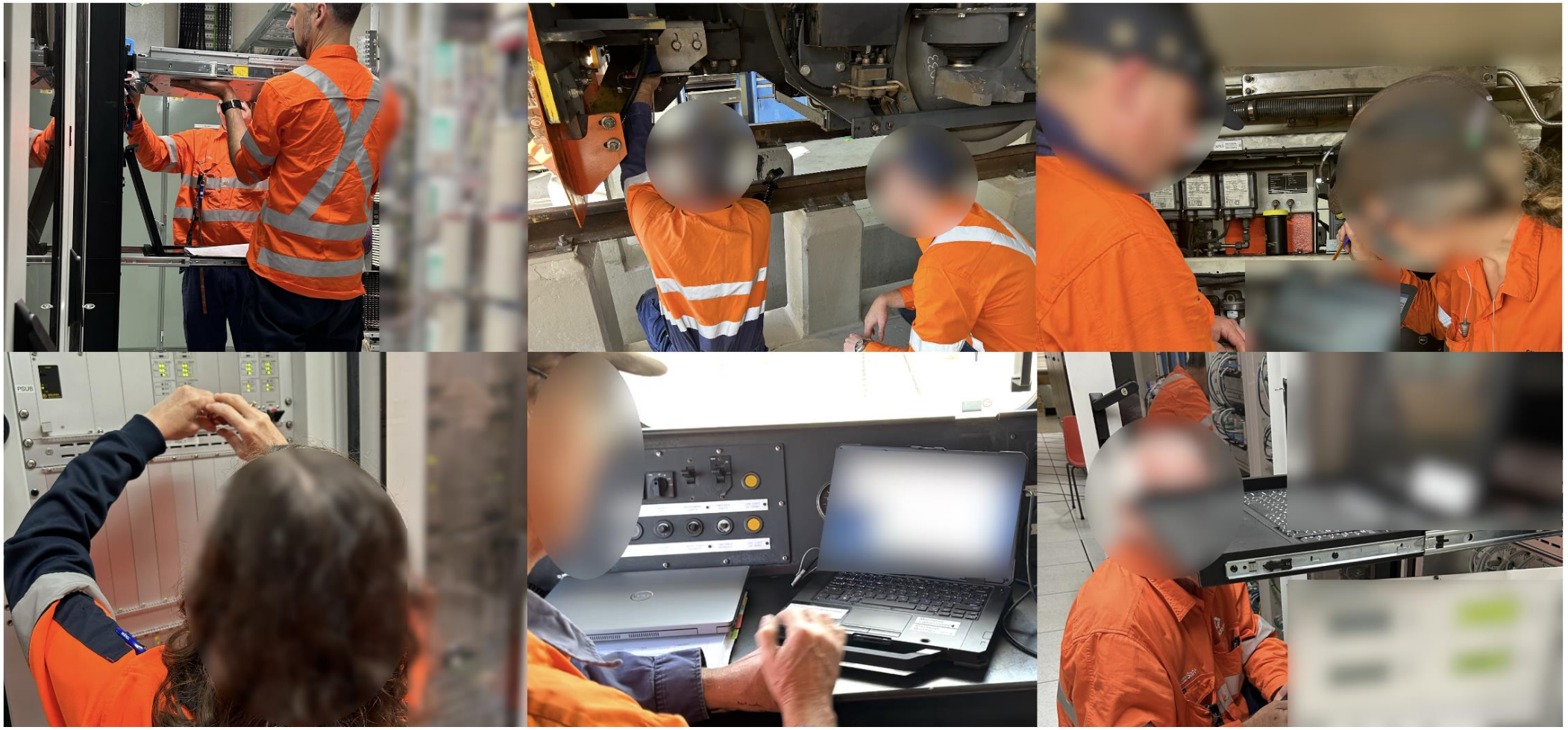
9. Conduct MDT



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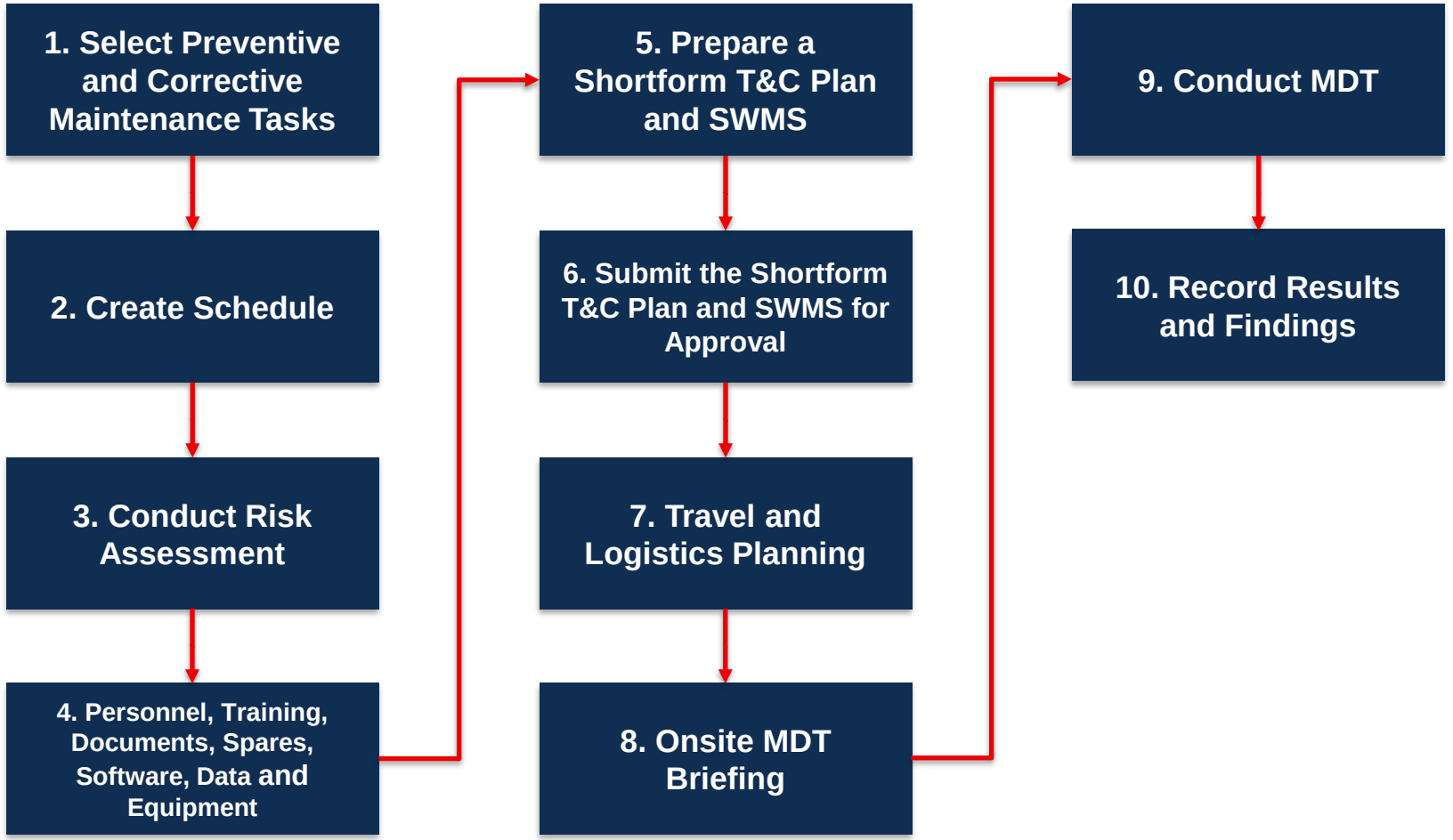
Maintainability demonstration test (MDT) process



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10. Record Results and Findings

SIEMENS AURIZON

Related Maintenance Manual:			
Maintenance Manual Section:			
Maintenance Task			
Maintenance Task Time			
Test Location			
	Name	Signature	
Maintainer (Aurizon)			
Witness (Siemens)			

Step	Method	Planned Activity Time (minutes)	Recorded Activity Time (minutes)	Remarks	Recommendations
Info					
1					
2					
3					
4					

- Results from each MDT were recorded and used to calculate the subsystem's MTTR using the formula below.
- These calculated results were compared with the predicted outcomes from the design phase RAM analysis.

$$MTTR_s = \sum_{i=1}^{n} \left\{ \frac{m_i MTTR_i \lambda_i}{\sum_{i=1}^{n} m_i \lambda_i} \right\}$$

MDT Results Comparison with Targets					
System	Requirement ID	Maintenance level	MTTR target [hrs]	Calculated MTTR - MDT [hrs]	Remarks
Onboard					
Onboard					
Centralised					
Wayside					

