EU-RAIL SYSTEM PILLAR

System Requirements Specification - Condition Based Maintenance Deployment

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Abstract	This documents specifies a set of CBM requirements and related inputs for STIP (including examples and use cases), taking into consideration the scope, the concept and the limitations of CBM.
Config Item	System Requirements Specification
Document ID	02 CBM/ System_Requirements_Specification_Condition_Based_Maintenance_Deployment#833638 System Requirements Specification - Condition Based Maintenance Deployment
Classification	Public
Status	In Progress (first discussion in domain started)
Version	1.2
Revision	833638
Last Change Date	23.02.2026
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1 Preamble

1.1 Purpose

Pupose of CBM document
The purpose of this document is to specify a set of CBM (Condition-Based Maintenance) requirements (including examples and use cases), taking into consideration the scope, the concept and the limitations of CBM. **[**SPPRAMSS-15572, Text **]**

CBM document applicability
The present document is applicable for product, sub-system and system railway operation.
[SPPRAMSS-15998, Text **]**

Limitation in the scope of the CBM document
The CBM implementation options presented in this document are all related to the vehicle performance; the infrastructure is not considered, this is a known limititation of this document in the implementation of the CBM.
[SPPRAMSS-16261, Issue **]**

1.2 Intended Audience

CBM document intended audience
This document is intended for the following users:

- Engineering Environment Team (to ensure harmonisation of content compared to the SPPRAMSS-4179 - [ERJU - SEMP]),
- System Pillar domains,
- Innovation Pillar teams,
- PRAMS engineers part of mirror group(s),

In addition, this document can be shared with a wider audience for informal opinion reviews:

- PRAMS engineers outside ERJU,
- Any other stakeholder from the railway sector.

Comments will be handled by the PRAMS team but they cannot block the delivery of the document in case of disagreement with the PRAMS team.
[SPPRAMSS-15573, Text **]**

1.3 Document Context

CBM document context
This document, according to SPPRAMSS-349 - [EN 50126-1:2017], shows the CBM requirements specification by the PRAMS team of ERJU. It reflects the discussion in the PRAMS team for the ERJU System Pillar. **[**SPPRAMSS-15574, Text **]**

1.4 Glossary

1.4.1 Terms and definitions

Term	Status	Definition
SPPR-2246 - Application Condition	Deleted	

Term	Status	Definition
		This definition was merged with SPPR-3728 - Application Condition. Referenced by: SPPR-2244

HOF - Human and Organisational Factors
Human and Organisational Factors (HOF) are at the heart of safety operations and management. They even play a key role in both Operational Safety and Occupational Safety. **[**SPPRAMSS-11147, Definition **]**

PdM - Product data Management
Product data management (PDM) is the name of a business function within product lifecycle management (PLM) that denotes the management and publication of product data.[1] In software engineering, this is known as version control. The goals of product data management include ensuring all stakeholders share a common understanding, that confusion during the execution of the processes is minimized, and that the highest standards of quality controls are maintained. PDM should not be confused with product information management (PIM). **[**SPPRAMSS-11146, Definition **]**

RCM - Reliability Centred Maintenance
The concept of reliability centred maintenance is defined in SPPRAMSS-11144 - [IEC 60300-3-11:2009].

Reliability-centered maintenance (RCM) is a concept of maintenance planning to ensure that systems continue to do what their users require in their present operating context. Successful implementation of RCM will lead to increase in cost effectiveness, reliability, machine uptime, and a greater understanding of the level of risk that the organization is managing. **[**SPPRAMSS-11145, Definition **]**

SRAC - Safety related application conditions
This definition was merged with: SPPR-3728 - Application Condition **[**SPPR-2244, Definition **]**

1.4.2 Abbreviations

- CBM
condition-based maintenance

preventive maintenance based on the assessment of physical condition

Note 1 to entry: The condition assessment may be by operator observation, conducted according to a schedule, or by condition monitoring (192-06-28

SPPRAMSS-4462 - condition monitoring, <of an item>) of system parameters.

[SOURCE: IEC 60050-192:2015, 192-06-07] **[**SPPRAMSS-4079, Definition **]**

- CCS-OB
Control-Command and Signalling - On Board **[**SPPRAMSS-97, Definition **]**

- Diagnostics
Diagnostics is the assessment of health and performance of an asset or a group of assets. Furthermore, the diagnostic system also provides all information of single components in the field like: software version, parametrisation file version, firmware version, hardware version, manufacturer part number, manufacturer serial number, ID in the field (e.g. NID_ENGINE), cumulated hours in operation, IP address, etc. The latter is being used for analysis purposes.
[SPT2TS-48931, Definition **]**

- FMECA
failure modes, effects and criticality analysis
quantitative or qualitative method of analysis that involves failure modes and effects analysis together with a consideration of the probability of the failure mode occurrence and the severity of the effects
Note 1 to entry: The term "fault mode, effects and criticality analysis" in IEC 60050-191:1990 (now withdrawn; replaced by IEC 60050-192:2015) is deprecated, since a fault (192-04-01) is a state and cannot logically have a mode, whereas a failure mode (192-03-17) is a change of state.
[SOURCE: IEC 60050-192:2015, 192-11-06]

