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FULL MOVING BLOCK (FMB) CONCEPT AND REQUIREMENTS SPECIFICATION FOR RAILROAD OPERATIONS

SUMMARY

The Federal Railroad Administration sponsored Transportation Technology Center, Inc., (MxV Rail), in collaboration with a rail industry stakeholder technical advisory group (TAG), to refine concepts and develop interoperable requirements for the Full Moving Block (FMB) method of train control. The team worked to develop an FMB Concept of Operations (ConOps) document with a focus on interfacing with alternative broken rail and rollout detection (ABRRD) system architectures; develop an Incremental FMB System and Segment Requirements Specification document; develop ABRRD system requirements; redline the Interoperable Train Control (ITC) Office-Locomotive Segment Interface Control Document (ICD), as well as the ITC Wayside-Locomotive Segment ICD, to capture recommended changes; develop migration considerations; and conduct a preliminary safety analysis. Research was conducted from May 2020 to September 2022.

BACKGROUND

As part of an ongoing program to support higher reliability and capacity train control (HRCTC), three new methods of train control have evolved from the current form of ITC Positive Train Control (PTC) (i.e., Overlay PTC): 1) Enhanced Overlay PTC (EO-PTC), 2) Quasi-Moving Block (QMB), and 3) FMB. Of these three train control methods, FMB offers the greatest safety, capacity and operational gains since it employs concepts necessary to approach the minimum theoretical headways and the maximum capacity on railroad main lines (Vieira, Rosales-Yepez, Polivka, & Brosseau, 2022).

Figure 1 shows an example of the overall FMB architecture message flow with two trains in a following move. FMB inherits most of its design from the existing ITC PTC and QMB architectures (Kindt, Vieira, & Polivka, In press), but employs an alternative method of detecting broken rail and rollouts to that of conventional track circuits. As presented in this project, FMB is essentially QMB integrated with an ABRRD system.

Authority is provided by a non-overlapping movement authority known as a PTC Exclusive Authority (PTCEA) and broken rail and rollout detection is provided by an ABRRD system. The team proposed three system architectures during this project:

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) Alternative Broken Rail Detection (ABRD): 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 that can cause excess train spacing

None of the EOT-mounted devices reviewed during this project could detect rollouts to a usable extent. Therefore, the EOT alternative is referred to as ABRD rather than ABRRD. If an EOT ABRD system is used, supplementary technology is required to detect rollouts.

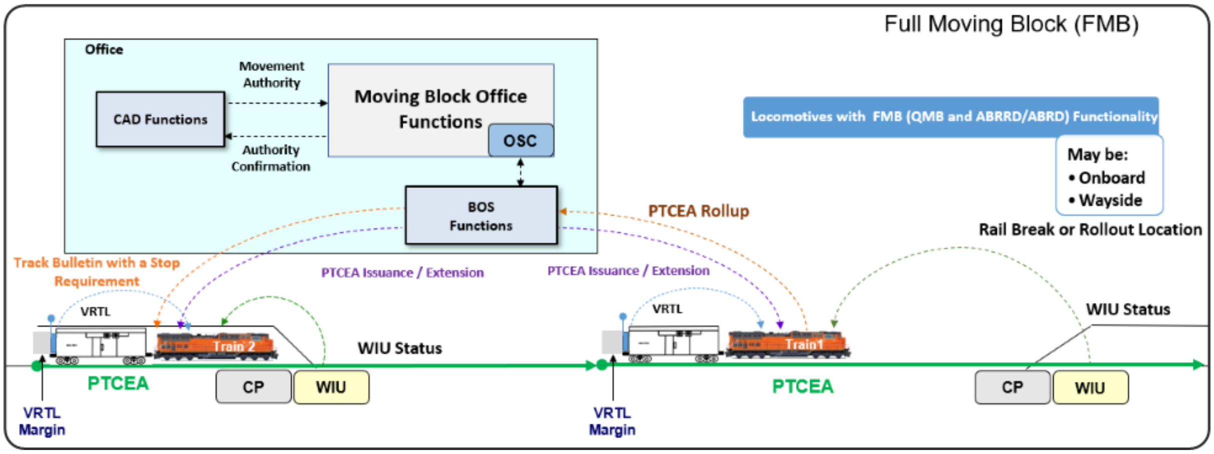

Figure 1. FMB Components and Key Message Flows

With FMB, the train authorization process retains the conventional route creation steps in which the computer-aided dispatch (CAD) system issues route requests that have traditionally been executed by control points or issued as track warrants. The moving block office segment uses the route request information to automatically create or update a train's PTCEA (ensuring it does not overlap with any other PTCEA) and then sends it to the train through the available communication path(s).