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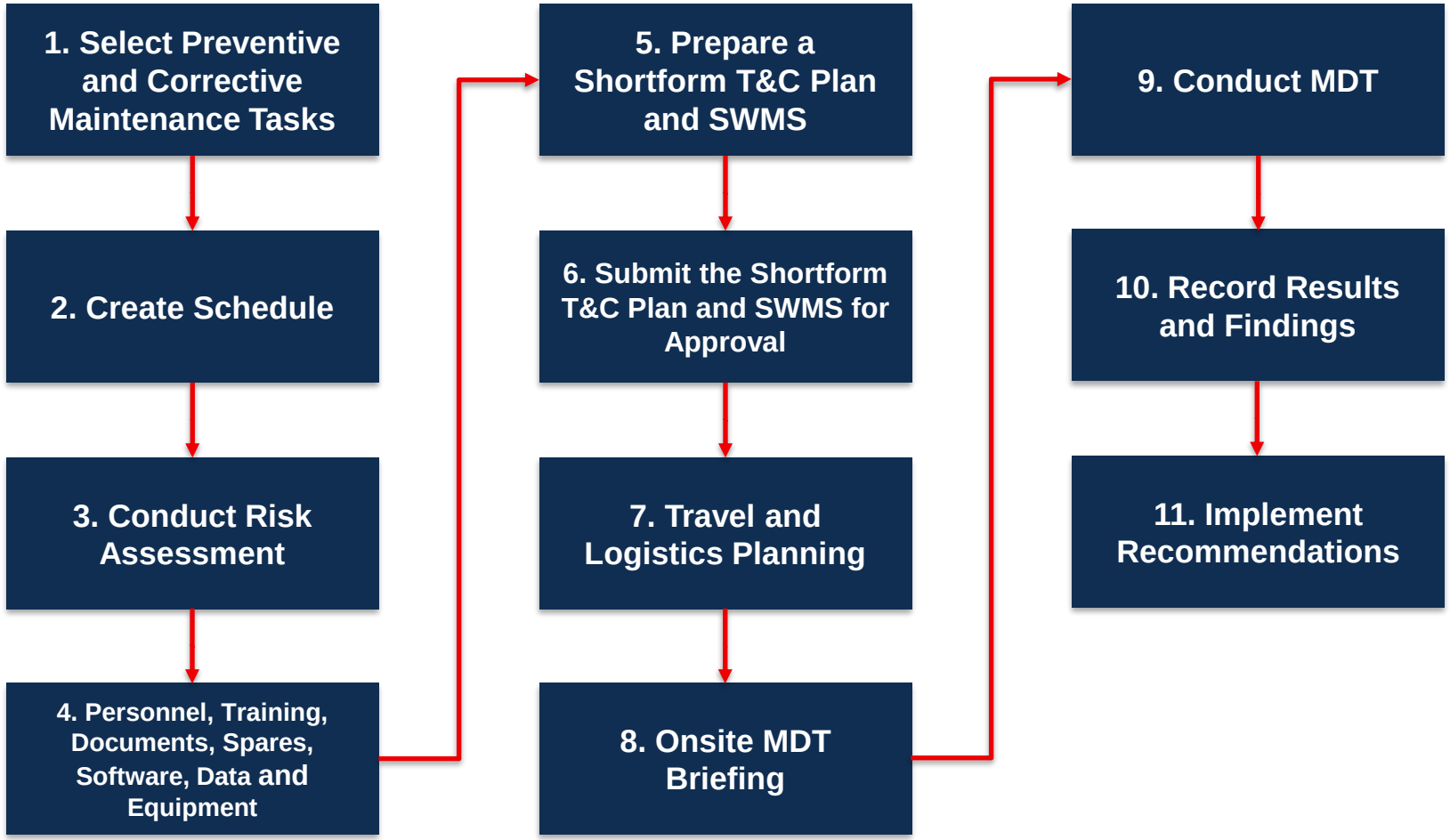
Maintainability demonstration test (MDT) process



