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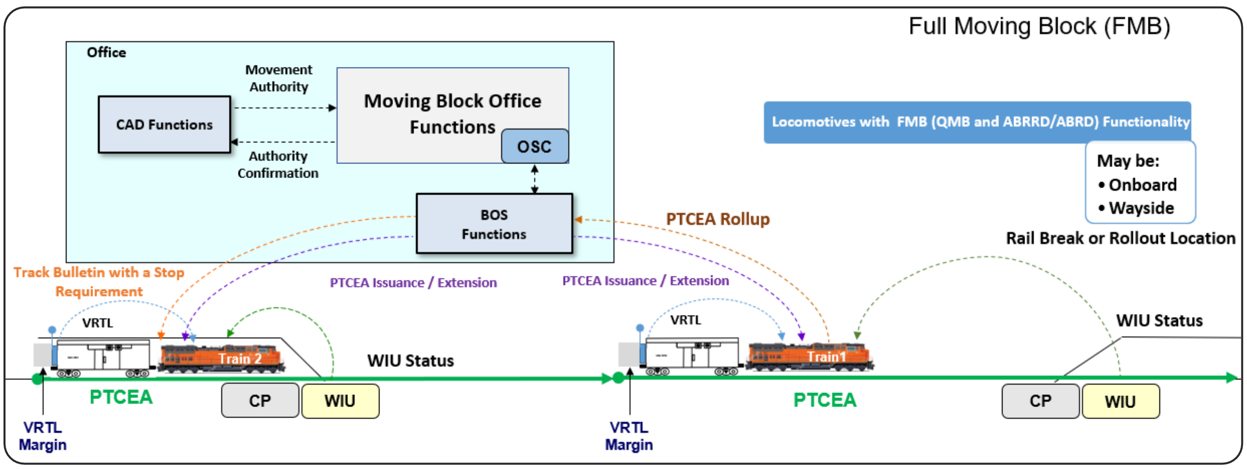
Federal Railroad Administration

Office of Research, Development and Technology
Washington, DC 20590

Full Moving Block Concept and Requirements Specification for Railroad Operations



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14. ABSTRACT
In a research project funded by the Federal Railroad Administration (FRA) from May 2020 to September 2022, Transportation Technology Center, Inc. collaborated with a railroad industry technical advisory group (TAG) to develop 1) the concept, 2) the system-level, segment-level, and interface requirements, 3) the migration considerations, and 4) the initial safety analysis for an Interoperable Full Moving Block (FMB) method of train control. The fundamental objective of FMB is to achieve safety and near theoretical maximum capacity benefits without the artificial constraints inherent in fixed block operations. Through research efforts and guidance from the TAG, the team concluded that the O-PTC and QMB architectural foundations can be fully leveraged for the implementation of FMB with minimal incremental changes.

15. SUBJECT TERMS
Full Moving Block, FMB, Interoperable Train Control (ITC), Overlay Positive Train Control (O-PTC), Quasi-Moving Block (QMB), Alternative Broken Rail and Rollout Detection/Alternative Broken Rail Detection (ABRRD/ABRD)

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ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

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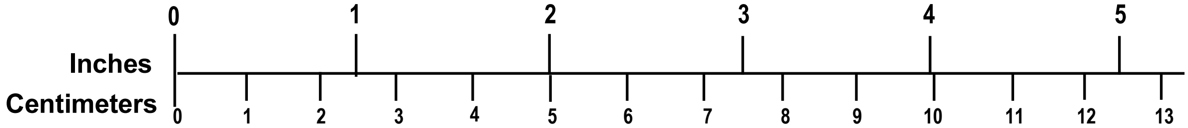
QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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Executive Summary

In a research project funded by the Federal Railroad Administration (FRA) from May 2020 to September 2022, Transportation Technology Center, Inc. collaborated with a railroad industry technical advisory group (TAG) to develop 1) the concept, 2) the system-level, segment-level, and interface requirements, 3) the migration considerations, and 4) the initial safety analysis for an Interoperable Full Moving Block (FMB) method of train control. The fundamental objective of FMB is to achieve safety and near theoretical maximum capacity benefits without the artificial constraints inherent in fixed block operations.

