RCA

Reference CCS Architecture

An initiative of the ERTMS users group and the EULYNX consortium

APS Concept Movable Object

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1 Preamble

1.1 Release Information

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3 Introduction

In railway operation it is key to protect movements of Physical Train Units (PTUs) such that no movement can impose any harm to another moving or stationary railway vehicle (e.g. PTU, single or grouped wagons or coaches) or human beings which have to be considered (e.g. track workers) . From the outset in railway history, two basic methods for keeping vehicles apart were used: time intervals between subsequent trains using a section of railway, or geometric spacing, which relies on the assignment of railway vehicles to block sections of the track so that only one PTU is allowed to enter a block at a time in most cases of normal operational conditions, or in other words, a block shall normally be used by one PTU only. Subsequent technical development followed this principle. The reliable determination of the absence of trains on track and the handling of track occupancies became the central concept of railway signalling and it was essential for the operation of railway systems. Today, most of the signalling systems in operation work under the concept of block sections, in which each block is defined by one or more sections of the track, delimited by trackside train detection (TTD) systems.

When focusing on trackside measures to improve operational capacity, the effects of the use of short block sections results in a disproportional increase of costs. As the railway capacity needs and the railway running costs continue to increase, the focus for further development shifts to the optimisation of traffic and on-board functionalities. This is called train-centric approach and it forms the basis of RCA's concepts.

Central part of the train-centric approach is the train-related Movement Permission, which includes securing the running path up to any arbitrary point on the railway track and the permission to move, see also /RCA.Doc.63/. To enable the granting of a requested Movement Permission, detailed information of given track occupancy or especially the respective Physical Train Unit is needed. In this concept, the static TTD system is supplemented (and later on also replaced) by solutions in which the PTU itself reliably reports position- and integrity-related information . Consequently, it should bring advantages to the infrastructure manager and operator such as the reduction of the number of trackside equipment and the possibility to optimise operational capacity by reducing headway times . Nevertheless, even though technical solutions are now focusing on the exact localisation of specific PTUs rather than detecting anonymous occupancies via a TTD system, the latter is expected to remain in consideration for a longer time.

To authorise and supervise the movement of railway vehicles (trackbound) it is necessary to know where they are located on the railway track and if they are in the required state. The Movable Object (MOB) is a digital representation of real-world movable objects on and/or near the rail track. It is presented as the base solution for tackling safe and accurate representation of track occupancies, and it therefore enables the safe authorisation of train movements. Furthermore, it is envisaged that with the technological advancements currently being realised, the abstraction of vehicles or persons will not only allow for the safe operation of trains working under "block-free" Movement Permissions but will also help to safely manage other significant non-trackbound objects that regularly interact with train operations, e.g. track workers and rail-road vehicles used for maintenance (also known as On Track Machines).

The target vision includes PTUs that are always connected and always reporting as is already been identified by ERA as a necessary improvement to enable game changer ETCS L3 (refer to chapter 'Future Considerations'). Thus, not identified PTUs that are not reporting will be an exception in the target picture. In practical terms however, while developing this concept it is also necessary to consider the technological migration scenarios, including travelling through the system-boundaries between traditional and the new signalling systems. As such, RCA subsystems aim to support signal-free mixed level operation ETCS L2/L3 or so called Hybrid Operation - in future /TSI CCS/ 2022 and here introduced as combined Level R (radio based ETCS) - as well as the boundary interfaces to legacy systems. The abstraction of the track occupancy information provided by TTD systems, and the prioritised management of all available digitalised information becomes therefore of equal importance for RCA.

This document describes the concept of the Movable Object and a proposal of its functional requirements. The general conceptual solution description for the abstraction and aggregation of track occupancy information on trainside localisation level is explored instead in the complimentary /RCA.Doc.68/. The focus of the Movable Object concept lies in the management of track occupancy claims reported by trackside and on-board train detection systems and not on track occupancy claims such as Movement Permissions (refer to /RCA.Doc.63/).

Please refer to /RCA.Doc.52/ for a general hints regarding how to read the APS concepts and style guide definitions that have been applied in the pictures.

3.1 Purpose

This concept is written as part of the RCA's vision for a digitalised and automated railway operation. It is one of the many detailed concept documents under the overarching APS Concept umbrella (refer to /RCA.Doc.51/) - a key part of the overall desired system architecture.

The purpose of this concept is the description of conceptional ideas about the representation of physical movable objects (that move onto, or in relation to, railway lines) by APS based on the basic requirements given in /RCA.Doc.51/. It is the key feature of APS to protect the movement of such objects, including the interdependencies of such movements. The document also gives continuation to the characterisation of the subsystems architecture and general conceptualisation of the subject of track occupancy defined in more details in /RCA.Doc.68/, which should therefore also be studied by the reader. Further detailing of this concept and considerations towards the issues listed in the chapter 'Future Considerations' shall take place in the next specification phases.

This paper contains the basic information for further definition by the Europe's Rail Joint Undertaking and it is aimed at infrastructure managers, railway undertakings, suppliers, authorities and other railway stakeholders. The document shall be treated as a concept and as an input to enable future discussions and conceptualisation, aiming to achieve a detailed system design and specification work.

Notes

- *This document is a concept and not a specification*
- *This document describes "solutions" in the problem space and rather not in the solution space - it shall not restrict the solution space and vendors' diversity of ideas, nor competition*

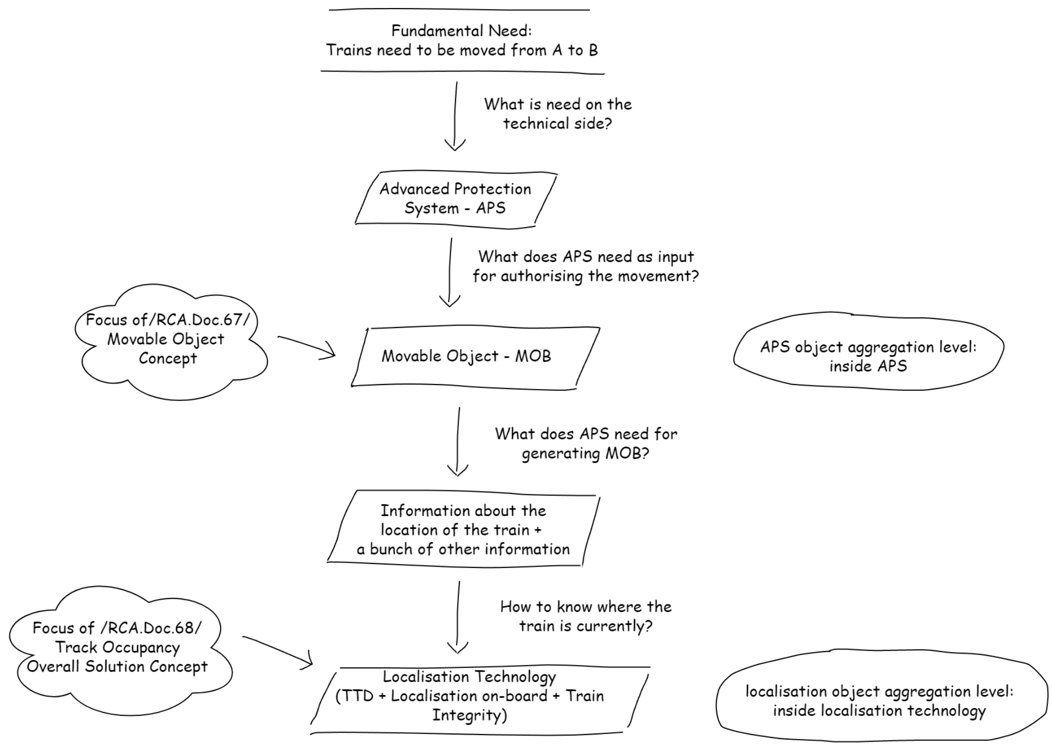
Additional information about current delimitations and assumptions can be found on chapter 'Delimitations' and on chapter 'Assumptions and prerequisites'.

3.2 Scope

Due to the complexity of signalling systems, the RCA's vision framework and the subsequent PE, APS and MAP concepts were further explored and detailed in sub concept documents - this document is one of the many. Whilst /RCA.Doc.68/ describes the elements which contribute to the attribution of an abstracted "occupancy" within this concept, this document gives an outline about Movable Objects and its intended usage for the safeguard of safety and integrity of the railway operation.

The MOB concept is then utilised on functional applications within APS, such as /RCA.Doc.63/. The conceptualisation is build over abstracted information from existing (and future) train detection technologies. Nevertheless, argumentation about specific localisation technology solutions are out of the scope of this document.

The following figure shows an example how aggregation of localisation information can be understood within the separate subconcepts:



3.3 References

Please refer to the references listed in /RCA.Doc.52/ *APS Detailled concepts overview* and /RCA.Doc.6/ *RCA documentation plan.*

3.4 Terms and abbreviations

Please refer to the abbreviations listed in /RCA.Doc.52/ *APS Detailled concepts overview* and /RCA.Doc.14/ *RCA terms and abstract concepts.*

3.5 Dependencies

Parts of the document are based on an MBSE model in Capella (are generated with information from the model):

Artifact	Version
Model name	RCA
Model branch/revision	master/refs/heads/master
MBSE tool version	5.2.0

3.6 Delimitations

The main purpose of this document is to give a first overview about the Movable Object topic. Complex technical issues are not explained in detail at this point but on future specification work. It is also anticipated that further scenarios will be derived from safety risk assessments which will take place in the next phases of development. Consequently, the term "usually" is sometimes used in this document to express that there may be situations where the given statement is not fulfilled without further detailing.

3.6.1 Normal Operation

According to the TSI Operation and Traffic Management /TSI OPE/ there are three major categories for operational modes:

- Normal operation
- Degraded operation
- Handling of emergency situations

Delimitation	This document is currently restricted to normal operation.

Note: Normal operation is considering the target vision with PTUs that are always reporting their position and are always connected - and thus, always identifiable - as well as migration scenarios with traditional TTD systems to locate PTUs, e.g. in case they don't.

3.6.2 Operational Scenarios

At this point in time, not all operational scenarios impacting the Movable Object approach can be listed and detailed.

Delimitation	This document covers only some operational scenarios. At a later stage a check between the technical solution Movable Object and the to-be-covered operational use cases and scenarios must be made. This will enlarge the conceptional ideas described within this document.

3.6.3 Movable Objects

At this point in time, not all types of Movable Object have been taken into consideration.

Delimitation	This document currently focuses on representation of railway vehicles such, i.e. Physical Train Units and single or grouped wagons or coaches, which are represented by Trackbound Movable Objects. Non-trackbound objects such as construction equipment and track worker have not been introduced yet.

3.6.4 Migration and handover

Handover situations to and from neighbouring APS or legacy systems have not yet been analysed. Once introduced, they will mainly impact the life cycle of the Resolved Trackbound Movable Object.
APS has to support various system migration strategies and their resulting technical restrictions. This includes also the support for system boundary crossing of PTUs without confirmed integrity and Start of Mission scenarios without any or without valid position known at trackside.

Delimitation	This document does currently not consider handover scenarios from and to neighbouring APS or legacy systems. This will be added in a later document version. This document does currently not consider migration scenarios. This will be added in a later document version. Except: • Start of Mission without valid position • Determination of rear end extent of the Movable Object in case of integrity not ensured on-board.

3.6.5 Localisation technologies

At this point in time, usage of on-board or trackside technologies for train-localisation other than localisation inside ETCS (with its resulting position report) and TTD systems have not been analysed.

Delimitation	This document has been created focusing on today's onboard (ETCS position reports) and trackside technologies using TVPS status for train positioning. Usage of alternative technologies will be considered in a later document version and may enlarge the conceptional ideas described within this document. Nevertheless, as new technologies are going to be evolved, an abstraction from specific localisation technologies has to be realised in order to ease their substitution in the future.