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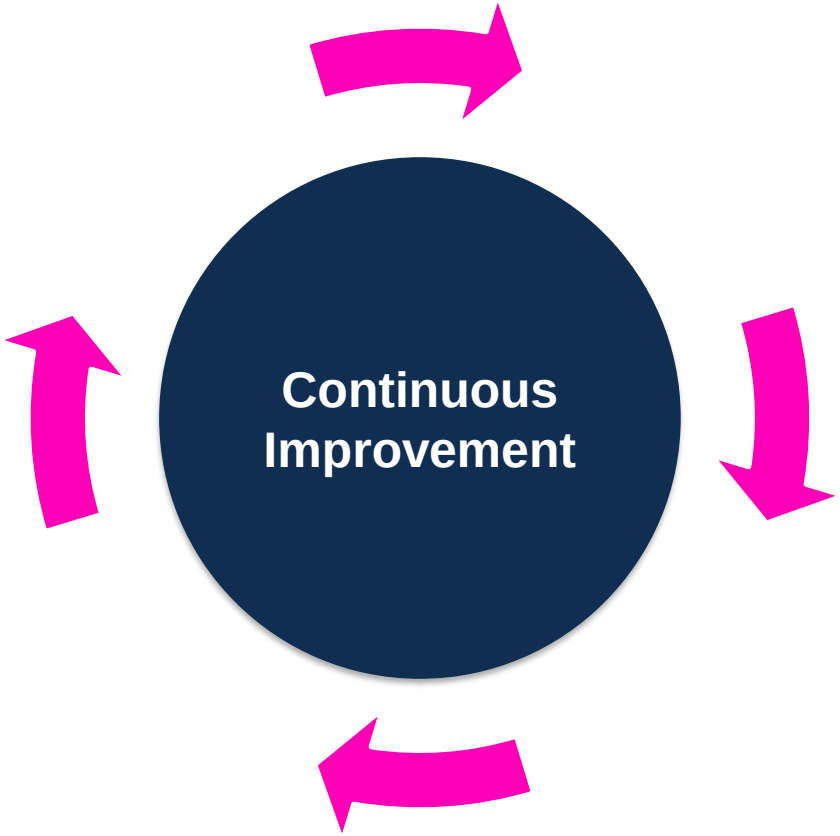
11. Implement Recommendations

- Improved Documentation Quality
- Identification of Training Gaps
- Verification of Maintenance Procedures
- Safety Assurance
- Operational Readiness
- Feedback for Design Improvements
- Increased Maintainer Confidence
- Early Detection of Issues
- Enhanced Communication



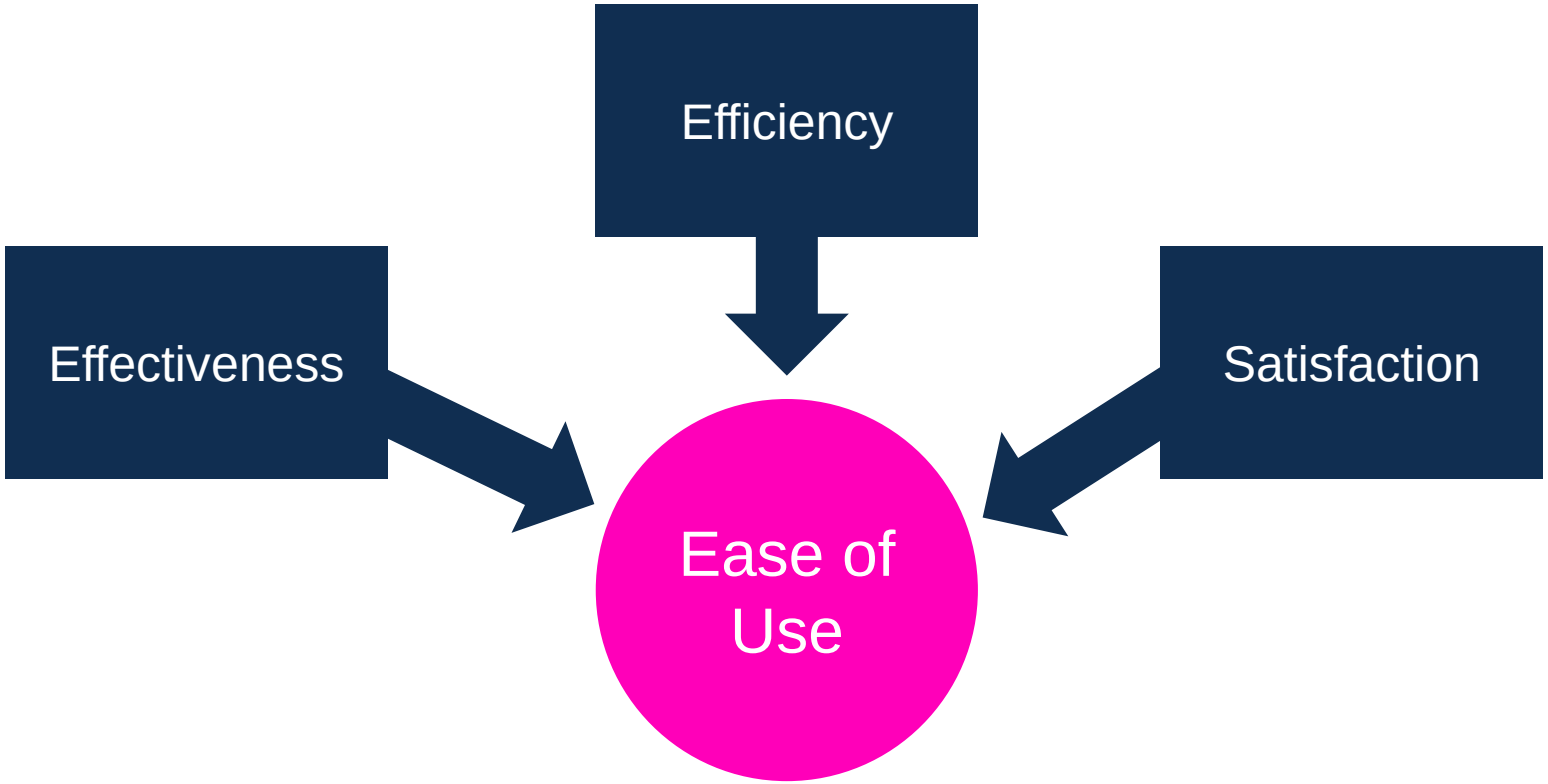
Human Factors Engineering and Maintainability