Note 2 to entry: FMEA is a systematic method of evaluating an item or process to identify the ways in which it might potentially fail, and the effects of the mode of failure upon the performance of the item or process and on the surrounding environment and personnel.
Failure modes may be prioritized according to their importance. The prioritization can be based on a ranking of the severity alone, or this can be combined with other measures of importance. When failure modes are prioritized, the process is referred to as failure modes, effects and criticality analysis (FMECA).
[SPPRAMSS-4047, Definition **]**

- PRAMS
Performance, reliability, availability, maintainability, safety **[**SPPRAMSS-5300, Definition **]**

- Sub-system (sometimes called “Building Block”)
Sub-systems are along ARCADIA systems on System Level 5. Not to be confused with sub-systems in the TSI / interoperability directive. In the TSI / interoperability directive context a sub-system shall be regarded as a interoperability constituent
A sub-system is a part of a system, which is not split into smaller entities. It represents a leaf element in the hierarchy of systems-of-systems.
Physically speaking, a sub-system is either a piece of hardware plus software, or just a piece of software.
A sub-system is a source able unit of the CCS system, in particular:

- a sub-system can be individually tendered to a supplier,
- a sub-system can be built individually by a supplier,
- a sub-system must be integrated into a system, which includes all necessary test, verification, certification and validation activities depending on the level of harmonisation.

The harmonisation of the sub-system’s features is to be defined according to the requested level:

- Functional Apportionment,
- Interoperability,
- Exchangeability, or
- Interchangeability.

[SPT2ARC-1013, Definition **]**

1.5 References

SPPRAMSS-16260 - [IEC 60812]
Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)

SPPRAMSS-349 - [EN 50126-1:2017]
Railway Applications – The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Generic RAMS Process

SPPRAMSS-335 - [EN 50126-2:2017]
Railway Applications – The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 2: Systems Approach to Safety

SPPRAMSS-336 - [EN 50128:2011 + A2/2020]
Railway Applications – Communication, signalling and processing systems - Software for railway control and protection systems

Nota: The standard is superseeded by SPPRAMSS-8814 - [EN 50716:2023], but the SPPRAMSS-328 - [Commission Implementing Regulation 2023/1695 "TSI CCS"] does not mention yet the standard.

SPPRAMSS-8814 - [EN 50716:2023]
Railways Applications - Requirements for software development

SPPRAMSS-334 - [EN 50129:2018/AC:2019-04]
Railway applications - Communication, signalling and processing systems - Safety related electronic systems for signalling

SPPRAMSS-634 - [EN 50657: 2017/A1:2023]
Railways Applications - Rolling stock applications - Software on Board Rolling Stock
Note: Document will be superseded by prepared EN 50716:2023

SPPRAMSS-11144 - [IEC 60300-3-11:2009]
Dependability management - Part 3-11: Application guide - Reliability centred maintenance
IEC 60300-3-11:2009 provides guidelines for the development of failure management policies for equipment and structures using reliability centred maintenance (RCM) analysis techniques. This part serves as an application guide and is an extension of IEC 60300-3-10, IEC 60300-3-12 and IEC 60300-3-14. Maintenance activities recommended in all three standards, which relate to preventive maintenance, may be implemented using this standard. The previous edition was based on ATA1-MGS-3; whereas this edition applies to all industries and defines a revised RCM algorithm and approach to the analysis process.

SPPRAMSS-11148 - Common safety methods on safety management system requirements]
COMMISSION DELEGATED REGULATION (EU) 2018/762 of 8 March 2018 establishing common safety methods on safety management system requirements pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulations (EU) No 1158/2010 and (EU) No 1169/2010

SPPRAMSS-11150 - [EuroSpec - Accelerator for user-oriented harmonisation of rolling stock]
This future EuroSpec “On-board Data Availability” will contain two topics: 1. Diagnostic Data and 2. Operational Data and other on-board data. This specification will cover hardware and software requirements for trains car builders and equipment suppliers.

MDCM-Introduction

2 Definition of the scope and concept of CBM

Definition of the scope and concept of CBM
The Condition-based maintenance (CBM) for Rail Systems is a maintenance strategy for the performance of Maintenance based on the actual condition of assets.CBM focusses on the actual condition and notices when certain (alarm/minimum) thresholds are passed, i.e. it monitors the actual condition of a system.
Very similar is the ‘Predictive Maintenance’ (PdM), which is based on the same (or additional) data points and on an algorithm for monitoring and predicting the degradation curve (health) of systems; as result, it predicts when determined thresholds (alarm/minimum) will be passed.
Generally, the CBM implementation is aimed at:

1. reducing preventive maintenance since the manual inspections may be replaced by a sort of remote monitoring;

2. prevent a certain amount of failures occuring in operation in order to save corrective maintenance costs,
3. enhance or better utilize component lifetimes as they are not replaced based on time, but on actual condition, therefore also material costs are saved (although it is limited with respect to corrective maintenance cost savings).