3.6.6 Automatic Train Protection

Delimitation	Whenever possible abstract terms are used in order to facilitate the possible application of the concept on other future ATP systems. At the present time, it is assumes that ETCS will be the major ATP system. Some ETCS related terms are used when necessary to give context.

4 Problem description

4.1 High level functionality

To enable granting a movement, APS needs information of current occupancy state of the allocated controlled area as representing an operational state.

4.2 Current solution and its problems

As state of the art, different combinations of products that perform CCS functionality are present. Two main bundles are:

- Interlocking with light signals and national Automatic Train Protection (ATP) or a non-radio based ETCS solution with ETCS L1
- Interlocking with interfaced Radio Block Centre (RBC) (with or without trackside signals)

For each form of legacy CCS system (i. e. interlocking and ATP) separate detection principles for railway vehicles and obstacles on the track are used.

Interlockings use a Trackside Train Detection (TTD) system which detects railway vehicle axles or wheels and is bound to fixed blocks. As there is no communication between track- and trainside, the representation of track occupancy cannot be related to a specific train without additional (normally non-safe) technology like train describer systems.

When using ETCS, additional localisation information of the train can be provided. ETCS uses a train-centric approach based a topological reference system (i.e. balise location) which is present on both on-board and trackside subsystems. As there is a communication session needed between trackside and train, a train specific position is normally available to the trackside protection system.

For further information about the challenges of localisation technologies please refer to /RCA.Doc.68/.

Since train control functions for supervision (e.g. ETCS) are specified and developed much later than interlocking technologies, there is a functional split that results in inherent challenges for the operation of today's railways. Due to this functional separation of ETCS, especially RBC, and route setting and locking systems (interlocking as non-interoperability trackside subsystem), there is no overall aggregation of the railway object representations in the particular safety-related subsystems. Each subsystem processes and stores its own representation using different sources of information and different principles with its inherent challenges in the following manner:

- ETCS:
  - Using position report information provided by PTU and route related information from interlocking
  - Termination of communication channel between train and trackside, e.g. after end of mission/mode change
  - Missing/invalid position information during e.g. start of mission
  - Manual entry of train data

- Train integrity information

- Interlocking:
    - Using TTD systems like axle counters or track circuits
    - Occupancy detection only for fixed geometric extension possible (block section)
    - Occupancy detection of a block section may encompass more than one PTU
    - Exact location of PTU within fixed geometric extensions unknown
    - No PTU information available
    - Reliability strongly influenced by environmental conditions such as leaves, snow, sand or dirt (particularly with track circuits) or metallic debris (axle counters)

In most applications the object information isn't exchanged, so that there is no common representation. Even if the interlocking transmits some route related information to RBC there is often no reverse flow of information from RBC to the interlocking in relation to specific interlocking or RBC representation of real world object (refer to /RCA.Doc.61/ for more information).

Besides trackbound railway objects, other movable objects are not directly represented in current command and control systems. I.e. there is no representation of track worker and non-trackbound (railway) vehicles or machinery in the technical system at all.

As it is not foreseen to have functional separation in APS, a common representation of real world railway objects is needed. Especially for those which influence the safe movement of railway vehicles for operational purposes.

4.3 Solution approach: basic requirements

Regarding the needs for harmonised representation to fulfil the needs of switchable field element, to grant and supervise Movement Permissions and also to fulfil the A.P.M. objectives /RCA.Doc.53/ as well as already defined APS requirements in /RCA.Doc.51/ several basic requirements can be derived:

- The representation of real-world object shall consist of abstracted information from different sources processed into an aggregated object, called Movable Object, shortly MOB.
- It shall not be visible how the several sources are combined to the aggregated MOB outside of the aggregation functionality, e. g. to the Plan Execution (PE) subsystem.
- Each MOB shall have an extent representing the real object as precisely and as safe as possible - i.e. technology-inherited measured inaccuracies are aggregated to the represented extent - on the underlying track-node-model given by MAP Data.
- MOB aggregation principles shall support migration scenarios with a variety of localisation technologies as well as scenarios with reduced availability of localisation technologies.
- MOB aggregation principles shall enable an easy and quick incorporation of new or changed localisation information without changing the core functionality of MOB aggregation.
- MOB aggregation principles shall remove the need for continuous TTD systems in order to decrease trackside asset costs.

- In order to ensure that the operating state representation in APS is up-to-date, the aggregation of MOB shall be achieved repeated each time localisation technologies provide new localisation information, e.g. when an ETCS Position Report or a TVPS status update is sent to APS.

The basic concepts to begin dealing with these requirements are introduced in this document.

The basic function of APS is to ensure a high degree of safety by use of technical principles. In this context the Movable Object serves as an enabler. Furthermore, MOBs must be able to support the provision of relevant, accurate and up to date information to the other RCA subsystems to empower them to achieve their safety and operational objectives. From the perspective of the MOB therefore, their design must be as such that PTUs are safely represented, and all necessary attributes can be efficiently aggregated and transmitted to interacting subsystems.

5 The Movable Objects Concept - Solution Details

5.1 Assumptions and prerequisites

The following prerequisites were considered when defining this concept. *Note: this concept is currently described under the subchapter 'Delimitations':*

5.1.1 TTD Area

Assumptions	The placing of TVPS must be done according to safety-related rules with regard to the possible overhang (distance between wheel and the end of the wagon) in areas of restricted clearance (e.g. fouling points). Nevertheless, this assumption may be removed in the future in case of implementing an alternative technical solution.

5.1.2 OTD Area

Assumptions	In areas not equipped with TTD system, the following conditions must be fulfilled: • All railway vehicles are always connected and always reporting, i.e. localisation information will be provided continuously. • All railway vehicles regularly report their current integrity state • System design and operational regulations ensure that other railway vehicles are not allowed to enter the APS AoC • System planning and operational processes ensure that a railway vehicle fulfilling the first two bullets is not split into parts which no more fulfil these requirements

5.1.3 Abstraction

Assumptions	• Localisation information is abstracted and available for consumption, i.e. APS needs localisation information abstracted out of (fused) sensor information received via the particular interface to APS localisation format, e.g. from train via TSI SUBSET-026 defined data or EULYNX SCI-TDS interface. Refer to /RCA.Doc.68/. • PTU localisation technology provides APS with front and rear end related information in one message at the same time.

5.1.4 ID Management

Assumptions	System-wide ID management is provided ensuring each physical object ID are unique and easily identifiable by the subsystems' users /operators.

5.2 Taxonomy of Movable Objects

In this concept document, Movable Objects are at first level distinguished based on the type of physical object being represented according to their movement constraints in relation to the track - i.e. trackbound or non-trackbound. At second level, as MOBs become responsible for storing the occupancy status of TVPS, they are distinguished based on whether APS can explicitly associate it to a PTU or not - i.e. 'resolved' or 'unresolved' MOB.

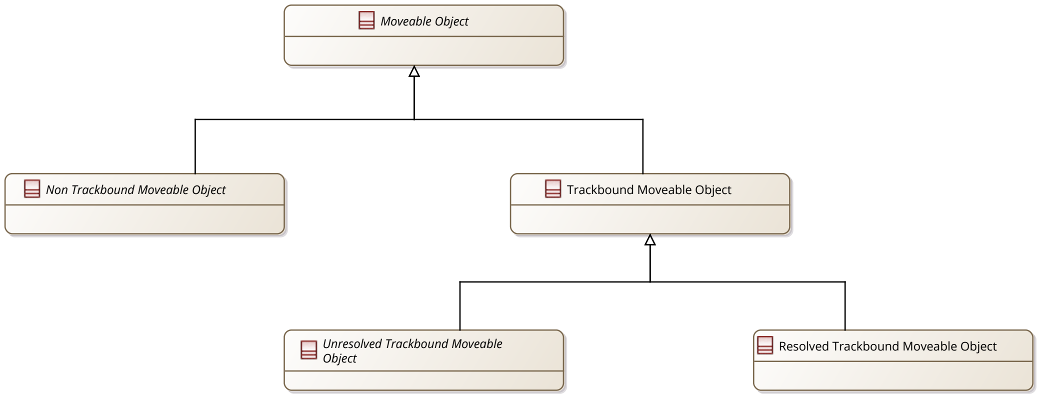


Figure 1: [O.CDB][AMOD-025] Moveable object taxonomy [Abstract concepts]

Term	Definition
Movable Object (MOB)	A Movable Object (MOB) is a representation of a real-world object as part of the physical railway system that moves. Such Movable Objects can be trackbound (such as Physical Train Units) or non-trackbound (such as Authorised Trackside Persons). Any real-world movable object which is detected as such by a person or system with safety responsibility will be represented as a Movable Object in System RCA.
Non Trackbound Movable Object (nMOB)	Identified and localised objects such as Contruction Equipment or Authorised Trackside Persons are represented as Non-Trackbound Movable Objects. The movement of these objects is not constrained along the paths defined in the railway network Topology domain.
Resolved Trackbound Movable Object (rMOB)	A Resolved Trackbound Movable Object (rMOB) is a Trackbound Movable Object which is identified, i.e. there is a 1:1 mapping between the virtual object in the model and a Physical Train Unit. Note: A Resolved Trackbound Movable Object represents an object which is known to the Advanced Protection System (identified), independent of the availability of localisation information, i.e. both objects with valid but also with unknown or invalid position are represented as rMOBs.

Term	Definition
Trackbound Movable Object (tMOB)	A Movable Object whose movement is strictly bound to the paths defined by the railway network Topology domain (that is, a Movable Object that is guided by the rails). Trackbound Movable Objects are distinguished between Unresolved Trackbound Movable Objects and Resolved Trackbound Movable Objects.
Unresolved Trackbound Movable Object (uMOB)	Represents Trackbound Movable Objects which is not (yet) identified, i.e. there is no 1:1 mapping between the virtual object in the model and Physical Train Units (PTUs). In case of using a Train Detection System this occurs when a track section is occupied. An Unresolved Trackbound Movable Object may in reality represent zero up to several separate unregistered PTUs in the same Track Vacancy Proving Section (TVPS). In areas without a Train Detection System installed, this can occur as a consequence of degraded situations. APS defines then an occupation extent by performing an internal calculation. Notes: • A track section can also be occupied in case there is no PTU located, but a disturbance of Train Detection System is given. • Strictly speaking, an Unresolved Trackbound Movable Object therefore only exists in case of missing knowledge that cannot be resolved by APS itself.

As further detailed in the following chapters, if a railway vehicle gets identified (e.g. establishes a session with APS or is announced via a neighbouring system) it will be represented as a Resolved Trackbound Movable Object.

Occupancies reported by a TTD system are going to result into Unresolved Trackbound Movable Objects if they cannot be safely attributed to one or multiple rMOBs (refer also to chapter 'Correlation of rMOB and uMOB' under 'Future Considerations'). In other words, a uMOB expresses uncertainty. It is the representation of one (even zero) or more railway vehicle(s) where better knowledge is not yet available. All what is known is that there might be some vehicle(s) within the TVPS; either not resolved yet or resolved but APS cannot safely exclude that there is no further unresolved vehicle located within the same TVPS. The resulting Unresolved Trackbound Movable Object will stay until it can be safely deduced that there is no vehicle (anymore) on the TVPS.

Please note: Even though the TVPS occupancy (and therefore a corresponding uMOB) is not moving, it is also represented as a subtype of the Movable Object in the Operating State because the TVPS itself is of no immediate interest to APS, while the TVPS-detectable (movable) railway vehicle is.

5.3 Attributes of Trackbound Movable Objects

5.3.1 General principles in the context of RCA

The major aim of abstracting railway vehicles into Trackbound Movable Objects is to hide protocol- (e.g. language) and train-related specifics from the layers above. By abstracting different PTUs into objects with a well-defined set of characteristics while considering information received from different sources (e.g. from TTD, Planning System, etc.), all upper layers of the system become independent of the real world. This leads to a simplified and unified access to object characteristics and reduces the necessity for software adaptations in case of changes in the outside world.