- What is the view from Human Factors Engineering on maintainability?
- Can we treat maintainability as a usability problem?
- How can Human Factors Engineering be used to enhance the measurement of maintainability?

Is Addressing Maintainability the Same as Dealing With Any Other Human Interaction?

Similarities	Differences
End User Involvement: Both prioritise involving end users in the assessment process.	**Context-Specific Applications**: Maintainability focuses on the ease of performing maintenance tasks. Other interactions may focus on job design, user satisfaction, or communication effectiveness.
Cognitive Ergonomics: Aims to reduce cognitive load and simplify information processing.	**Task-Specific Ergonomics**: Maintainability emphasises accessibility and ease of handling components. Other interactions may focus on control room layout, software interface design, or workstation ergonomics.
Safety and Risk Management: Both are concerned with identifying and mitigating risks and errors.	**Training and Skill Requirements**: Maintainability often requires specialised training for complex systems and technical repairs. Other interactions may require broader skill sets like customer service or general equipment operation.

What Does Usability Mean?



How Can We Measure Usability?

Metric	Validation Question	Measurement Formula	Notes
Task Completion	What proportion of tasks are completed?	Number of tasks completed / Total number of tasks attempted	The closer to 1.0 the better
Task Effectiveness	What proportion of the goals of the task are achieved correctly?	The sum of the proportions of each incorrect component in the task output	Use a scoring system for task effectiveness
Error Frequency	What is the frequency of errors?	Number of errors / number of tasks attempted	The closer to 0 the better
Task Time	How long does to take to complete a task?	Time on task	Generally, the smaller the better
Task Efficiency	How efficient are the users?	Task Effectiveness / Task Time	Generally, the larger the better
User Satisfaction	How satisfied is the user?	Standardised satisfaction questionnaire	Dependent on questionnaire

How Can We Bring Together Usability and Maintainability?

- Can use usability metrics to extend quantitative definitions of Maintainability
- For example, considering task efficiency alongside task time (mean time to repair)
- MTTR is a measure of time taken to carry out a task
  - Time taken = measure of efficiency
  - But not the only measure of efficiency
- For example, if the effort or workload (another measure of efficiency) was too high, would meeting the MTTR target be ok?

Practical Example: System Diagnostics

Validation Objective	Measure	Finding
Demonstrate that maintenance tasks can be completed effectively to the required standard.	At least 78% of general tasks are completed without assistance. Use error frequency (task attempts / observed errors) is better than 0.03.	**Pass** 99% of scenario tasks were carried out without the assistance from the facilitator. Use error frequency was 0.02.
Demonstrate that maintenance tasks can be performed efficiently.	The workload associated with the tasks is rated at 4 or less on the Modified Cooper-Harper Workload Scale.	**Pass** The median value from participants Cooper-Harper ratings was 3.