Ideally, with the implementation of Condition-Based Maintenance (CBM), maintenance activities are performed only when specific diagnostic indicators reveal declining performance or the likelihood of an impending failure. In this approach, dedicated monitoring equipment continuously assesses the condition of the assets and triggers targeted maintenance actions, thereby reducing the need for routine manual inspections.
According to SPPRAMSS-4079 - CBM , the condition-based maintenance is a preventive maintenance based on the assessment of physical condition; the condition assessment can be by operator observation, conducted according to a schedule, or by condition monitoring of system parameters. **[**SPPRAMSS-5731, Text **]**

General approach for defining a maintenance plan
A general approach for defining a maintenance plan, based on RCM-principles is provided within SPPRAMSS-11144 - [IEC 60300-3-11:2009]. This approach can be adapted to the needs within the railway system.
Common basic steps may be implemented:

1. Planning of CBM
2. Analysis of failure modes and failure consequences (FMEA / FMECA)
3. Evaluation of failure consequences and selection of appropriate maintenance principle
4. Realization
5. Continuous improvement

However, this approach does not take into account for continuous monitoring (CBM, PdM and prescriptive maintenance), as the options are the 'classical' maintenance policies as inspections, scheduled actions and deferred maintenance. **[**SPPRAMSS-10195, Text **]**

Assets to be characterized by CBM
The railway system is a complex system, considering of distributed subsystems on-board and trackside, further called assets. These assets can be characterized by:

- Long lifetime
- Based on different generations of systems (e.g. trains within a fleet, trackside assets) with consequently different monitoring options
- Availability of data and data quality

Therefore, the implementation of CBM into a system may serve different purposes:
1 CBM is used as backup or add on of current preventive maintenance. (RAM influenced)
Here, CBM is only supporting preventive maintenance (not replacing it).
The influence is mainly on RAM:
- Reliability: better detection of issues before failure.
- Availability: fewer unexpected breakdowns → higher uptime.
- Maintainability: better planning of maintenance actions, reducing downtime.
Safety is not directly affected, since preventive ,aintenence is still in place and CBM just optimizes it.
2 Implementing of CBM and change of some non-safety related maintenance processes. (RAM influenced)
When CBM replaces or modifies some maintenance tasks not directly tied to safety, the impact is still

only on RAM.
Example: adjusting lubrication schedules based on oil quality sensors.
This influences performance and cost efficiency but does not directly affect safety cases.
3 Implementing of CBM and change of some safety related maintenance processes. (RAMS influenced)
If CBM is used to change tasks that do impact safety (e.g., brake inspections, bogie bearing replacements), then Safety also becomes influenced.
CBM must be validated to ensure it still meets safety requirements under EN 50126 / EN 50129.
This requires formal RAMS demonstration (safety case, hazard analysis, approval by authorities).

[SPPRAMSS-5740, Text **]**

2.1 Assumptions and limitations related to CBM applicability

Introduction of CBM has technical as well as organizational implications
The introduction of CBM has technical as well as organizational implications.
Based on the characteristics mentioned in SPPRAMSS-5740 the following challenges were pointed out:

1. Collection and analysis of all the data streams that come from the numerous on-board sensors monitoring the assets. The conditions e. g. the bandwidth to transmit the data can differ between on-board and trackside assets. Nowadays, most of the CBM activities are performed on non safety related systems; and most of the SRAC are actually covered by humans following safety related processes. For a successful CBM implementation, it is necessary to define CBM application requirements for "non safety related" or "Basic Integrity Level" only.
   If safety related processes are involved, a safety analysis is necessary to allocate the SIL to the CBM system.
2. Prognosis of a remaining useful life time of the asset under the consideration of safety (if used for a safety related asset)
3. Handling of difficulties, dealing with data with different quantity and quality
4. Implementation of CBM within an organization and the resulting changes within processes (Railways, Infrastructure Manager). E.g. during a migration phase different maintenance principles are necessary (fixed cyclic inspection vs. condition based) which requires sufficient personnel and flexibility in carrying out the relevant maintenance activities

Some railway undertaking like SNCF and DB are implementing by themselves CBM processes on safety related functions. A further study for implementing CBM by the Vehicle Suppliers is provided in the current document (refer to section SPPRAMSS-8106 - Implementation of CBM). **[**SPPRAMSS-5732, Text **]**

2.2 Distinction between the scope of diagnostics and CBM

Distinction between the scope of diagnostics and CBM
A definition of diagnostics is given within the SP domain SPT2-TransversalSystems. It is defined in SPT2TS-48931 - Diagnostics.

It can be summarized that diagnostics focus on identifying specific issues or faults within an asset by collecting and analyzing various types of data (e. g. events, environmental data, operational states etc.). It covers the actual state and reveal problems already present. The ‘issue’ regarding diagnostics it that it is generally a reactive based system, that means that first an issue or fault has to occur, before the diagnostic system responds with a diagnostic message (the interface to the driver or maintenance staff).