The FMB Concept of Operations (ConOps) document inherited concepts from previously developed Interoperable Train Control (ITC) Overlay Positive Train Control (O-PTC) and Quasi-Moving Block (QMB) ConOps. The FMB method consists of QMB integrated with an Alternative Broken Rail and Rollout Detection/Alternative Broken Rail Detection (ABRRD/ABRD) method. The FMB ConOps presents three architectures for ABRRD/ABRD systems along with the interfaces and messaging associated with each architecture.

The team developed FMB system- and segment-level requirements and accompanying ABRRD/ABRD system requirements. The FMB system- and segment-level requirements define additions and changes to both the existing O-PTC system and the proposed QMB system requirements to implement FMB functionality. The FMB requirements are not intended to duplicate requirements already addressed by existing O-PTC and proposed QMB requirements specifications. The ABRRD/ABRD system requirements are agnostic to the ABRRD/ABRD technology employed whenever possible. These requirements were used in the downstream development of the FMB system and segment requirements that covered the Office, Wayside, and Onboard segments.

FMB also requires the implementation of a Vital Rear-of-Train Location (VRTL) system, which provides vital End of Train (EOT) location information to the locomotive onboard system. VRTL must be implemented prior to or with a migration to FMB.

Through research efforts and guidance from the TAG, the team concluded that the O-PTC and QMB architectural foundations can be fully leveraged for the implementation of FMB with minimal incremental changes. Additionally, it was noted that FMB can be implemented as an overlay to existing field interlocking systems; however, if this is the case, full capacity may not be achievable in some specific and typically infrequent operational scenarios. If field interlocking is retained, subsequent decommissioning of conventional track circuits can be accomplished, except for approach and On Sheet (O/S) track circuits. Complete decommissioning of track circuits will require the implementation of alternative methods of interlocking systems, such as centralized interlocking.

The team also prepared a migration considerations report, including a high-level description of items to consider and possible steps necessary to deploy an FMB system. Multiple paths are provided depending on conditions of existing systems, volume of train traffic, and other variables.

Researchers also developed a preliminary safety analysis focused on the hazards that may be introduced by integrating the ABRRD/ABRD system architectures with the existing O-PTC and proposed QMB train operations methods (as described in the FMB ConOps). This analysis did

not uncover any major hazards that could not be mitigated. Several hazards related to the EOT-ABRD interface with the Moving Block (MB) Office subsystem were identified, and appropriate mitigation procedures were presented. Overall, the team found that if the proposed mitigations are implemented, the residual risks will be equal to or lower than existing O-PTC hazards, according to an established Hazard Risk Index (HRI).

1 Introduction

In a research project funded by the Federal Railroad Administration (FRA) from May 2020 to September 2022, Transportation Technology Center, Inc. collaborated with a railroad industry technical advisory group (TAG) to develop 1) the concept, 2) the system-level, segment-level, and interface requirements, 3) the migration considerations, and 4) the initial safety analysis for an Interoperable Full Moving Block (FMB) method of train control. In this research, the team analyzed critical issues, developed key technical documents needed for system development, and built on the existing Interoperable Train Control (ITC)-Positive Train Control (PTC) system and Quasi-Moving Block (QMB) train control technical documents.

1.1 Background

As part of FRA-sponsored research on Higher Reliability/Capacity Train Control (HRCTC), several enhanced methods of railroad operation that leverage elements of current ITC-PTC systems have been identified and shown to provide benefits over conventional methods of train control. The stages of train control defined by the HRCTC program are:

- Overlay PTC (O-PTC) – ITC PTC currently deployed in compliance with the Rail Safety Improvement Act of 2008 (RSIA'08)
- Enhanced Overlay PTC (EO-PTC)
- Quasi-Moving Block PTC (QMB)
- Full Moving Block PTC (FMB)

Each of the above train control methods can be considered a mode of PTC that builds on its predecessor. Consequently, each successive enhanced mode incorporates the benefits of its predecessor and increases those benefits or provides additional benefits. A railroad may employ one of these train control modes in one area and a different mode in another area, with a seamless transition between these areas. FMB design and implementation leverage QMB architecture and design.

As in QMB, FMB issues non-overlapping movement authorities, known as PTC Exclusive Authorities (PTCEA), for every train operation, offering safety improvements over current O-PTC, including the ability to provide collision protection at any speed. PTCEAs are issued and updated dynamically as the "moving blocks" of movement authority required for QMB and FMB operation.