Movable Objects shall aggregate all relevant characteristics of the associated physical objects which are transmitted by these objects and that are required by different RCA subsystem's life-cycle at any one point in time. These attributes enable APS to clearly identify the abstracted objects, to position it in relation to a reference system, and to evaluate its applicability in relation to the required safety checks.

It is anticipated that the different RCA subsystem functionalities will request and utilise specific MOB attributes. Only a limited number of attributes were currently mapped within the various RCA concepts (see tables in sub chapters). It is expected that these attributes lists are going to be extended as further RCA subsystems functionalities are defined in later stages of the conceptual development.

The attributes, which can change within a permitted range at each processing cycle update, will be dynamically stored in APS. Each subsystem, even outside APS, shall be capable of accessing the relevant information to process their intended functions.

5.3.2 Resolved Trackbound Movable Object

Attribute	Description	Remark
rMobID	Reference ID utilised during the MOB's life cycle for which abstracted information from real-world object shall be linked to.	This unique ID is created by APS at the time of rMOB creation.

Attribute	Description	Remark
rMobDomainID	The ID of the physical object from which characteristics are being reported and stored in the equivalent digital abstraction. An rMOB is identified only if the linked real-world object has reported its domain ID. This unique ID will be used as reference to access the MOB information on all subsystem within APS or within the different RCA subsystems. Each rMobDomainID shall be unique within the whole system and easily identifiable by the subsystem users/ operators. Therefore, a system wide ID-Management is needed. *Note: Within ETCS the unique identification of a PTU is usually the OBU ID of the leading engine that is transmitted to APS during communication session establishment. For other sources of localisation/ occupancy abstractions there has been no specific assumptions made yet regarding the origin of the ID.*	This ID is unique and fix system wide, i.e. it does not usually not change during the life cycle of the physical object. The management of the rMobDomainID is out of scope of APS. For a PTU that always reports the same rMobDomainID during connection establishment, the rMobID can differ every time. It is envisaged that one rMOB may include more than one associated device (e.g. leading and non-leading cabs). However within the scenarios discussed in this concept document only one rMOBDomainID per abstracted object is being considered at the present time.
rMobState	A logical attribute for the handling of the MOBs life cycle states and interaction with other subsystems and functions.	Please refer to chapter 'Life cycle of Movable Objects' for more detailed information about the different rMOB states.

Attribute	Description	Remark
rMobExtent	An optional rMobExtent is defined by at least one position, the extent itself (that can be zero) and optional safety margins. The extent of an rMOB must not be zero in OTD areas unless alternative safety measures are applied. In TTD areas, the extent of an rMOB may be unknown or zero, e.g. in case: • the rMOB is not yet localised • the rMOB performs start of mission and did not (yet) report train integrity (migration plateau without always connected, always reporting trains)	APS uses different sources of information to localise an rMOB in the topology and to derive the corresponding occupancy extent, e.g. • front end position reported by real-world object • safe train length reported by real-world object in case of confirmed integrity • occupancy information reported by an underlying TTD system Please refer to /RCA.Doc.68/ for further details. Please see also chapter 'Representation of rMOB as a point' under 'Future Considerations'.
rMobDirection	The rMOBDirection corresponds to the train running direction.	APS determines the direction of an rMOB as soon as it becomes localised. This attribute is used e.g. to check if the direction of a permitted movement corresponds to the rMOB direction (refer to /RCA.Doc.63/).
rMobSpeed	The speed of the PTU derived from onboard measurement and reported to trackside.	This attribute can be used e.g. to check whether an rMOB is at standstill.

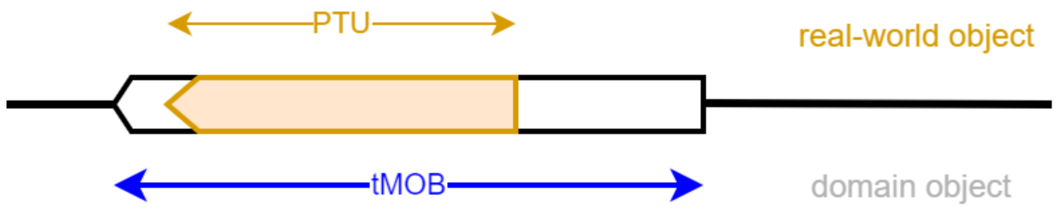
5.3.3 Unresolved Trackbound Movable Object

Attribute	Description	Remark
uMobID	Reference ID utilised during the MOB's life cycle for which abstracted information from real-world object shall be linked to.	This unique ID is created by APS at the time of uMOB creation.

Attribute	Description	Remark
uMobDomainID	The optional ID of the physical object for which the occupancy has been reported. Example: TVPS ID if the occupancy has been reported via a TTD system *Note: In case APS has created the uMOB itself (e.g. due to an abnormal situation), the uMobDomainID is not used.*	A uMOB may possess an ID of its domain of the linked real-world object it represents.
uMobExtent	Contiguous Track Area consisting of one or multiple Track Edge Sections potentially occupied by unidentified vehicle(s).	A uMOB always has an extent, independent of the fact whether it is derived from occupancy information provided by a TTD system or calculated by APS itself.

5.3.4 Determination of Trackbound Movable Object Extent

tMOBs represent the real world movable objects from the trackside and onboard to be used by APS to safely and efficiently operate the railway. A Trackbound Movable Object shall be created or updated as soon as the related physical object reported characteristics are modified. The tMOB does normally not have the same extent as its corresponding Physical Train Unit (PTU).



The following two subchapters describe how the extent of a tMOB is determined. The determination depends on the movable object's type because rMOB and uMOB signify different levels of confidence/accuracy regarding localisation and identification of the corresponding movable object and thus, are handled differently by APS. Please refer to /RCA.Doc.68/ for details regarding ETCS position report information (e.g. calculation of safe train length).

5.3.4.1 Resolved Movable Object Extent

The rMOBs are used to represent identified railway vehicles in RCA (at present time usually PTUs). They provide the basis for APS to ascertain technical and operational safety principles for railway operation and, in parallel ensure efficient operation of other RCA subsystems. Consequently, rMOB attributes have to be updated every time new information is made available to APS.

One attribute - the rMobExtent - plays an important role in the RCA system as it contributes to the representation of track occupancy related occupancy claims and therefore to an efficient and safe usage of the railway network. Depending on the concrete situation, system configuration and available input, the following aspects have to be considered for rMobExtent determination (the examples below are mainly focus on normal operational conditions, without considering additional safety margins besides the existing inaccuracy constraints of existing localisation technologies):

- Position information provided by the railway vehicle including inaccuracy information
- TVPS status information provided by the TTD system
- DPS status information
- Additional safety margins if required

Regarding these aspects the following design principles may have to be deduced:

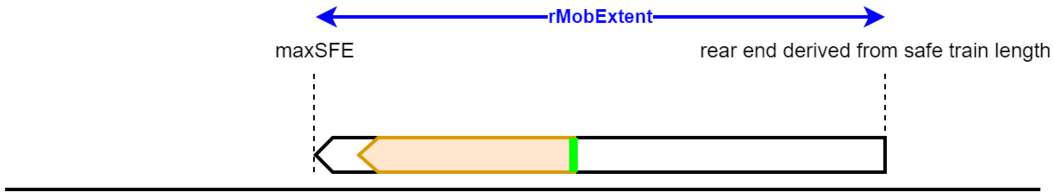
- The localisation of a PTU including its extent is subject to localisation technology inherited inaccuracy, therefore an rMOB is usually larger than the corresponding PTU.
- If start of mission is performed without history and the PTU has not yet reported train integrity, then the corresponding rMOB is represented as a point. *Note: This situation is only applicable for TTD areas. In OTD areas this should not occur or result into a dedicated safety reaction at the time of loosing the information about the train position and/or extent, respectively.*
- Dependent to current rMOB state and the state of its attribute values, the information update from the particular localisation sources will change the rMOB and its attributes, e.g. shortening the extent at the rear end or lengthen the extent at the front end.

The following design principles may have to be deduced also but are not considered in the current stage of this concept:

- An rMOB does also extend into other dimensions (e.g. height and depth). For the scenarios described within this document, only the longitudinal dimension (dimension along an abstracted rail-track) has been considered. Future conceptual scenarios may include up to 3-dimensional characterisation of rMOB (refer to 'Future Considerations').
- Whether or not additional safety margins (e.g. rollback distances) have to be added to the rMobExtent, needs to be further analysed (refer to chapter 'Future Considerations').
- Whether the extent is defined generically by a Contiguous Track Area (CTA) or Linear Contiguous Track Area (LCTA), needs to be defined in a later document iteration. In the target system where all railway vehicles are always known to APS, always connected and always reporting, the rMobExtent corresponds to a LCTA. Nevertheless, as long as we need to cope with migration scenarios, in particular start of mission with invalid/unknown position and without history, different approaches are possible.

Examples for determination of safe rMobExtent based on:

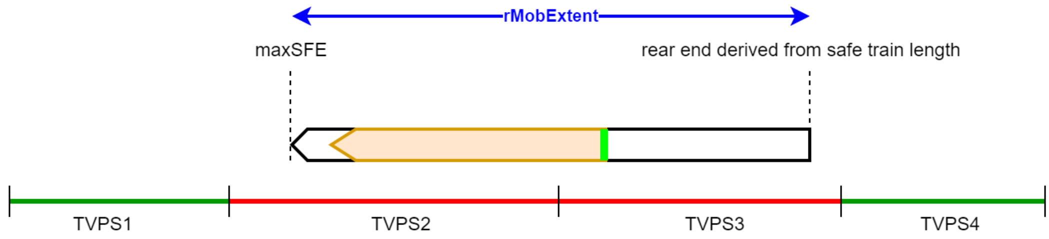
- ETCS Position Report (no underlying TTD system, on-board integrity status reported, no points, no additional safety margin considered)



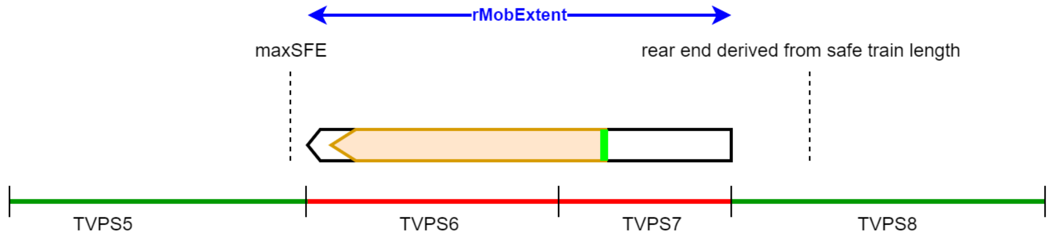
The extent of the rMOB is calculated based on the train front end (maxSFE) reported by the PTU and the reported safe train length indicating the rear end position at the time integrity was reported last.

- ETCS Position Report and TTD system occupation information (no points, no additional safety margin considered)

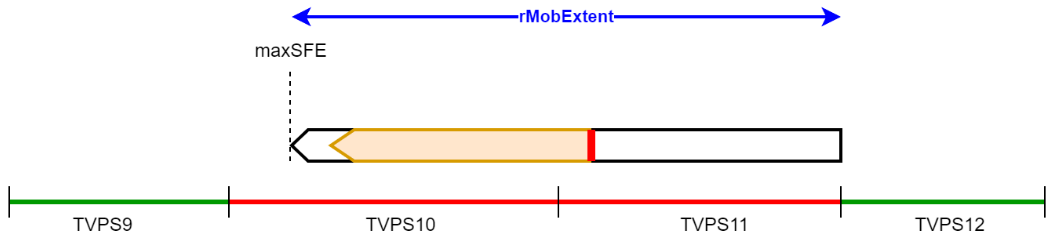
Situation A: Train integrity reported, PTU front and rear end located inside not vacant TVPS



Situation B: Train integrity reported, PTU front and rear end located in vacant TVPS



Situation C: Missing train integrity



Situation A depicts that the safe rMobExtent is exclusively derived from the information provided by means of an ETCS position report in case train integrity has been reported and both train front and rear end are located within a non-vacant TVPS. In this situation the ETCS position report provides more accurate information about the actual rMOB occupancy claim on the railway track.