Conversely, CBM is a use case that focuses on continuous monitoring to predict potential failures by analyzing real-time data and trends. Its aim is to forecast a failure before it occurs.

In contrast, diagnostics reactively identifies existing issues, CBM takes a proactive approach by assessing the system health through the use of predictive analytics and monitoring functions. This helps to reduce downtime and optimize maintenance.

The definition of data structures for diagnostic, also messages for the purpose of CBM is not in scope of PRAMS. This will be done within the affected domains.
[SPPRAMSS-10194, Text **]**

2.3 Definition of necessary preconditions and requirements

Definition of necessary preconditions and requirements
Implementing Condition-Based Maintenance (CBM) effectively requires certain preconditions to be in place from RAMS perspective. They can be derived from the basic steps necessary for implementation of CBM:

1. Reliability Analysis: A comprehensive reliability analysis of the asset has to be performed. This involves understanding failure modes, historical failure data and reliability metrics to identify critical components that warrant CBM implementation.
2. Availability, accuracy and integrity of of Critical Data: Access to critical data related to equipment performance, failure history and environmental factors that impact reliability. This data availability, acuracy and integrity are essential for effective CBM decision-making.
3. Maintenance Strategy Integration: Integration of CBM into the broader maintenance strategy, aligning it with existing maintenance practices and reliability-centered maintenance principles. This can enhance the overall RAMS objectives.
4. Risk Assessment and Safety Strategy: A risk assessment is necessary to identify potential safety hazards associated with CBM implementation. Safety requirements and mitigation strategies are helpful to minimize risks to personnel, assets and operation during CBM activities.
5. Training and Competency Development: Adequate training and development programs for personnel involved in CBM implementation shall be provided.

(from vehicles, infrastructure, maintenance plan, safety/reliability analyses, etc…) **[**SPPRAMSS-10196, Text **]**

2.4 Documentation for specifying or implementing CBM processes

Evaluation of CBM Safety Aspects
The following documents are normally required for specifying or implementing CBM processes (e.g. from vehicles, infrastructure, maintenance plan, safety/reliability analyses, etc…):

- Functional description of the equipment or systems under condition monitoring
- Procedures for condition monitoring and diagnostics
- Procedures for fault or defect handling
- Maintenance records
- Procedures to identify defects and failures that cannot be prevented by condition monitoring and diagnostics and to revise the CBM scheme accordingly
- System maintenance manual
- Maintenance schedule
- Roles and Responsibilities regarding the personal involved in Maintenance (and CBM), including training material for the involved people.

[SPPRAMSS-10193, Text **]**

2.5 Milestones

Document milestones
The document is created iteratively and comprises the defined milestones in SPPRAMSS-5701 - Milestones for 2024. **[**SPPRAMSS-7142, Text **]**

3 Evaluation of CBM Safety Aspects

Evaluation of CBM Safety Aspects
For the homologation of a railway system, it is necessary to provide evidence that the conditions for system safety acceptance are satisfied. This justification is normally realised through a structured safety justification document, like the safety case described in the SPPRAMSS-334 - [EN 50129:2018/ AC:2019-04]. A specific part of the safety case addresses the SRACs (Safety Related Application Conditions). Compliance with SRACs supports the safety demonstration and is thus a necessary part of the superordinate level Safety Case. SRACs normally represent requirements or procedures which cannot be satisfied/performed within a specific system and therefore shall be passed on to the final user (Operator / Maintainer); their observance is necessary to the continued safe operation of the system.
In case of an already validated and assessed system, the replacement of a SRAC by a Maintainer with a condition-based procedure represents a challenging issue, since the related CBM process in some cases:

- Shall be agreed with the system supplier and the Assessor, since it could be a significant change.
- Require specific safety analyses to allocate the SIL to the CBM system, if safety related systems are involved.

[SPPRAMSS-7113, Text **]**

CBM vs SRAC
The PRAMS team shall provide an analysis and requirements on the possibility to replace safety related preventive maintenance activities (i.e. through SRAC) by CBM ones. This will be done in a future release of the document. **[**SPPRAMSS-10191, Issue **]**

4 Expectations and requirements from other Domains

4.1 Diagnostics Domains

3.1 Diagnostics Domains
The diagnostics represent the main interface to CBM, namely for receiving inputs and, very important, to formulate specific requirements, in particular regarding the technicality on how the data is delivered; the data typology should be harmonised.
The SP Transversal Domain is developing a generic diagnostic concept Generic Diagnostic Concept; the document provides a generic concept of diagnostic and monitoring services for the CCS system and features the needs for standardisation of the diagnostic/condition data collection process. The development of this concept considers a high level and generic architecture including interfaces to be standardised to support the indented diagnostic and monitoring services.
The concept described in that document provides a generic solution for the whole CCS system (including on-board and trackside) considering it as a black box in the first step and intended to be further refined in the next phases following the SEMP methodology.
Examples of Inputs for CBM are juridical recorder data, field monitoring data and storage of the data.
[SPPRAMSS-10197, Text **]**