FMB offers greater capacity and operational gains than QMB by eliminating unnecessary constraints associated with fixed-block train control systems and employing the train control concepts necessary to approach the minimum theoretical headways and maximum theoretical capacity on railroad main lines. Figure 1 depicts the potential for reduced headways using the FMB method of operation compared with conventional 4-aspect block signaling and conventional track circuits.

With some modifications, FMB can leverage existing O-PTC and planned QMB architecture and infrastructure. This includes the potential reuse of onboard PTC hardware (with modified software), interoperable train control messaging (ITCM), and 220 MHz radio communications. In addition to the modification of onboard software, the PTC Office segment will require modifications to include FMB Office functions. FMB also requires train integrity monitoring (e.g., a vital VRTL determination system, as may be used optionally with QMB) and an alternative to conventional track circuits for the detection of broken rails and unauthorized occupancies (e.g., rollouts).

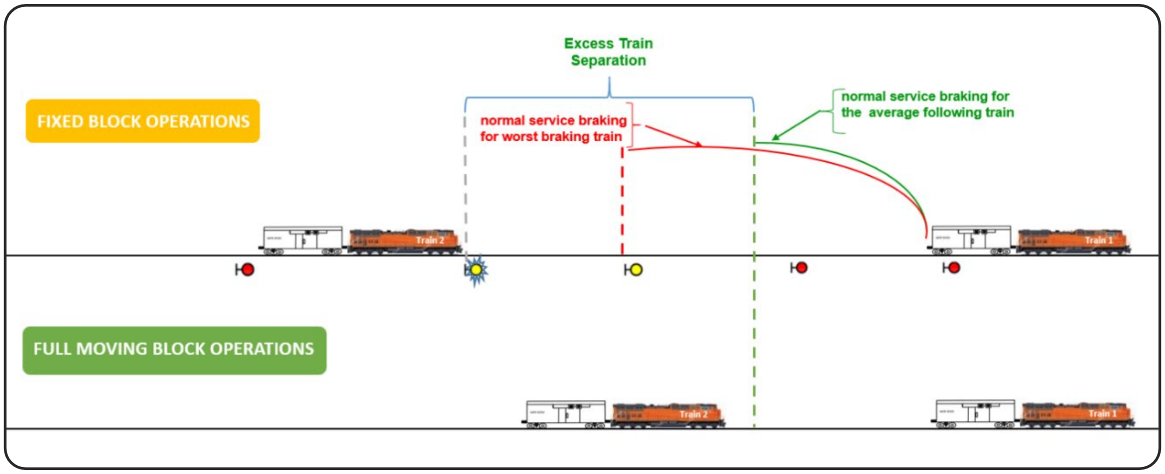

Figure 1. Fixed Block and Moving Block Spacing Comparison

1.2 Objectives

The objective of this project was to develop the FMB concept and requirements for railroad operations. This effort included the development of 1) the FMB concept of operations, 2) supporting FMB requirements specifications, 3) FMB migration considerations, and 4) a preliminary FMB safety analysis.

1.3 Overall Approach

Researchers worked with both a TAG composed of representatives of freight and passenger railroads and FRA on this project, holding periodic meetings where concepts and requirements were reviewed as part of project development and organizing technical discussions as needed throughout the development process.

The team developed the FMB ConOps and the QMB and ABRRD/ABRD requirements in parallel on related projects. Researchers then developed the FMB system and segment level requirement documents, including modifications to existing Interface Control Documents (ICDs) needed to support the concept. Migration considerations and safety analyses were developed in parallel with the FMB requirements.

1.4 Scope

The scope of the project included the development of both the ConOps and system and segment level requirements for interoperable FMB train control, leveraging from the foundation of current O-PTC and proposed QMB systems. The effort also included the development of migration considerations, recommended changes to existing ICDs, and a preliminary safety analysis to identify potential new or altered hazards introduced by the FMB concept. The scope of the requirements effort was limited to changes to existing O-PTC and proposed QMB to support the FMB concept; the requirements developed during this project are not intended to specify functions or capabilities already present in the previous methods of train control.

The development of concepts and requirements for FMB also used the latest development efforts of additional technologies required for FMB operation, i.e., ABRRD/ABRD alternatives to track circuits and vital train integrity monitoring systems (e.g., VRTL). No analysis was done on theoretical alternatives that may not be feasible or are too incipient. The team considered trree categories of alternatives to conventional track circuits for the detection of broken rails and unauthorized occupancies (e.g., rollouts) (Section 2.1). Wayside status messages (WSMs) for switch, and in some cases track, status were retained. The developed concepts and requirements assume that FMB is being implemented as an overlay to existing field interlocking systems; however, if a centralized interlocking alternative is implemented, minimal changes to the requirements would be required. The concepts and requirements are limited to ITC-compliant systems.