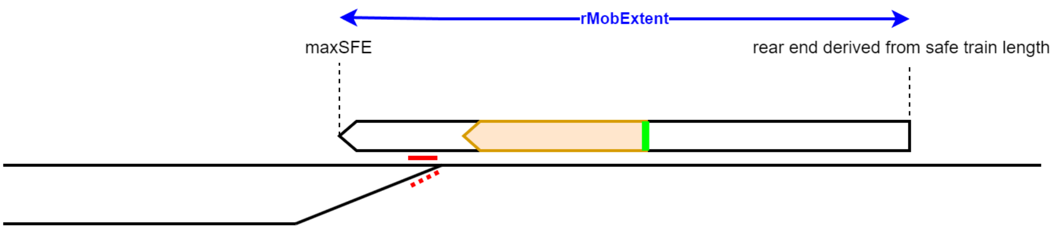
As soon as either reported train front end or determined rear end or both (as depicted in situation B) are located within a vacant TVPS, APS considers additionally the more accurate information provided by the TTD system to determine the corresponding position. As a consequence, the resulting rMobExtent is smaller than the extent indicated by the position report. The discrepancy between occupancy extent derived from an ETCS position report and occupancies reported by the TTD system mainly results from ETCS location inaccuracies and the fact that the train position and integrity are on-board determined at different point in times. Please refer to /RCA.Doc.68/ chapter 2 for more detailed information.

In situation C, the PTU does not report train integrity. The corresponding rMobExtent is determined based on the outer train front (maxSFE) derived from the ETCS position report and TTD status information, i.e. the border to the next vacant TVPS (in this example to TVPS12).

Please note: If APS cannot safely exclude that further (undetected) vehicles are located within the same TVPS (i.e. in a part physically not occupied by the PTU), additional safety measures will be applied, e.g. by creating (a) parallel uMOB(s).

- ETCS Position Report and DPS status information (no additional safety margin considered)

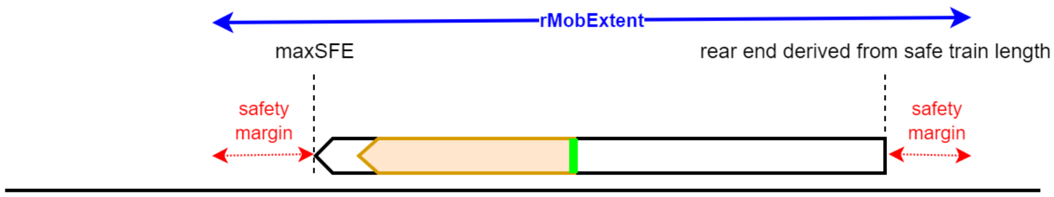
Additional information is required when mapping positions derived from an ETCS position report to the topology if points are involved.



The picture illustrates that one part of the rMobExtent spans over a facing pair of points (in this case the side of the PTU front end but a similar situation can occur with regard to the PTU's rear end). In this situation, APS is required to evaluate the DPS status information in order to determine the rMobExtent unambiguously (refer to /RCA.Doc. 62/ - i.e. to map the rMOB to the correct points leg.

If the DPS is not physically occupied by the PTU (as indicated by the orange colour in the picture), it would - from a safety point of view - be possible to switch the point direction, but APS has no knowledge about the PTU's real extent. This results from the fact that the received position information contains odometer inaccuracies. As it is a fundamental safety principle in APS that a DPS request for change in position is rejected if the corresponding DPS is located inside an occupancy claim such as MOB and MP, no change would be allowed in the depicted situation (refer to /RCA.Doc.62/ for more detailed information). Having this in mind it becomes obvious that large on-board odometry confidence intervals may cause severe operational obstructions, e.g. if the opposite point position is needed for operational purposes or with regard to junction clearance times. Requirements towards operational optimisation (e.g. to achieve a more accurate picture about the real PTU extent) shall be addressed via the corresponding localisation technology (e.g. a decrease of localisation technology inherited inaccuracy) or should be taken into account during system design (e.g. by local use of TTD systems in point areas).

- ETCS Position Report and additional safety margins



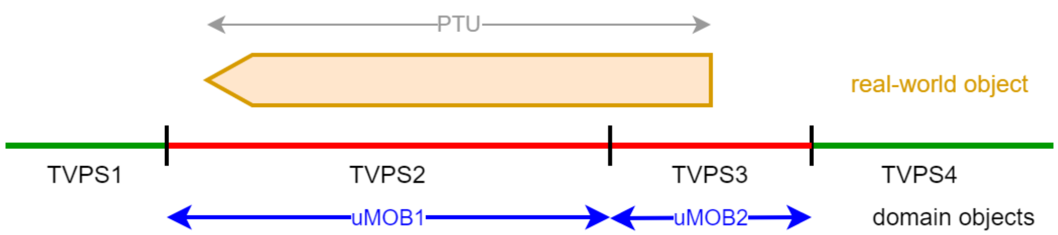
Depending on the further development and design of subsystem functions as well as the safety analysis, it may be necessary to take further safety margins (at front end/or rear end) into account when determining the safe rMobExtent. One example would be the consideration for rollback distances at the rMOB's rear end.

5.3.4.2 Unresolved Movable Object Extent

Unresolved Trackbound Movable Objects are used to represent unidentified railway vehicles (at present time usually PTUs) in the RCA system and thus, other considerations when determining the extent of the uMOB have to be made:

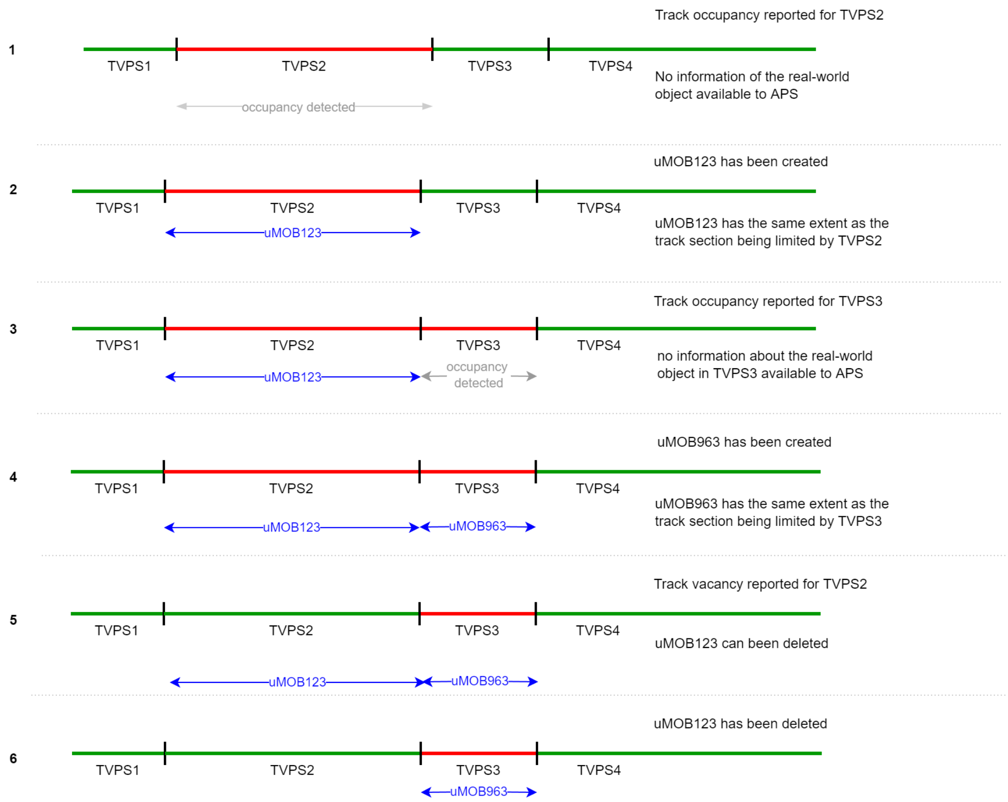
- For the present time it is assumed that the uMobExtent correlates to the extent of the TVPS in case the occupancy is reported by a TTD system. /RCA.Doc.68/ describes in chapter "Track Occupancy Determination" system inherent limitations of today's localisation systems. One of them is the undetected vehicle overhang into the neighbouring TVPS. Nowadays, this issue is solved by design rules or operational measures. A technical solution could be implemented in the future by adding an associated safety margin to the uMobExtent. Nevertheless, this topic requires further analysis.
- There isn't a direct 1:1 relation between uMOB and its corresponding PTU(s) as it is like for rMOB.
  - One TVPS can be occupied by more than one railway vehicles
  - If the uMobExtent is derived from a TTD system, it covers exactly one TVPS, e.g. an unknown real-world object occupying two subsequent TVPS will result into the creation of two uMOBs (see figure below). *Please note, that the numbering of uMOBs in the figures are only of exemplary nature.*

- uMobExtent does not change, but the uMOB (and thus also the uMOBExtent) can be removed



The following example depicts the determination of the uMobExtent applying the principles introduced above.

Already in the first step the far-reaching effect of the differences in availability of train information compared to rMOBs is apparent. APS lacks the knowledge of the real-world object(s) occupying TVPS2 and therefore determines the extent of uMOB123 to be the length of the track section being limited by TVPS2 (see step 2). The real world object(s) occupying the tracks are dynamic: They are movable and they can alter their length (e.g. stretching freight trains). In step 3 another occupancy is reported by TVPS3 and again, APS does not know if the train occupying TVPS2 is moving, stretching, loosing a wagon etc. Therefore, in step 4 a new uMOB963 is being created which has the same extent as the track section being limited by TVPS3. In this example, vacancy is being reported by TVPS2 which triggers APS to delete uMOB123. From the viewpoint of APS it is not known if the object that has caused uMOB123 moved to TVPS3 (although that is the most probable situation).



Please note:

- *The scenario above is also valid if a TVPS is disturbed and thus, an occupancy will be reported.*
- *The manner in which an unknown PTU represented by uMOB will be allowed to move (operational process, receiving a MP, etc) is to be decided.*
- *The behaviour of uMOBs in an OTD area will defer from the principles introduced above due to on-board information being available. Please refer to 'Correlation of rMOB and uMOB' in chapter 'Future Considerations'.*

5.4 Life cycle of Movable Objects

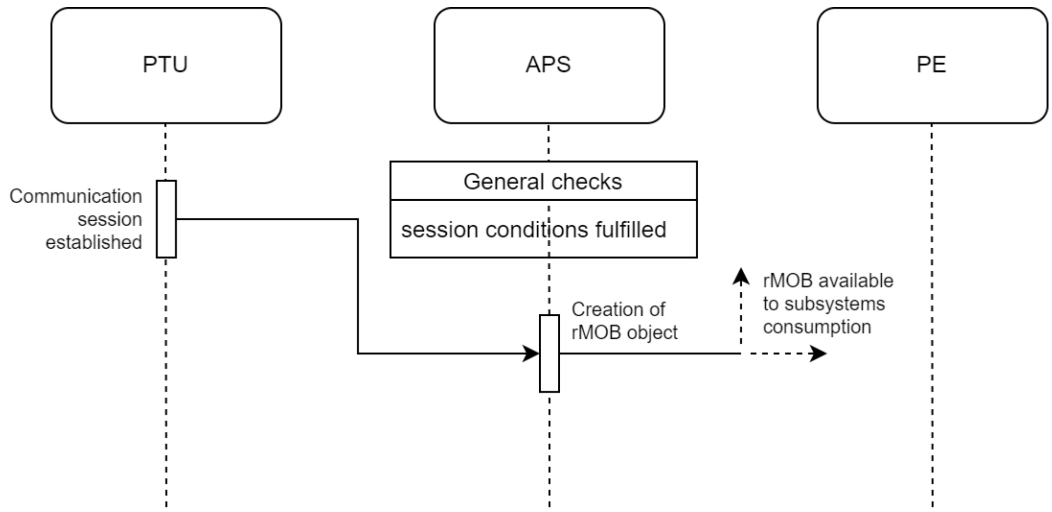
5.4.1 Overview

For safety and operational reasons it is important to have a representation exact as needed within the RCA system of all relevant real-world objects that are located on or near the railway tracks . The life cycle of a Movable Object consists of the following phases:

Creation

APS is responsible to create a Movable Object if it receives information about it, i.e.