4.2 Domain for Human and Organisational Factors (HOF)

Domain for Human and Organisational Factors (HOF)
The HOF represents an important interface to CBM, since they impact on Maintenance Operations. A specific domain is developing clear and practical recommendations on how to implement HOF in companies in order to:

- improve their performance and safety levels.
- provide support within their internal organisation, in particular in the SMS (refer to SPPRAMSS-11148 - Common safety methods on safety management system requirements]

The Domains is also elaborating HOF specifications in the frame of EU Regulations (TSI/CSM/Standards/ SP documents) to the suppliers and operators for managing the HOF integration in all the project phases, in particular at the beginning; this includes HOF impact assessment, designing HOF plan, integration of HOF Team, HOF requirements. In this context, specific requirements related to HOF will be formulated. The CBM and HOF experts should assess the HOF requirements in order to strengthen the quality and efficiency of those requirements and to provide the necessary inputs, which may have impact on CBM. **[**SPPRAMSS-10198, Text **]**

4.3 Domain for PRAM, KPI's, definitions, apportionment to systems of target rail system

Domain for PRAM, KPI's, definitions, apportionment to systems of target rail system

As already specified in the ERJU PRAMS Plan, "the minimum level of performance is determined and influenced by technical and operational aspects on system, vehicle and operational level, such as but not limited to: reliability, availability, maintainability, safety, security, human factors, quality, mission profile, environment, environmental conditions, life cycle costs and laws and regulations. This means the scope and boundaries (span of control) of performance need to be defined clearly."

The Performance Domain is working on the refinement of Performance KPIs and definition of Performance Targets for a modular railway architecture (refer to System Concept - Performance KPI definition). Specific CBM procedures and any related modification of standard maintenance procedures may impact the performance. Therefore, the CBM Domain shall consider inputs coming from the Performance one and specify appropriate measures. **[**SPPRAMSS-10199, Text **]**

Work in the SP Domain Transversal

The SP Domain Transversal has initiated a configuration management process for the future CCS building blocks; on-board and trackside.

This is defined in the documents:

- TCCS Configuration - Operational Epics
- TCCS Configuration - High Level Concept
- TCCS Configuration - System Requirements
- Logical Concept
- TCCS Service Function Configuration (SFC) L5

The PRAMS team has been involved as reviewers for these artefacts.

The listed documents will not be updated anymore as their items are transfered to the SRS_TCCS - Part 3.

The general concept is described in SPT2TS-125572 - Environment and systems for the configuration management process . **[**SPPRAMSS-1229, Text **]**

5 Implementation of CBM

Implementation of CBM within SP

The first version of the document does not cover the deployment of the present CBM aspects within SP Domains. This is due to a lack of resources within the PRAM team to lead this task. This may be continued in a future remit (further than SC2.4). **[**SPPRAMSS-10185, Issue **]**

Implementation of CBM

Three different ways for implementing CBM can be identified:

1. CBM on MDCM (Mobile Data Communication Module)
2. CBM on native software of the vehicle
3. CBM on the ground on the server

[SPPRAMSS-10200, Text **]**

5.1 CBM on Mobile Data Communication Module (MDCM)

CBM on Mobile Data Communication Module (MDCM)
This way for implementing the CBM allows the operator to upload directly on MDCM the diagnostic functions on it. Various uses cases of MDCM are already implemented in the industry, refer as example to SPPRAMSS-8125
According to SPPRAMSS-11150 - [EuroSpec - Accelerator for user-oriented harmonisation of rolling stock]*, the Data Acquisition Module is the Hardware and software that acquires the configured data from the on-board systems (e.g. TCMS), while the Data Communication Module is the Hardware and software which transmits the collected data from the data acquisition module to the wayside and which receives the instructions from the wayside for data transmission.
The requirements for the MDCM are already specified in SPPRAMSS-11150 - [EuroSpec - Accelerator for user-oriented harmonisation of rolling stock] . For the implementation of CBM would be necessary to include specific functions and the CBM algorithm into the MDCM.
With this implementation, the MDCM will generate Counters, but also analog signals for voltage, current, pressure, etc..., which may be used for various purposes. However, it is necessary to have a MDCM which would be capable for such diagnostic functions.
Some specific maintenance requirements to potentially be added to MDCM are specified in section 6.1.1.
Advantages of the implementation onto the MDCM are:

- No need for developing specific functions on the train software
- Flexibility for the development of the specific CBM algorithm of each Operator.
- Various uses cases are already implemented in the industry.