Migration considerations included the identification of cost drivers for the implementation of FMB. These considerations may be used by a railroad when developing its own cost-benefit analysis.

The research team produced the following documents:

- FMB ConOps
- FMB Migration Considerations report
- ABRRD/ABRD Requirements Specification
- FMB System and Segment Requirements Specification
- Incremental updates to ICDs
- Preliminary FMB Safety and Hazard Analysis

1.5 Organization of the Report

The report is organized into the following sections: Section 2 provides an overview of the deliverables developed for this project. Section 3 provides the project conclusions and recommendations for future work. Several appendices listed at the end of the report are available by request from FRA:

- Appendix A – FMB Concept of Operations
- Appendix B – FMB Migration Considerations
- Appendix C – ABRRD/ABRD Requirements Specification
- Appendix D – FMB System and Segment Requirements Specification
- Appendix E – Sections of the relevant redlined ICDs
- Appendix F – Preliminary FMB Safety and Hazard Analysis

2 Project Overview

In this project, the research team developed the following items:

- FMB ConOps
- FMB Migration Considerations Report
- ABRRD/ABRD System Requirements
- FMB Incremental System and Segment Requirements
- Incremental Updates to Existing ICDs
- FMB Preliminary Safety Analysis

These tasks are explained further in the following subsections.

2.1 Concept of Operations (ConOps) for FMB

The team collaborated with TAG participants to develop the FMB ConOps document. The FMB method of train control is based on:

- Inheriting core principles from O-PTC
- Inheriting selected principles from QMB
- Employing alternative broken rail and rollout detection systems in territory where track circuits are currently in use
- Including vital train integrity monitoring

The core new functionality introduced by FMB is non-fixed block broken rail and rollout protection. These functions, coupled with PTCEAs and a VRTL determination system (introduced with QMB), complete the FMB solution. ABRRD/ABRD systems are the key and most challenging component to enable migration from a track-centric fixed block architecture to a train-centric moving block train control architecture. The team proposed three ABRRD/ABRD architecture alternatives, any one of which will support train-centric moving block architecture:

1. **Head-Of-Train (HOT) ABRRD**: Onboard broken rail and rollout detection that interrogates the track ahead of the train
2. **End-Of-Train (EOT) ABRD[1]**: Onboard broken rail detection that interrogates the track behind the train
3. **Wayside ABRRD**: Alternative wayside broken rail and rollout detection, i.e., wayside-based but without the limitations of fixed block track circuit-based detection

[1]The ConOps refers to EOT ABRD as an alternative broken rail detection (ABRD) system rather than an alternative broken rail detection and rollout detection (ABRRD) system. The rationale is that there was no notable mounted EOT device at the writing of the ConOps that could detect rollouts to a usable extent. Therefore, a complementary rollout system such as derails, O/S circuits, etc., will need to be used with this option.

These alternatives can be implemented as standalone solutions or in combinations of two or all three alternatives. Interfacing to the train control systems is further discussed in the FMB ConOps (Appendix A).

2.2 Migration Considerations

The migration considerations report includes a high-level description of the items to consider and the steps that need to be undertaken to deploy an FMB system for each of the potential ABRRD/ABRD alternatives. In the cases of the HOT-ABRRD and Wayside-ABRRD solutions, 3 implementation stages with 10 potential paths were identified and detailed. In the case of the EOT-ABRD, two implementation stages and five potential paths were identified and detailed. The team produced a high-level analysis of the cost drivers for implementing the core FMB functions as well as optional items that can be used by a railroad to help guide the decision to implement FMB in each territory.

As described in Appendix B, the research team reports that the EOT-ABRD solution would be available soonest due to the maturity of the technology, but the HOT-ABRRD option would be more desirable because it provides the capability of rollout detection that EOT-ABRD cannot provide on its own. However, just like the Wayside-ABRRD option, the HOT-ABRRD solution is at a significantly lower technology readiness level than that of the EOT-ABRD systems and, therefore, will likely lag in adoption.

The FMB Migration Considerations report is included in Appendix B.