- A Resolved Trackbound Movable Objects is created as soon as the linked railway vehicle gets identified (e.g. during the establishment of communication).
- An Unresolved Trackbound Movable Objects is created as soon as the underlying TTD system reports an occupancy that cannot be safely mapped to already existing rMOB(s). Alternatively, it will be created as soon as APS detects the necessity for it.



Update

A Movable Object collects all attributes of the object it represents that are relevant to interfacing subsystems to execute their given functions. The attributes of a MOB will be dynamically updated where new related information is made available at every processing cycle.

Note: Updates are only applicable for Resolved Trackbound Movable Objects. Unresolved Trackbound Movable Objects are only created or removed. The number of characteristics that shall be stored for an rMOB depends on the type of object it represents and the information being reported at a specific time. At the time of writing of this concept only a small number of characteristics were defined for rMOBs. It is expected that further development of the concept will lead to an increase of the number of characteristics required by interfacing subsystem's functionalities.

Note: With exception of uMOBs, dependent on the type of the localisation technology in place or the frequency/latency of the available communications, updates may result in changes to the geometric extent of the MOB.

Deletion

APS removes Movable Objects from its Operating State if it can conclude safely from the received information that the corresponding track topology is no longer occupied by the corresponding real-world object(s). This can happen for example if an rMOB leaves the APS AoC.

In case of removing a Resolved Trackbound Movable Object while an underlying TVPS is still reported to be occupied, an Unresolved Trackbound Movable Object needs to be created in case it does not exist yet (see creation bullet point above).

5.4.2 State machine of Resolved Trackbound Movable Object

Please note: The rMOB life cycle below has been derived focusing on a basic scenario, where a PTU with valid and trustworthy position starts-up in ETCS Level R and receives an ETCS Movement Authority from trackside. Other authorisations (e.g. SR Authorisations to achieve a valid position first) as well as revocations have not yet been considered (refer to chapter 'Delimitations' / 'Normal Operation').

Please also note: Granting a Movement Permission to an rMOB covers two steps, i.e. protecting the route path and sending the associated authorisation to the PTU (refer to /RCA.Doc.63/). Route protection is possible independent of the current state of the rMOB while sending an authorisation is only useful if the corresponding PTU is also able to process it. The state machine below supports the latter.

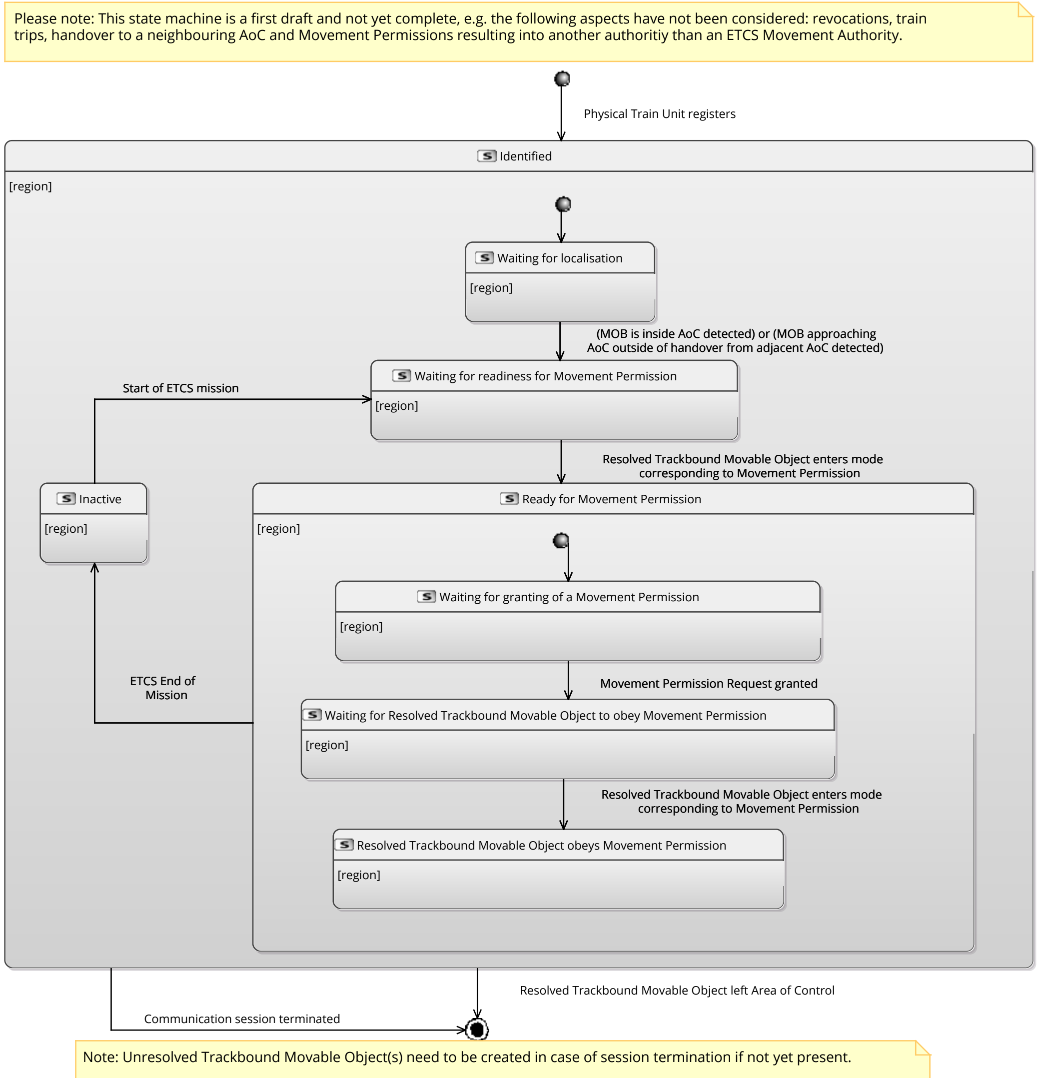


Figure 10: [S.STM][AMOD-034] Resolved trackbound movable object states [Abstract Concept States]

State	Description
Identified	The unique identification of the corresponding real-world object is known to System RCA.
Waiting for localisation	The session with the corresponding real-world object is established but it has not reported a valid and trustworthy position and can therefore not be safely located in the topology.
Waiting for readiness for Movement Permission	The corresponding real-world object is not yet ready to receive/ process an ETCS Movement Authority.
Ready for Movement Permission	The corresponding real-world object is localised, has sent train data and trackside has acknowledged this train data, i.e. the real-world object is ready to receive a Movement Permission.

State	Description
Waiting for granting of a Movement Permission	The corresponding real-world object is ready to receive/process an ETCS Movement Authority but System RCA has not yet granted a Movement Permission.
Waiting for Resolved Trackbound Movable Object to obey Movement Permission	A Movement Permission has been granted and the associated authorisation has been sent to the corresponding real-world object but the latter has not yet switched to a mode indicating that it obeys this authorisation.
Resolved Trackbound Movable Object obeys Movement Permission	The corresponding real-world object has reported a mode indicating to obey the granted authorisation.
Inactive	The corresponding real-world object has terminated the mission but the communication session still exists.

5.4.3 State machine of Unresolved Trackbound Movable Object

The next pictures illustrate the life cycles of Unresolved and Resolved Trackbound Movable Objects.

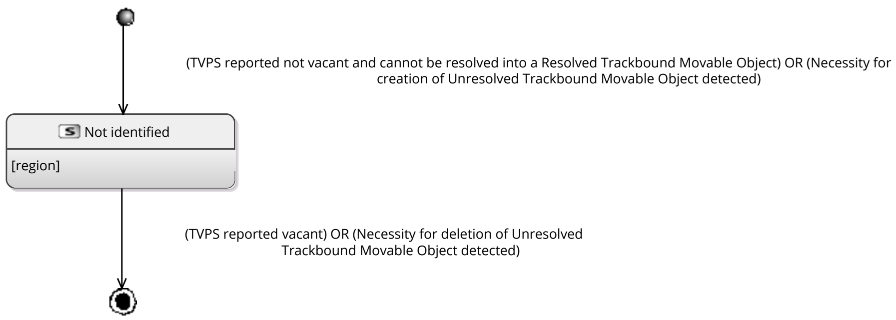


Figure 11: [S.STM][AMOD-034] Unresolved trackbound movable object states [Abstract Concept States]

State	Description
Not identified	The unique identification of the corresponding real-world object is not known to System RCA.

5.5 List of functions

The following functions are required in order to manage Trackbound Movable Objects during their life cycle.

Including ETCS shall not restrict the solution space nor lead to the assumption RCA only works with ETCS. Using /SUBSET-026/ for particular issues in the following functions shall not prevent other solutions, e. g. for transmitting Train Data in SUBSET-026 format.

Function name	Description	Remark
map TVPS update to occupancy state	This function translates the TVPS state reported by the external actor into an APS internal representation of the occupancy state.	Both TVPS states "disturbed" and "occupied" are translated into "not vacant". APS only knows two occupancy states, i.e. "vacant" and "not vacant".
check unique mapping of occupancy information with existing MOBs	This function checks if the occupancy information can be mapped safely to an rMOB or uMOB and triggers the associated action.	If the occupancy state of a TVPS changed to "vacant" and • one or more rMOBs are (partly) located within this TVPS → function "Change rMobExtent" • a uMOB exists for this TVPS → function "remove uMOB" If the occupancy state of a TVPS changed to "not vacant" and there is no rMOB that can be safely mapped to this occupancy → function "create uMOB"
Change rMobExtent	The function is triggered by "check unique mapping of occupancy information with existing MOBs" after detecting that a TVPS covered by the current rMobExtent became "vacant". It determines the new extent.	
create uMOB	This function creates a uMOB for the given occupancy extent.	
remove uMOB	This function removes the corresponding uMOB.	
create rMOB	This function creates an rMOB.	The creation of an rMOB is performed as soon as its domain ID becomes available. At that point in time no further information is available yet (e.g. localisation data, train date etc.)
handle position report	This functions translates an ETCS position report into APS relevant data.	The result of this function will be used in → function "aggregate rMOB".

Function name	Description	Remark
aggregate rMOB	This function processes localisation information received from the actor PTU and determines the extent and direction of the corresponding rMOB	
handle movable device data	This function translates the train data related ETCS message into APS relevant data.	This contains e. g. • max speed • train length • unique domain ID
update rMOB	This function updates the attributes of an rMOB.	
Handle End of Mission	This function processes EoM-Message from PTU and sets rMOB inactive or terminates session.	The behaviour depends on the ability of PTU to support "always connected, always reporting". If not: request session termination to PTU.
Process Session Termination	This functions processes an intentionally closed communication session between track- and trainside.	
Remove rMOB	This functions removes rMOB after session is terminated intentionally and creates one or more uMOB if not present yet.	Please refer to chapter 'Future Consideration' for more detailed information.

5.6 Basic scenarios

The following scenarios shall depict the above mentioned solution approach for some typical operational scenarios. The selection is not complete but it shall strengthen the understanding of the solution approach. In a first step it only depicts selected basic scenarios in detail. Other normal and degraded operation scenarios will be elaborated in detail in a later stage of this concept.