Cons:

- Additional equipment to be mounted on the vehicle

(*) SPPRAMSS-11150 - [EuroSpec - Accelerator for user-oriented harmonisation of rolling stock] addresses Diagnostic Data Operational Data and other on-board data, covering hardware and software requirements for trains car builders and equipment suppliers. **[**SPPRAMSS-10201, Text **]**

5.1.1 OCORA MDCM documentation

OCORA MDCM documentation
An introduction of the MDCM for on-board (called MDCM-OB) and a system specification have been developed by the OCORA Team: SPPRAMSS-9974 - [OCORA release R3].
The introduction document SPT2TS-1098 - MDCM-Introduction aims to provide an overview about the main aspects, ideas and concepts for the OCORA MDCM-OB building block. It provides an overview of the MDCM-OB, the objectives, the relation with the Subset -149 and a roadmap
The Monitoring, Diagnostics, Configuration, Maintenance subsystem (MDCM-OB) is a building block of the OCORA CCS-OB architecture. Its main purpose is the provision of services for monitoring, diagnostics and configuration of onboard functions.
The specification document defines the system-level requirements for the OCORA Monitoring, Diagnostics, Configuration,
and Maintenance On-Board (MDCM-OB) building block. **[**SPPRAMSS-10202, Text **]**

5.2 CBM on the native software of the vehicle

CBM on the native software of the vehicle
For managing the maintenance data on the vehicle, it is assumed that it is not always possible to have a crew member on board with competences in data analysis. Therefore, it is needed to integrate fault detection and diagnostic logic into the condition monitoring itself.
This way for implementing CBM is meant to develop the native software of train with specific CBM functions, using the built-in diagnostics of the vehicle for providing the necessary inputs. This requires a specific development during the vehicle design phase.
An evaluation of the feasibility and applicability of the CBM is made during its development and approval; the technical and maintenance documentation is used for determining whether the condition monitoring

system can detect any problems through the inputs received from the diagnostics.
Dedicated CBM requirements for the hardware and the software for this case are specified in section 6.1.1; a part of more general requirements may be derived from the ones related to the MDCM and DAM (refer to SPPRAMSS-11150 - [EuroSpec - Accelerator for user-oriented harmonisation of rolling stock])
Advantages of the implementation onto native vehicle software are:

- Developing of diagnostic functions during vehicle design
- No need of additional equipment

Cons:

- More requirements for software developing and maintenance, which would become more demanding.

[SPPRAMSS-10203, Text **]**

5.3 CBM on the ground on the Operator's server

CBM on the ground on the Operator's server
With this kind of implementation, the Server on the ground collects and analyses the data coming from the vehicle.
According to the analysis results, a specific measure should be implemented depending on the specific monitored component/system. In particular, the maintenance schedule will change from planned to variable intervals.
The main issues in this case are the availability and the consistency of data, for which a data certification system is necessary. Moreover, the lack of data may also represent an issue, since a process should be established to decide the measures to be taken if the expected data is not delivered.
Advantages of this implementation of CBM are:

- No need for developing specific functions on the train software
- Maximum Flexibility for CBM algorithm.
- Various applications are already working.

Cons:

- Risk for inconsistencies of raw data coming from vehicles.
- Few standardisation
- More data transmitted to the ground (more bandwidth required)

[SPPRAMSS-10204, Text **]**

5.4 Examples of items to be conditioning monitored

Examples of items to be conditioning monitored
Following items are examples of systems/components to be conditioning monitored (list not exhaustive):

- Train Doors
- Traction Converter
- CCS and its constituents (e.g. odometry sensors)
- Traction Motor
- Brake System
- Wheel Axle Bearing
- Bogie (Instability)
- Wheels (Flat wheel detection)
- Toilets
- Filters
- Gearbox
- Voltages/currents
- Passenger Comfort (analysis)

[SPPRAMSS-10205, Text **]**

6 Specification of a set of requirements for CBM

First set of specifications for CBM
The PRAM team was only able to propose a limited set of requirements related to CBM for the SP Domains. This activity shall be continued in a future remit (further than SC2.4). **[**SPPRAMSS-10186, Issue **]**

6.1 Requirements for manufacturers

CBM for manufacturers
The following requirements apply to the manufacturers:

- The built-in diagnostics of the trains shall fulfil following requirements:
  - The typology of diagnostic output data shall be standardised (refer also to SPPRAMSS-11150 - [EuroSpec - Accelerator for user-oriented harmonisation of rolling stock]).
  - The output diagnostic data shall be provided in a harmonized form, which may be useful for CBM implementation.
- The SRACs, if any, shall be formulated for being potentially implemented in a CBM process of the Maintainer (agreement with Maintainer is necessary)
- The ownership of data shall be agreed between supplier, RU and maintainer before implementing the CBM process

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

6.1.1 Hardware and software requirements for on the vehicle

Requirements for the hardware and software for on the vehicle
For implementing condition maintenance functions into the development of the vehicle native software, specific requirements shall be considered. The ones already specified in SPPRAMSS-11150 - [EuroSpec - Accelerator for user-oriented harmonisation of rolling stock] are applicable to this configuration too and shall be implemented, as well as the compliance with the CENELEC Standards (see

SPPRAMSS-11140 - References). Additionally the requirements specified in the following sub-sections shall also be considered.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

6.1.1.1 General planned maintenance requirements:

Record vehicle software
The vehicle software shall be able to record and analyse all the items, for which maintenance is required (according to existing maintenance plans)

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Maintenance parametrisation
The software shall allow the parametrisation of the maintenance period and of the operation time of system, equipment, and their components.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Planned maintenance interval
For each equipment, it shall be possible to record the related planned maintenance interval, schedule and responsible entity/persons.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Maximal maintenance interval
An exceeded maximal maintenance interval shall be notified (e.g. warning for the maintainer).