2.3 ABRRD/ABRD System Requirements Specification

The FMB system requires an ABRRD/ABRD system to support increased capacity, while achieving at least the same level of safety (i.e., rail break and rollout detection performance) as conventional track circuits. Thus, the team used these initial requirements (Alternative Broken Rail Detection System Requirements LD-TD21-003, 2021) to develop a standardized framework for developing ABRRD/ABRD systems while the requirements stay agnostic to the details of the technology.

The ABRRD/ABRD Requirements Specification is included in Appendix C.

2.4 FMB Incremental System and Segments Requirements Specification

The team developed an FMB system and segment requirements specification that captures the system, segment, and interface requirements, as well as the main message flows for FMB functionality for each of the three ABRRD/ABRD architectures. In addition, a companion ABRRD/ABRD system requirements document was developed to further the development of this essential FMB support system.

The requirements in the specification are prioritized in that firm (i.e., essential) requirements in the document contain the word ***shall***. Desirable but not mandatory requirements or goals contain the word ***should***.

The FMB system-level and subsystem/segment-level requirements will lead to additions and changes in the O-PTC and QMB systems to implement FMB functionality. It is not intended for the requirements specification to duplicate requirements already addressed by existing O-PTC specifications; however, a few requirements are restated (e.g., nuanced to accommodate

QMB/FMB requirements). Additionally, existing O-PTC and QMB functionalities are not eliminated with the addition of FMB functionality (i.e., functions implemented in O-PTC and QMB that FMB uses will remain unchanged unless otherwise specified.) The FMB system retains all necessary functionality for backward compatibility to support the operation of trains in territories with legacy ITC PTC systems that have not been upgraded to support FMB (i.e., in O-PTC and QMB territories).

The document identifies high-level interfaces with external systems, subsystems, and users. Referenced ICDs are used to define detailed interfaces and message contents.

The segment and system definitions used in the document are as follows:

- Computer-Aided Dispatch (CAD) System
- PTC Office Segment including:
    - Moving Block Office Subsystem
    - Office Safety Checker (OSC) Subsystem
    - Back Office Server (BOS) Subsystem
- PTC Wayside Segment, i.e., Wayside Interface Unit (WIU) System
- PTC Locomotive Segment, i.e., Onboard Segment
- HOT-ABRRD System
- EOT-ABRD System
- Wayside-ABRRD System
- VRTL System

The FMB system and segment requirements specification includes natural tracing for a given system-level requirement; one or more segment-level or subsystem-level requirements are listed directly beneath each. Each system-level requirement flows down to one or more segment-level or subsystem-level requirements via one of the following methods:

- Direct Allocation is used when a requirement can be flowed down "as is" to a next lower-level specification (e.g., to a segment requirement). It applies directly to the lower-level element.
- Apportionment is used when a requirement must be split up into portions, each of which flows into a different lower-level specification.
- Derivation applies to all other requirements. A derived requirement differs from its higher-level parent requirement in some way other than apportionment.

Some requirements reference other requirements in different sections. In such cases, a note or narrative text provides context for this reference.

The FMB system and segment/subsystem-level requirements contained in Appendix D are not implementation specific, except to the extent necessary to support interoperability, allowing the maximum possible flexibility for a system architect to develop the most effective design.

2.5 Recommended Changes to Interface Control Documents

While developing the QMB/FMB system/segment requirements specifications, the team identified necessary changes to the ITC PTC Office-Locomotive Segment ICD and PTC Wayside-Locomotive Segment ICD. These ICDs provided the interoperable messages exchanged between the Office and Onboard segments and the Wayside and Onboard segments, respectively. Recommended changes to the existing AAR standards were captured via redline markup (i.e., S-9361 applicable to QMB/FMB for the Office and Onboard segments, and S-9362 applicable to QMB/FMB for the Wayside and Onboard segments). Additionally, the onboard track file will need to be updated to accommodate the addition of HOT-ABRRD, EOT-ABRD, and Wayside-ABRRD. These changes are captured via recommended changes to S-9501: PTC Data Model Definition and S-9503: Interoperable Train Control Track Data File Format ICD. The ICDs with the proposed changes are referred to as Incremental ICDs applicable to FMB.

The team reviewed the proposed changes to the ICDs with the TAG. In general, the TAG advised that additional burden added to the onboard functionality should be kept to a minimum, and messages identified for modification were to be modified so as not to distort their initially intended purposes.