Summary

Summary

- Maintenance Demonstration Testing is crucial for several reasons:
  - MTTR: It is difficult to measure MTTR in the field.
  - Verification of Maintainability: Confirms that the system can be maintained within the specified parameters and timeframes.
  - Identification of Issues: Detects potential maintenance problems or inefficiencies before they impact operations.
  - Validation of Procedures: Ensures that maintenance procedures are practical, effective, and can be executed as planned.
  - Training and Familiarisation: Provides hands-on experience for maintenance personnel, improving their skills and familiarity with the system.
  - Safety Assurance: Verifies that maintenance activities can be performed safely, reducing the risk of accidents and ensuring compliance with safety standards.
  - Cost Efficiency: Helps to optimise maintenance processes, potentially reducing downtime and associated costs.
  - Dependability Improvement: Contributes to overall system availability by ensuring that maintenance can be performed quickly and effectively, minimising operational disruptions.

Summary

- If we see Maintainability as involving a specific type of Human Factors Engineering, we can find avenues for improvement
- In particular, seeing Maintainability as a type of ‘usability’ helps us structure and measure Maintainability requirements

Questions

Thank you

Advancing Railway Dependability: A Case Study on ETCS Level 2 Maintainability Demonstration

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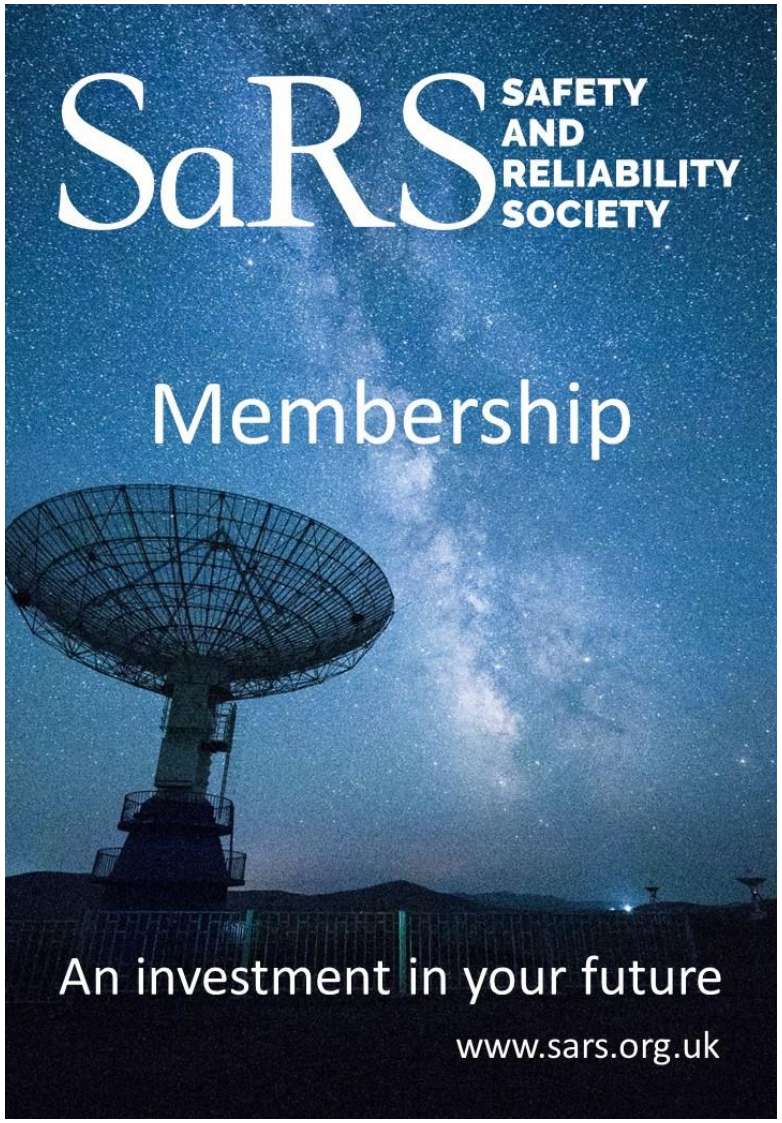

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UPCOMING WEBINAR

- **London Branch: Santiago Rail Crash – Failure to do a risk assessment.** 9th October at 18:00 UK time. Presented by James Catmur, Director of JC and Associates. This will be a joint face-to-face meeting in London and online webinar event.

- **London Branch: Application of Engineering Safety Management on a Major Project - Lessons Learnt.** ***From Crossrail to the Elizabeth Line.*** This will be a 3 part series starting with Part 1 on the 16th October at 12:30 UK time. The series will be presented by a team of system safety, engineering and integration experts drawing from a combined 50 years of experience on the Crossrail project alone

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