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

6.1.1.2 Maintenance recording functions

The software shall implement the following maintenance recording functions.

Implementation of counters
The software shall allow the implementation of counters and any input signals/data for each system/ equipment under maintenance.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Performed maintenance activities
All performed maintenance activities shall be recorded, addressing following information (not exhaustive):

- Identification of the system/equipment under maintenance (e.g. Part Number, Serial Number, version)
- Performed maintenance activities and related protocol (including the date);

- Replaced parts, if any

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

6.1.1.3 Specific functions for condition monitoring

Analyse the current values of the system
The Software shall monitor and analyse the current values of the system/equipment, in particular:

- Date and time of measurements
- Values
- KPI (e.g. a metric that can be defined and used to monitor the deviations of the system respect to a target)

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Diagnostic algorithm
The diagnostic algorithm shall be implemented into the Software, which shall be able to be parametrized according to the following inputs:

- Planned maintenance data and intervals,
- Typology and frequencies of the Input Signals from diagnostics, as well as the necessary.

The CBM diagnostic algorithm shall be configured with maintenance plan data and other inputs in order to give an advantage to the different stakeholders for system with flexible design and and different operational needs.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

6.1.2 Generic hardware requirements

Hardware development
The hardware shall be developed according to SPPRAMSS-334 - [EN 50129:2018/AC:2019-04] (for signalling equipments) and/or EN50155:2021 (for all rolling stock equipments).

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

6.1.3 Uses Cases and examples

In this section, examples regarding the application and implementation of some requirements will be described by using specific use cases.

Vehicle data communication vs Services
In the document Vehicle data communication vs Services, relations between data and use cases in fleet monitoring are described.
In order to build a successful business case around the remote monitoring, one of the first assessment need is related to the capability to apply maintenance decisions (use-cases) based on data collected from the assets.
For addressing this point the activity consists in building the full data flow (type of data collected, frequency of the update, avoidance of lost of data, data storage, on-board and off-board data manipulation, off-board data management and integration, etc…) linking the data content (value in

providing answers) to the specific use cases.
A top down approach may lead to the description of the different use cases (benefit for the customer) and afterwards to check if and how the data collection can support a proper input for every specific case. In the document an equivalent approach has been performed: starting from the type of data available at vehicle level (this information is quite consolidated), the data flow and its practical features are followed step by step until the link to the different use cases.
The objective of this exercise is to provide visibility on the full data flow to the several experts, who contribute in the realization of the data monitoring system.
In the first section of the document (in yellow), there are the steps related to the vehicle level. The type of available data is clustered (Vehicle data) with a short description of each cluster (what it is; where are the data sources). In those examples all the data are cumulated on board (MCG= Mobile Communication Gateway, equivalent to an MDCM or MDM for this function) with a specific (maximum) frequency.
In the next session (green) is described the possibility of having some on board computation (Data handling) and the process to transfer data (based on customer request) to a specific server (when and how) including the transfer to the ground server (how).

In the last session (blue) is described in blocks the link between the data (now off board and available with standard tools) and the specific use cases. **[**SPPRAMSS-8125, Text **]**

6.2 Requirements for Railway Operators

Following requiremens shall be applied to Railway Operators:

Specific CBM strategy and workflow
A Specific CBM strategy and workflow shall be established.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Maintenance personnel
All the maintenance personnel shall properly be instructed in analysing the field data and apply the foreseen maintenance actions.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Monitoring sensors
Monitoring sensors shall be installed on specific assets, where the related measurement is applicable according to the CBM concept and procedures. A risk or failure analysis shall be perfomed to identify the critical assets for which monitoring sensors are needed.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Monitoring tools
Monitoring tools shall be used for specific assets, where applicable according to the CBM concept and procedures.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Update of existing maintenance plans
All the maintenance plans for already developed systems shall be updated according to the CBM

procedures. A process for the update and approval of changes to the maintenance plans shall be defined.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

Maintenance plans during the development phase
During the development phase,the maintenance plans shall be specified considering the CBM procedures.

To be derived by Team	SP Task 2 TrafficCS, SP Task 2 Train CS, SP Task 2 Trackside Asset CS, SP Task 2 CONEMP Computing Environment, SP Task 4 DAC/FDFTO

6.2.1 Uses Cases and examples

In this section, examples regarding the application and implementation of some requirements will be described by using specific use cases.

6.2.1.1 CBM Data Path created by DB Cargo

CBM Data Path created by DB Cargo
DB Cargo has ambitions to use the CBM data path also for safety-related maintenance activities.

Regarding the figure presented below:
The CBM algorithm within the **AIC/Asset Intelligence Center (D)** is analyzing sensor data coming from the vehicles in order to trigger and schedule maintenance activities within the SAP ISI maintenance planning tool.
Within **SherLOK (F)** the data quality is checked via two quality gates (QG1, QG2).