Note: The mentioned states refer to chapter 'State machine of Resolved Trackbound Movable Object'. The scenarios are described with the use of ETCS references for simplification, the use of ETCS interface is not a pre-requisite defined at this stage.

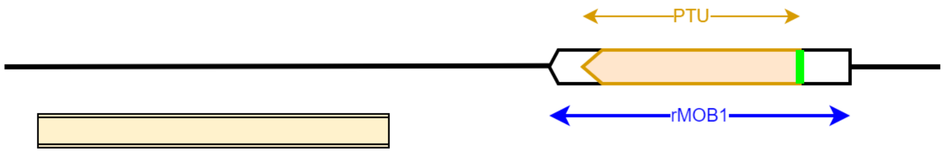
5.6.1 PTU with integrity (always reporting position) performs a mission with valid position

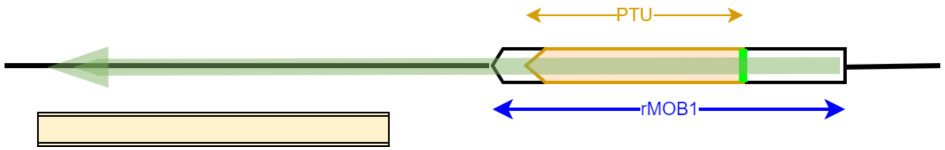
This scenario reflects the ideal situation in which a PTU that has been parked and that has always reported its position including train integrity performs start of mission with a valid position, moves along the extent of a granted Movement Permission and performs end of mission after reaching the target location.

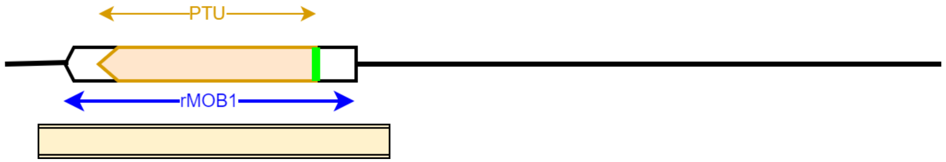
Preconditions:

- formation of PTU did not change compared to last mission (e.g. same length, same active cab, integrity continuously available)
- PTU has continuously reported position including integrity, i.e. communication session between PTU and APS is established and therefore rMOB1 is known to APS
- there are no other railway vehicles close to the PTU

Scenario:

Description	APS view
PTU is parked and continuously reports position and integrity 	rMOB1 is known to APS with depicted extent rMobState = 'inactive' no other rMOB close to rMOB1 no parallel uMOB
PTU performs ETCS SoM: • PTU sends SoM Position Report indicating valid status	rMobState changes from 'inactive' to 'Waiting for readiness for MP' because rMOB is already localised
• PTU sends Train Data and APS acknowledges it	rMobState changes from 'Waiting for readiness for MP' to 'Waiting for granting of a Movement Permission' because the PTU is now able to process an ETCS MA

Description	APS view
Plan Execution (PE) requests a Movement Permission 	APS performs safety checks and grants MP (please refer to /RCA.Doc.63/ for more details) APS sends ETCS MA to PTU. rMobState changes from 'Waiting for granting of a Movement Permission' to 'Waiting for Resolved Trackbound Movable Object to obey Movement Permission'
PTU receives ETCS MA, changes ETCS mode and reports mode change 	rMobState changes from 'Waiting for Resolved Trackbound Movable Object to obey Movement Permission' to 'Resolved Trackbound Movable Object obeys Movement Permission'
PTU starts moving and frequently reports its position including integrity 	APS updates the rMobExtent based on the received localisation information APS shortens the Movement Permission at the rear end of the PTU according to the defined safety principles (please refer to /RCA.Doc. 63/)
PTU reaches target location, stops and sends position report including integrity 	APS shortens the Movement Permission at the rear end of the PTU according to the defined safety principles (please refer to /RCA.Doc. 63/)

Description	APS view
PTU performs end of mission 	APS updates the rMobExtent based on the received localisation information rMobState changes from 'Resolved Trackbound Movable Object obeys Movement Permission' to 'inactive' The MP will automatically be removed if all relevant conditions apply (see /RCA.Doc.63/).
PTU is still sending position reports including integrity	APS updates the rMobExtent based on the received localisation information

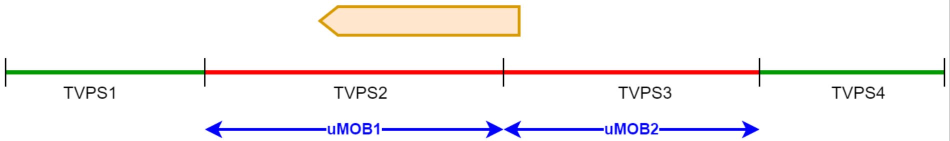
5.6.2 PTU with integrity (not always reporting) performs SoM with valid position

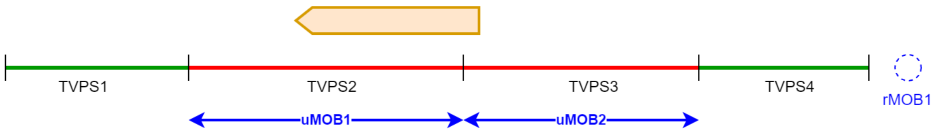
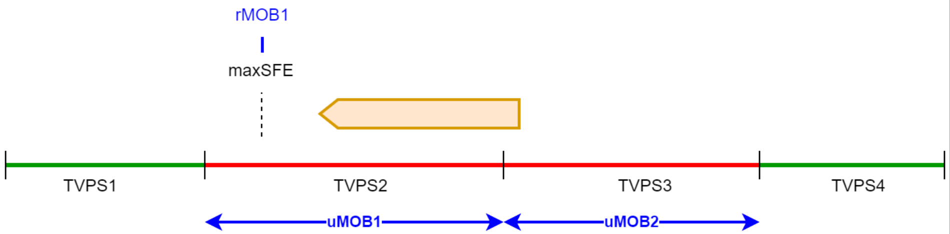
This scenario reflects the situation in which a PTU with confirmed integrity that is located inside a TTD area and that has not continuously sent position reports performs start of mission with a valid position. This may happen for example if a parked PTU, which is equipped with a cold movement detector, starts up or if a non-active PTU performs SoM after train splitting.

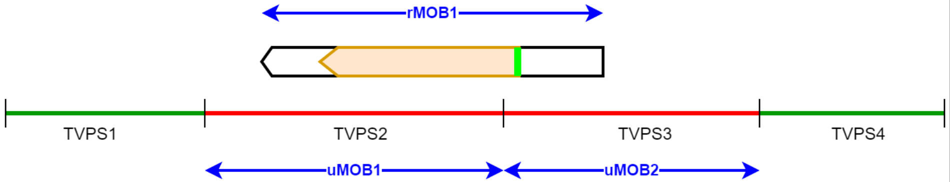
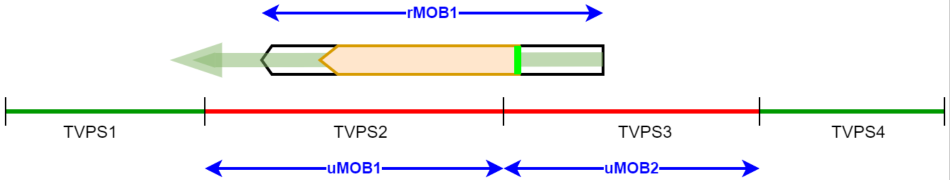
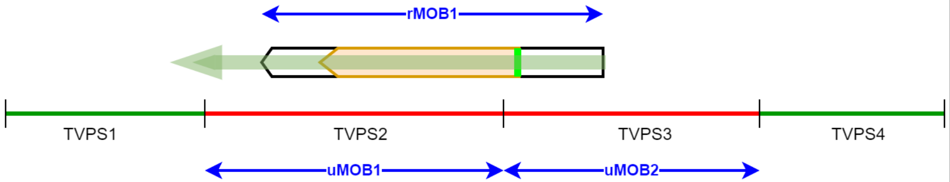
Preconditions :

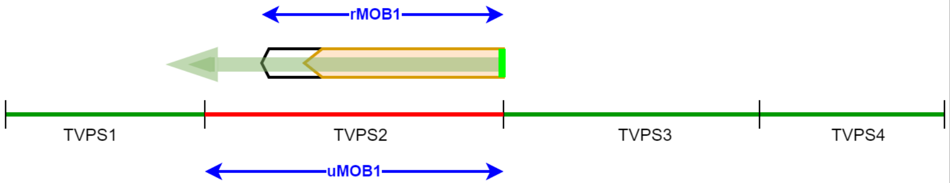
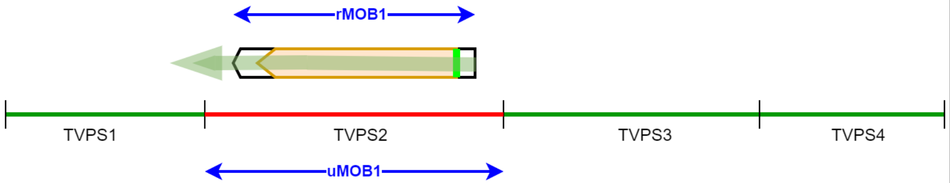
- TTD system is installed and works under specified conditions
- PTU has performed end of mission and does not report its position
- Train integrity is confirmed on-board

Scenario:

Description	APS view
PTU has performed end of mission in a TTD area and does not report its position. TTD system has reported occupancy for TVPS2 and TVPS3. 	As APS has no communication session with the PTU and an occupancy has been reported for TVPS2 and TVPS3, two uMOBs (representing these occupations) have been created.

Description	APS view
PTU establishes communication session with APS (and reports domain ID). 	APS recognises that conditions for session establishment are fulfilled and creates rMOB1. *Note: At this point in time the rMOB cannot be placed in the topology as it has not yet sent localisation information.* rMobState is set to 'wait for localisation'
PTU performs ETCS SoM  • PTU sends SoM Position Report indicating valid status, train integrity confirmed but not yet reported to trackside	If APS can exclude that the PTU is not located on a parallel points leg (e.g. due to shunting movements prior to start of mission), rMOB1 position is determined in the topology. rMobState changes from 'wait for localisation' to 'wait for readiness for Movement Permission'. *Please note: According to the current solution proposal of CR940 (safe train length) train with confirmed integrity will not report integrity to trackside until train data has been acknowledged by trackside. If the SoM position report does not indicate train integrity, the localisation of the rMOB in the topology is performed exclusively based on the reported front end information and the rMOB is depicted as a point (please refer to 'Representation of rMOB as a point' in chapter 'Future Considerations' for potential open issues). If the PTU already reports train integrity within the SoM Position Report, the rMobExtent is determined as described in chapter 'Determination of Trackbound Movable Object Extent' but this is out of scope of the current scenario.*
• PTU sends Train Data and APS acknowledges it	rMobState changes from 'Waiting for readiness for MP' to 'Waiting for granting of a Movement Permission' because the PTU is now able to process an ETCS MA

Description	APS view
PTU sends Position Report indicating integrity  	APS determines rMobExtent as described in the chapter 'Determination of Trackbound Movable Object Extent' above.
Plan Execution (PE) requests a Movement Permission  	APS performs safety checks and grants MP. APS sends ETCS MA to PTU. rMobState changes from 'Waiting for granting of a Movement Permission' to 'Waiting for Resolved Trackbound Movable Object to obey Movement Permission' *Please note: in scope of the MOB concept the type of MP and resulting ETCS MA does not matter. However the uncertainty in occupancy needs to be supervised by APS. Please refer to /RCA.Doc.63/.*
PTU receives ETCS MA, changes ETCS mode and reports mode change  	rMobState changes from 'Waiting for Resolved Trackbound Movable Object to obey Movement Permission' to 'Resolved Trackbound Movable Object obeys Movement Permission'