QMB/FMB makes use of all existing PTC messages but relies on specific key messages that enable QMB/FMB functionality. The messages with specific FMB functionality and their level of modifications are presented in Table 1.

Table 1. PTC Messages with Specific QMB/FMB Functionality

Inherited O-PTC Messages with no Functional Content Modification	Key Recommended Messages Inherited from O-PTC for QMB/FMB with Additional Functional Content Modifications
(01041) Bulletin Dataset **(01043)** Bulletin Cancellation **(01083)** Confirmation of Enforcement Warning/Braking Notification **(01085)** Confirmation of Train Handling Exception Report **(01087)** Confirmation of Locomotive Fault Report	**(01050)** Confirmation of Crew Authority Request **(02050)** Crew Authority Request **(01051)** Movement Authority Dataset **(01080)** Request Locomotive Position Report **(02080)** Locomotive Position Report **(02083)** Enforcement Warning/Braking Notification **(02085)** Train Handling Exception Report **(02087)** Locomotive Fault Report **(02090[2])** Broken Rail Occupancy Detection Report **(01090)** Request Broken Rail/Occupancy or Unauthorized Occupancy Detection Report **(05100)** Wayside Status Message

All other existing O-PTC messages will perform as originally designed and are inherited as is by FMB train control. The key messages are named per existing ICDs. The proposed changes, including name changes, can found in the redlined ICDs in Appendix E.

Once the technologies are mature and ready for deployment, other standards that are not redlined but will require changes to accommodate ABRRD/ABRD device data in the track files include S-9501: PTC Data Model Definition and S-9503: Interoperable Train Control Track Data File

[2] Proposed (02090) message to report broken rail status and occupancy to the Moving Block Office that was detected by an HOT-ABRRD or EOT-ABRD interfaced with the FMB Onboard. Functional contents of the message are defined in the S-9631 – "Locomotive to Office ICD document – Applicable to QMB/FMB."

Format. These changes require the identification of ABRRD/ABRD systems interfaced with the locomotive and locations of any auxiliary devices necessary for the functioning of the ABRRD/ABRD systems.

2.6 Preliminary Safety Analysis

The safety analysis effort included identifying potential new or altered hazards introduced by the FMB concept. This analysis also considers new or altered hazardous situations identified during the development of the FMB ConOps and System Requirements (focusing on the ABRRD/ABRD systems) because these are the incremental components added to QMB to achieve FMB.

Researchers did not uncover any major hazards that could not be mitigated; however, some hazards related to the EOT-ABRD interface with the PTC Office segment and supplementary rollout detection were found for which the team specified appropriate PTC Office segment-based mitigations. The HOT-ABRRD and Wayside-ABRRD hazards were similar to existing cab signaling and wayside-based hazards and mitigations. The updated ConOps and the QMB/FMB system and segment requirements specifications were updated when necessary to align with the findings in the safety analysis. The safety analysis is a preliminary draft that will require further updates by any railroad planning to deploy FMB, particularly to account for railroad-specific characteristics.

The team concurrently performed complementary safety analyses on two related projects: 1) QMB System Requirements Development for the identification of potential hazards introduced by QMB for functions leveraged by FMB, and 2) the OSC for PTC Office segment related hazards. Ideally, these documents should be reviewed with the presented FMB preliminary safety analysis when advancing to subsequent safety analysis stages. The FMB preliminary safety analysis is included in Appendix F.

3 Conclusions

The research team worked with an industry TAG to develop the concept for the FMB method of train control as well as the requirements specification for railroad operations. During this project, the team developed the following documents: FMB ConOps, FMB System/Segment Requirements Specification, redlined Office-Locomotive Segment and Wayside-Locomotive Segment ICDs, migration considerations, and preliminary safety analysis to capture any recommended changes. Per the guidance of the TAG, any additional burden added to the onboard processor was kept to a minimum, and messages identified for revision were modified to avoid distorting their initially intended purposes.