Blue lines: CBM Use-case specific components
Violet lines:Vehicle-specific components
Green lines: CBM Software interfaces

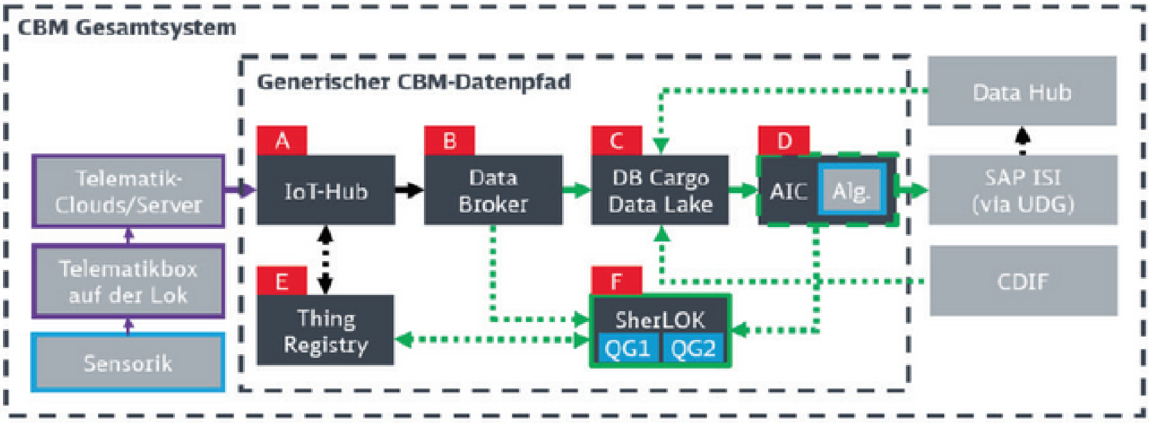
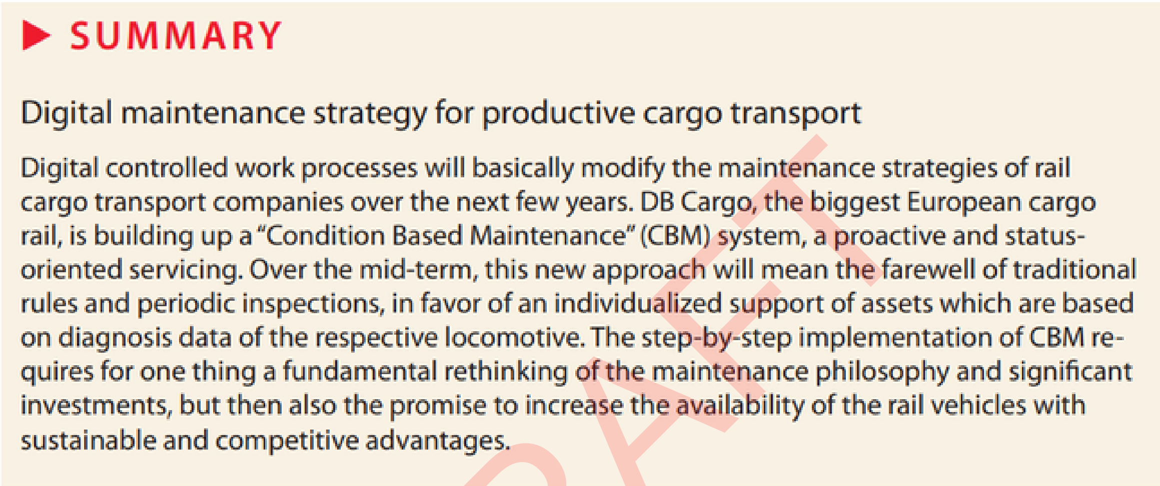


Figure # CBM Data Path developed at DB Cargo (figure extracted from an article published in 2021 in ETR, Eisenbahntech. Rundschau:



SUMMARY

Digital maintenance strategy for productive cargo transport

Digital controlled work processes will basically modify the maintenance strategies of rail cargo transport companies over the next few years. DB Cargo, the biggest European cargo rail, is building up a "Condition Based Maintenance" (CBM) system, a proactive and status-oriented servicing. Over the mid-term, this new approach will mean the farewell of traditional rules and periodic inspections, in favor of an individualized support of assets which are based on diagnosis data of the respective locomotive. The step-by-step implementation of CBM requires for one thing a fundamental rethinking of the maintenance philosophy and significant investments, but then also the promise to increase the availability of the rail vehicles with sustainable and competitive advantages.

Figure # Article in "ETR-Eisenbahntechnische Rundschau", 2018

[SPPRAMSS-7115, Text **]**

6.2.1.2 CBM Implementation in other companies

Discussion with other partners

The PRAM team shall provide hints on current CBM activities performed by ERJU partners in today's systems (e.g. SNCF, Alstom, Siemens). This will be done in a future version of the document.
[SPPRAMSS-10192, Issue **]**