<table>
<tr><th>Description</th><th>APS view</th></tr>
<tr><td>PTU starts moving and leaves TVPS3. TVPS vacancy report for TVPS3 sent from TTD system

</td><td>APS removes uMOB2 due to TVPS vacancy report from TTD system.
APS shortens rMobExtent (at rear end) due to the TVPS vacancy report. An update at the front is not performed as APS has not yet received a new position report from the PTU.
APS shortens the Movement Permission at the rear end of the PTU according to the defined safety principles (please refer to /RCA.Doc. 63/)</td></tr>
<tr><td>PTU continues to move and reports position including integrity

</td><td>APS updates the rMobExtent (front and rear) based on the received localisation information from the PTU.
APS shortens the Movement Permission at the rear end of the PTU according to the defined safety principles (please refer to /RCA.Doc. 63/)</td></tr>
</table>

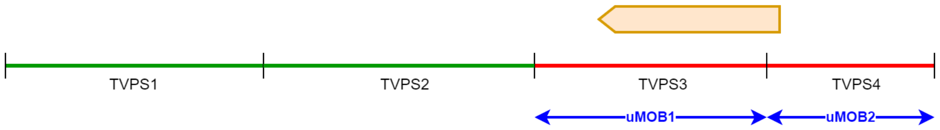
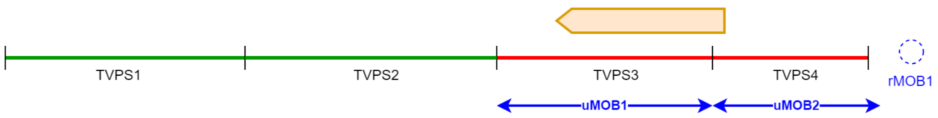
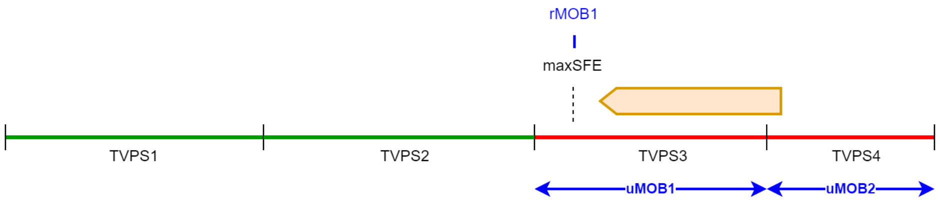
5.6.3 PTU without integrity (not always reporting) performs SoM with valid position

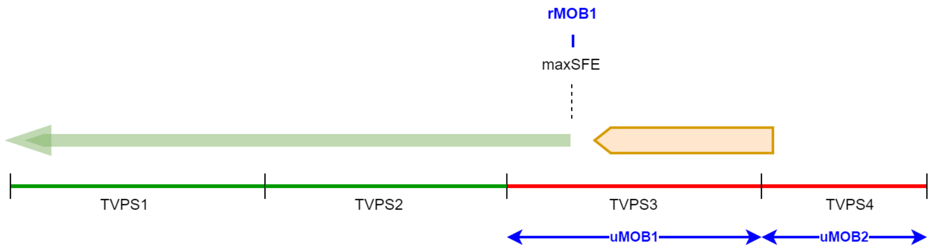
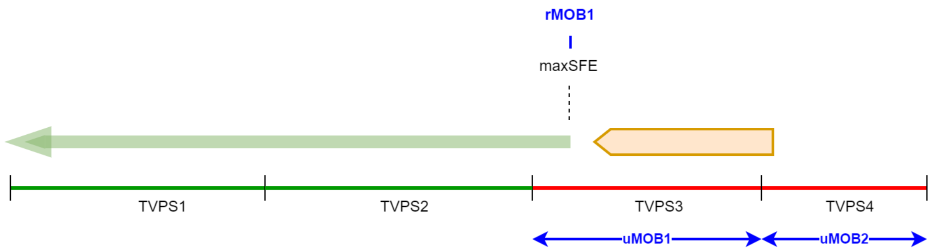
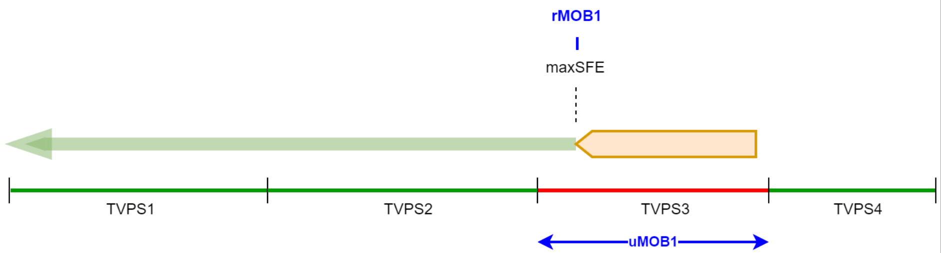
This scenario reflects the situation in which a PTU that is located inside a TTD area and that has not continuously sent position reports performs start of mission with a valid position. Train integrity cannot be confirmed on-board.

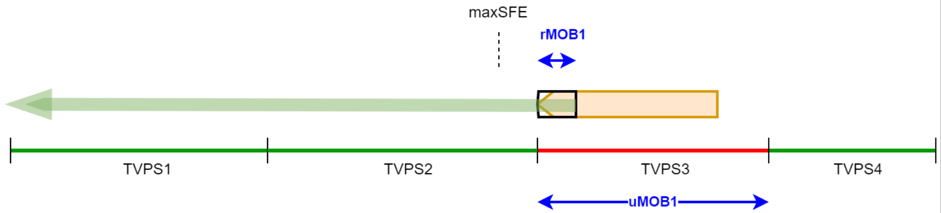
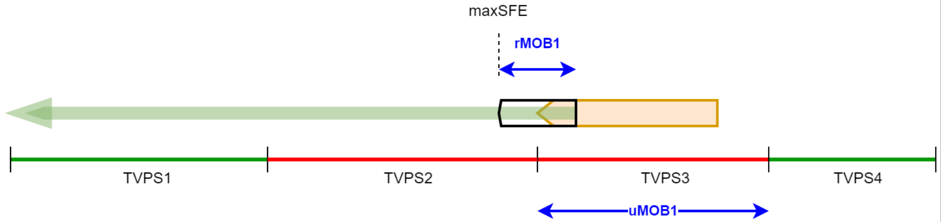
Preconditions :

- TTD system is installed and works under specified conditions
- PTU has performed end of mission and does not report its position
- Train integrity cannot be confirmed on PTU side

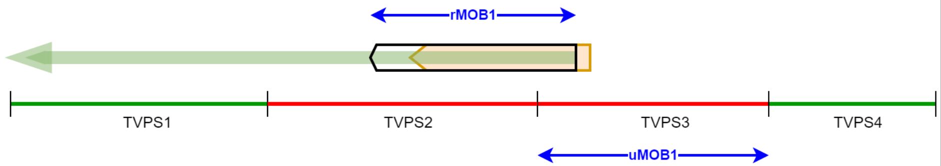
Scenario:

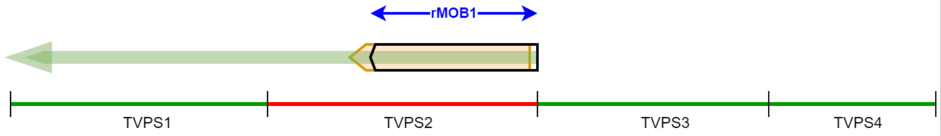
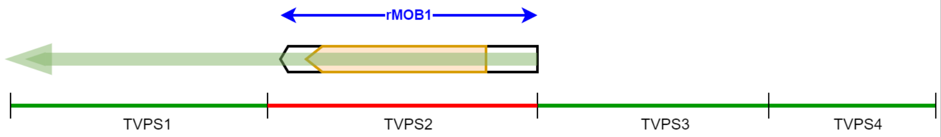
Description	APS view
PTU has performed end of mission in a TTD area and does not report its position. TTD system has reported occupancy for TVPS3 and TVPS4.  	As APS has no communication session with the PTU and an occupancy has been reported for TVPS3 and TVPS4, two uMOBs (representing these occupations) have been created.
PTU establishes communication session with APS (and reports domain ID).  	APS recognises that conditions for session establishment are fulfilled and creates rMOB1. *Note: At this point in time the rMOB cannot be placed in the topology as it has not yet sent localisation information.* rMobState is set to 'wait for localisation'
PTU performs ETCS SoM:  • PTU sends SoM Position Report indicating valid status, no integrity	If APS can exclude that the PTU is not located on a parallel points leg (e.g. due to shunting movements prior to start of mission), rMOB1 position is determined in the topology. The rMobExtent is zero, i.e. rMOB1 is depicted as a point (see explanation in previous table). Please refer to 'Representation of rMOB as a point in chapter 'Future Considerations' for potential open issues. rMobState changes from 'wait for localisation' to 'wait for readiness for Movement Permission'.
• PTU sends Train Data and APS acknowledges it	rMobState changes from 'Waiting for readiness for MP' to 'Waiting for granting of a Movement Permission' because the PTU is now able to process an ETCS MA

Description	APS view
Plan Execution (PE) requests a Movement Permission 	APS performs safety checks and grants MP request. APS sends ETCS MA to PTU. rMobState changes from 'Waiting for granting of a Movement Permission' to 'Waiting for Resolved Trackbound Movable Object to obey Movement Permission' *Please note: in scope of the MOB concept the type of MP and resulting ETCS MA does not matter. However the uncertainty in occupancy needs to be supervised by APS. Please refer to /RCA.Doc.63/.*
PTU receives ETCS MA, changes ETCS mode and reports mode change 	rMobState changes from 'Waiting for Resolved Trackbound Movable Object to obey Movement Permission' to 'Resolved Trackbound Movable Object obeys Movement Permission'
PTU starts moving and leaves TVPS4. TVPS vacancy report for TVPS4 sent from TTD system 	APS removes uMOB2 due to TVPS vacancy report from TTD system. rMobExtent and MP remain unchanged as not related to uMOB2. This results from the fact that the rMOB is depicted point-shape and completely located inside TVPS3.

<table>
<tr><th>Description</th><th>APS view</th></tr>
<tr><td>PTU continues to move and reports position without integrity

</td><td>APS updates the rMobExtent, i.e.
the rear remains at the previous position
the front is moved to the TVPS border between TVPS2 and TVPS3 as maxSFE is located within a vacant TVPS (TVPS2)</td></tr>
<tr><td>PTU enters TVPS2. TVPS occupancy report is sent from TTD system

</td><td>APS does not create an uMOB for TVPS2 if the occupancy can be safely attributed to rMOB1 (e.g. maxSFE located inside TVPS2, PTU has MP covering TVPS, etc.)

Please note: conditions how APS safely determines that a TVPS occupancy is caused by a dedicated rMOB need to to be defined (see 'Correlation of rMOB and uMOB' in chapter 'Future Considerations')

rMobExtent is updated to cover the previously reported maxSFE position</td></tr>
<tr><td>PTU reports position in TVPS2

</td><td>APS updates the rMobExtent, i.e.
the rear remains at the previous position
the front end is updated according to the received position information</td></tr>
</table>

Description	APS view
PTU leaves TVPS3. TVPS vacancy report is sent from TTD system 	APS removes uMOB1 due to TVPS vacancy report from TTD system. APS updates the rMobExtent, i.e. • the rear end is moved to the TVPS border between TVPS2 and TVPS3 due to the TVPS vacancy report • the front remains at the previous position as no new position has been reported by PTU yet APS shortens the Movement Permission at the rear end of the PTU according to the defined safety principles (please refer to /RCA.Doc.63/)
PTU sends position report without integrity 	APS updates the rMobExtent, i.e. • the rear remains at the TVPS border • the front is updated according to the received position information

5.6.4 PTU (not always reporting) performs SoM with invalid /unknown position

If a PTU does not report a valid position and therefore cannot be safely localised on the railway track, then APS cannot grant a Movement Permission resulting into an ETCS MA. Nowadays, this problem is often solved by granting an ETCS Staff Responsible Authorisation instead that allows the PTU to move under driver control. As soon as a new reference location (i.e. ETCS balise group) is passed and the PTU gets localised, an upgrade MA is sent. It has to be defined on operational and system level how to cope with these situations in the future keeping in mind that the safety responsibility of drivers shall be reduced and that railway operation shall be automated, including driver-less and unattended train operation. As soon as the corresponding concepts have been defined on operational/system level, this scenario can be detailed within this paper.