The major conclusions from the project include:

- The O-PTC and QMB architectural foundations and system requirements can be fully leveraged for the implementation of FMB with minimal changes to the appropriate ICDs. The recommended changes to support specific FMB functionality were made to existing ITC messages specified in AAR standards, including "Office-Locomotive Segment ICD" (AAR Standard S-9361 V3.0) and "Wayside-Locomotive ICD" (AAR Standard S-9362 V1.1). Additional complementary changes to accommodate FMB are referenced for "PTC Data Model Definition ICD" (AAR Standard S-9501) and the "Interoperable Train Control Track Data File Format ICD" (AAR Standard S-9503).
- Office hardware requirements for the implementation of FMB are expected to be fully satisfied with QMB implementation. Additional FMB software functionality in the PTC Office segment will cause minimal demand in computing processing and other hardware requirements such as memory and storage.
- Any of the three ABRRD/ABRD alternatives considered in the development of the project can support FMB operations.
    - Additional Onboard software implementation will be required for ABRRD/ABRD interfacing and functionalities; however, current Onboard hardware is expected to support ABRRD/ABRD interfacing and functionalities by leveraging existing Onboard EOT-HOT, CAB signaling, and Wayside signaling interfaces and functionalities.
    - Implementation of Wayside-ABRRD will require modification of the WSM message structure (described in the incremental S-9362 ICD for FMB functionality) and additional payload for alerting messages when an exception occurs, which should cause negligible additional message traffic loading.
    - Per the guidance of the TAG, the team revised preliminary versions of the FMB ConOps and FMB system and segment requirements specifications to include a Stop requirement to protect other trains in EOT-ABRD territories when a broken rail is reported. This approach was taken in keeping with currently established operating procedures to protect against a defective rail report.
    - The lack of a standard framework was identified as an impediment to developing the ABRRD/ABRD hardware necessary to support the migration to FMB; thus, an ABRRD/ABRD requirements specification document was prepared as part of this project.

- FMB can be implemented as an overlay to existing field interlocking systems; however, full capacity may not be achievable in some specific and typically infrequent operational scenarios.
- If field interlocking is retained, conventional track circuits can be decommissioned, except for approach and O/S track circuits. Decommissioning approach track circuits would require implementation of centralized interlocking.
- If not yet implemented prior to the adoption of FMB, positive EOT location determination with messaging between an EOT component (e.g., VRTL) and the HOT will have to be implemented with FMB.

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Appendices

The following appendices are available by request from FRA:

Appendix A: Concept of Operations for Full Moving Block (FMB)

Appendix B: Migration Considerations for Full Moving Block (FMB)

Appendix C: ABRRD/ABRD Requirement Specifications

Appendix D: QMB/FMB System / Segment Requirements Specification

Appendix E: Incremental Interface Control Documents (ICDs)

Appendix F: Preliminary Safety Analysis for Full Moving Block

Abbreviations and Acronyms

ACRONYM	DEFINITION
ABRD	Alternative broken rail detection
ABRRD	Alternative broken rail and rollout detection
ABS	Automatic block signaling
ACK	Acknowledgement message
AG	Advisory group
ATP	Authority to pass signal at Stop
BOS	Back-office server
BPP	Brake pipe pressure
CAD	Computer-aided dispatch
CAD-MA	CAD movement authority
CBTC	Communications-based train control
CIXL	Centralized interlocking
ConOps	Concept of operations
CP	Control point
CRC	Cyclic redundancy check
CTC	Centralized traffic control
EO-PTC	Enhanced overlay-Positive Train Control
EOT	End-of-train
FMB	Full moving block
FRA	Federal railroad association
GCOR	General code of operating rules
GPS	Global Positioning System
HMAC	Hash-based message authentication code
HMI	Human-machine interface
HOT	Head-of-train
HRCTC	Higher reliability and capacity train control
HRI	Hazard risk index
ICD	Interface control document
IJ	Insulated joint
ITC	Interoperable train control
MAS	Maximum authorized speed
MD	Mandatory directive

ACRONYM	DEFINITION
NAK	Negative acknowledgement message
NGTC	Next generation track circuits
O&SHA	Operating and support hazard analysis
OSC	Office safety checker
O/S	On Sheet
PHA	Preliminary hazard analysis
PTC	Positive Train Control
PTCEA	Positive Train Control Exclusive Authority
QMB	Quasi-moving block
RF	Radio frequency
RSIA ‘08	Rail safety improvement act of 2008
RSR	Restricted speed restriction
SHA	System hazard analysis
TC	Track circuit
TWE	Train, workers, or equipment
TWC	Track warrant control
TTCI	Transportation technology center, inc.
TWC-ABS	Track warrant control with automatic block signals
VBTC	Virtual block track circuits
VRTL	Vital rear-of-train location
WIU	Wayside interface units
WSM	Wayside status message