5.7 Future Considerations

As described in the previous sections a number of points are still under consideration and subject to further development. Some of them are summarised below.

5.7.1 Resolved Trackbound Movable Object

5.7.1.1 Change requests with impact

The final implementation of the change requests below in future version of the ETCS specifications (e.g. /SUBSET-026/, /SUBSET-091/) need to be analysed as they directly impact the Movable Object concept.

5.7.1.1.1 CR940 (Minimum Safe Rear End position and position reporting ambiguities)

This CR deals with the safe train length reported by means of an ETCS Position Report to APS. Depending on the implemented solution, there may be operational situations in which a PTU with integrity does not report integrity to APS (e.g. SoM prior train data acknowledgement by APS, when sending position reports outside of an ETCS Mission). These situations and the resulting impact on the rMobExtent must be analysed in order to derive adequate measures on system layer.

5.7.1.1.2 CR1304 (Missing Level 3 safety requirements)

The CR addresses that /SUBSET-091/ does not cover ETCS Level 3 requirements. The CR solution should finally deal with several aspects, e.g. SIL of on-board train integrity monitoring technology and SIL of the safe train length sent in an ETCS position report in case of train confirmed train integrity. The discussions currently ongoing in scope of this CR reflect that some integrity-related information may only be provided with SIL 2. This has an impact for APS as additional safety measures might need to be defined in case of clearing the track behind a PTU based on a train position report because TTD systems that nowadays provide safety for train movements are SIL 4.

5.7.1.1.3 CR1350 (always connected, always reporting)

It has to be analysed if there are still regular operational situations in which the communication session with trackside is terminated. In that case, the fact that APS does not receive any information from the PTU has to be classified as normal operational situation again rather than as degraded one. On the one hand, this needs to be considered when making MOB-related design decision (like removal on rMOB in case of session termination as outlined also in chapter 'State Machine of Resolved Trackbound Movable Objects'). On the other hand, this must be addressed in an impact analysis in order to derive adequate measures (e.g. regarding the usage of OTD areas).

5.7.1.1.4 CR1367 (cab anywhere supervision)

Nowadays the active ETCS cab is always located at the train front (except for reversing mode) referring to the train running direction and both train front and rear are derived from the side of the active cab. Consequently, an integrity loss (e.g. due to a lost wagon) does not affect the train running direction and corresponding safety measures need to be applied only in reverse direction. If in future the cab can be located anywhere in the train formation, APS needs to be able to perform safety reactions affecting the movement direction, e.g. if the active cab is located at the rear end of a train formation, a lost wagon can move in train running direction and may therefore overpass the end of Movement Permission and the risk buffer. Furthermore, the concrete CR implementation needs to be checked with regard to the information provided in the ETCS position report. Possible changes towards the determination of train front and rear end determination as well as information derived from the direction controller will have a direct impact on localising a PTU in the topology and determination of the train running direction.

5.7.1.1.5 CR1389 (reaction when CI of the odometry is exceeding the accuracy requiremen t of 5m+5% (SS-41))

This CR deals with definition of an adequate reaction (e.g. enter ETCS mode System Failure) in case the PTU's confidence interval exceeds the performance requirement defined in /SUBSET-041/. The impact of the concrete solution on the Movable Object concept needs to be analysed in order to be able to cope with this situation.

5.7.1.1.6 CR1408 (Train data before SoM position report)

This CR describes the problem that in some situations a PTU may send validated train data after communication session establishment prior to a SoM position report. The impact of the CR solution needs to be analysed as it may impact MOB-related system design.

5.7.1.2 Attributes

It is expected that characterisation attributes other than occupancy related features should be updated when made available following specific request-response flows between the involved RCA subsystems. However the definition of all required characteristics of the different MOB types is still ongoing, and therefore is also the decision-making regarding how these are to be managed by the system.

5.7.1.2.1 Multidimensional characteristics of rMobExtent

Currently, dimensional attributes were regarded mostly from a uni-dimensional point of view (parallel to the track). It is possible however that the characterisation of rMOB in bi- or tri-dimensional manner (i.e. depth and height) would enable the optimal (most operationally efficient) handling of situations such as protection of limited clearance areas and fouling points as well as protection from/for non-trackbound objects and the handling of warnings and warning areas. This multi-dimensional characterisation could be executed by using the available information regarding train characteristics (e.g. type, cant, etc.) and track characteristics (e.g. gauge, curvature, etc), or still be assigned specific values.

5.7.1.2.2 Multi-cab train formation

ETCS train formations usually consist of active and non-active cabs, where the active cab is normally located at the front relating to the train running direction (exception: reverse and shunting movement). Nowadays, the trackside safety system has no knowledge about the train formation, i.e. which cabs are contained in it. As a consequence, different cabs establishing a communication session with APS would be identified as different PTUs that have no correlation to each other. This can lead to operational obstructions in case of dedicated scenarios such as joining, splitting and SoM after turnaround movement, especially with regard to OTD areas. In the current concept each rMOB is expected to be assigned one specific rMobDomainID because at this point in time the handling of basic scenarios such as the reporting of the non-leading cabs were not yet defined. It is expected therefore that one rMOB will in the future be able to store more than one domain ID, as well as other relevant characteristics. Changes are also expected with regard to the active cab position. A cab located at any arbitrary position in the train formation may become a normal operational scenario rather than an exceptional situation. This does also have an impact on the MOB concept and needs to be further detailed.

5.7.1.2.3 State Machine

The rMOB state machine needs to be extended under consideration of further scenarios including MP revocations, handover from and to neighbouring AoCs and, if applicable, MPs resulting into authorisations other than ETCS Movement Authorities.

5.7.2 Non-Trackbound Movable Objects

The abstraction of the many objects and elements that form an operational railway - and the simplified (in terms of diversity) safe-handling of this information by APS - is one of the main objectives of this overall Conceptual Development. It brings many opportunities to tackle operational issues that today are responsible for restricting overall performance gains. One of these opportunities is of course the safe and more efficient handling of physical interventions to the infrastructure.

From a APS safety-related perspective, there is an opportunity to ultimately diminish the number of incidents or accidents involving personnel or light vehicles. The concept of non-trackbound Movable Objects (nMOB) comes then here to play its part.

Although this concept has not yet been greatly rationalised, it relies in large on a assumed technology which shall be able to the relatively precise localisation of personnel or other light movable-objects on a defined work-site. These abstracted objects can then be individually, or collectively, aggregated of a safety margin area, which would be supervised by APS against open line movements.

Of course, besides the availability of a technological solution to support this early concept, further safety parameters, supervision triggers and reactionary measures, and operational-safety procedures need still to be discussed and defined at the next stages of development.

5.7.3 Overall Trackbound Movable Objects safety considerations

5.7.3.1 Definition of safe aggregation rules

When considering future scenarios further rules have to be defined for safe determination of the rMobExtent.

5.7.3.2 Correlation of rMOB and uMOB

APS does not create a uMOB if a TVPS vacancy report can be safely attributed to existing rMOB(s). Conditions for checking this must be defined.

According to the current concept, APS only removes uMOBs in case of receiving a TVPS vacancy report from the TTD system. Additional trigger (e.g. operator input) may be defined in order to ease and speed up operational situations (e.g. SoM).

5.7.3.3 Representation of rMOB as a point

It has to be re-analysed whether a representation of the rMOB as a point in case of SoM without history and missing integrity information is really an adequate solution. Representation of an rMOB as a point during SoM has the advantage that the implementation of complex algorithms to determine a potential rear end without achieving additional safety benefits is avoided. In theses situations safety (i.e. to prevent a collision with another train) is already achieved by the uMOBs that exists parallel to the rMOB and that prevents that APS grants unrestricted Movement Permissions allowing other PTUs to enter occupied TVPSs. The problem of a punctual representation results from the fact that APS needs to decide where to place this punctual rMOB, i.e. to choose a dedicated train front end position. Currently, the maxSFE is used as rMOB location but depending on the localisation technology inherited inaccuracy, it can be located quite far away from the PTU's physical front end. It has to be analysed whether the estimated front end is more suitable for a punctual point-shaped rMOB representation or if an alternative solution approach such as spanning the initial rMobExtent over the PTU's confidence interval is more suitable.

5.7.3.4 Overlapping rMobExtents

It has to be analysed how to handle the overlapping of rMOBs when considering operational scenarios such as joining, splitting and two PTUs closely approaching each other (e.g. in case of multiple stopping points in a station).

5.7.3.5 Safety margins

Whether or not additional safety margins (e.g. rollback distances, TVPS overhang, trackworker position) have to be considered by APS for determination of the MOB extent needs further investigation. This topic is mainly linked to the question whether localisation or detection systems providing input information to APS already cover these aspects or not. There is no need to introduce additional safety margins on APS level if they are already considered somewhere else.

5.7.4 Scenarios to be detailed on operational and/or system level

Sequence diagrams to describe the scenarios shall be considered in later version of the MOB concept.
The following operational scenarios need to be detailed on operational/system level as they directly impact MOB-related design decisions.

5.7.4.1 How to start up with invalid/unknown position

Sometimes it happens that a PTU cannot be localised in the topology, e.g. if the PTU is not always connected, always reporting and it starts-up

- with invalid position. Example: Nowadays, PTUs not equipped with a cold movement detector always start-up from ETCS mode No Power with invalid position (e.g. after being parked). This results from the fact that cold movement cannot be excluded and therefore the stored position information may be invalid. In legacy systems, these situations are resolved by allowing the PTU to move under driver responsibility until passing the next reference location. As soon as a new reference location is reported to trackside, the PTU can be localised in the topology and upgraded with an ETCS MA, i.e. safety is transferred back from driver to the train control system.
- with unknown position if trackside was not able to acknowledge the previously reported invalid position
- with unknown position during initial commissioning

It has to be clarified on operational/system level whether SoM with invalid/unknown position - where nowadays the safety responsibility completely lies on the driver side - is still applicable in the future or not, especially with regard to driver-less and unattended train operation. Depending on the decision either alternative solutions need to be defined or measures that prevent the situation from occurring need to be derived.

5.7.4.2 Availability of localisation technologies

There are several types of availability of localisation technologies. In later stages of this concept it has to be analysed what availability means exactly (e. g. unavailability caused by loss of radio connection, or increased confidence interval or axle counter failure) and how to handle them regarding safety. This analysis shall also contain alignment with operational concepts owner on how this will influence operational performance.

6 Conclusion

With RCA, the concept of Movable Object will be introduced. This concept comprises the RCA representation of trackbound (e.g. trains) and non-trackbound (e.g. track worker) movable railway objects. In a first step, the concept describes how different information from trackbound and trainborn localisation technologies are aggregated to a rMOB to represent a PTU. The rMOBs will then contain information abstracted from these objects which is relevant to RCA , including the position of PTUs and its estimated extent (i.e. including localisation technology inaccuracy). Hence, rMOBs are supposed to be the unified and unique representation of one PTU for all subsystems of RCA (e. g. APS or PE). In case of uncertainty, e.g. there is no radio connection between trackside and PTU, a uMOB can be created instead of an rMOB. In further steps the concept will define more details of rMOB, uMOB and introduces determination of nMOB. The MOB concept is a fundamental enabler for the corresponding MP concept / RCA.Doc.63/ with its train-centric approach.