A train's onboard segment sets its target limits based on the PTCEA received from the office, along with any other information. As the train moves, it automatically releases the track behind it by rolling up its PTCEA, using either its calculated or detected EOT location. Once the office is informed of the rollup, it can then extend a following train's PTCEA. The status of field devices is continuously monitored by the onboard segment via wayside status messages (WSMs) broadcast from wayside interface unit (WIU) locations. The status of the track is provided by whichever ABRRD solution has been adopted, either onboard or by a wayside device.

FMB offers benefits in the areas of safety, capacity, and reliability, as detailed in Table 1.

Table 1. FMB Expected Benefits

Category	Expected benefit
Safety	Improved broken rail detection between closely following trains
Capacity and Efficiency	Near theoretical maximum train throughput capacity
	Reduction in delays when returning to MAS after traffic interruptions
Reliability-Maintainability	Increased pull-apart protection when the reported vital end-of-train indicates greater train length than estimated, in which the pulled-apart cars are protected within the limits of the train's PTCEA

OBJECTIVES

The objectives of the FMB Concept and Requirements Specification project were to:

- Develop and document the FMB ConOps
- Develop and document FMB migration considerations
- Develop and document incremental FMB system/segment requirements
- Develop and document an FMB preliminary safety analysis

METHODS

The team met with a TAG, represented by key industry stakeholders, to report on project progress, make decisions on project-related issues, discuss the FMB concepts, and present and review the results of technical analyses. The effort focuses on:

- Developing the FMB ConOps
- Developing the Incremental FMB System-Level and Segment-Level Requirements Specification
- Developing the FMB Migration Consideration Plan
- ICD changes
- Preliminary FMB hazard and safety analysis

RESULTS

The team created a FMB ConOps document that expanded on concepts developed during the HRCTC and QMB projects with regard to PTCEAs. The document also incorporated the proposed ABRRD architectures, functionalities, and interfaces.

Both System-Level and Segment-Level Incremental Requirements for the FMB method of train control were developed. These requirements define additions and changes to the ITC PTC and QMB systems to implement FMB functionality. They are not intended to duplicate requirements already addressed by existing ITC PTC/QMB specifications. In addition, ABRRD requirement specifications were developed to support FMB implementation by providing a standardized framework for the development of ABRRD systems.

The team also developed considerations for migrating an existing train control system to FMB. Several architecture-dependent migration pathways were presented.

Researchers identified necessary changes to the ITC PTC Office-Locomotive Segment and PTC Wayside-Locomotive Segment ICDs. Recommended changes were documented via redline markups to the existing AAR standard S-9361 and S-9362 ICDs, respectively. Other standards not redlined but which will require changes to accommodate ABRRD/ABRD related device data are S-9202, S-9501, and S-9503 (Association of American Railroads, 2020).

The safety analysis involved identifying potential new or altered hazards introduced by the FMB concept. In particular, the team identified any hazards that may have been introduced by integrating alternative ABRRD systems. No major hazard(s) were identified that could not be mitigated. Some hazards were identified related to the EOT-ABRD interface with the PTC Office segment, and the appropriate PTC Office segment-based mitigations were presented.

CONCLUSIONS

Researchers worked with an industry TAG to develop the concepts, requirements, and preliminary safety analysis for the FMB method of train control. Per the guidance of the TAG, additional burden to the onboard processor was kept to a minimum, and messages identified for modification were modified in a manner that was in keeping with their original intended purposes. This guidance, along with other project-related research, led to the following major outcomes from the project:

- 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.
- To support FMB, recommended changes to existing ITC messages in AAR standards Office-Locomotive ICD (S-9361) and Wayside-Locomotive ICD (S-9362) were documented via redline markups to those standards. AAR standards S-9202, S-9501 and S-9503 were identified as additional standards that will require edits to accommodate ABRRD/ABRD device information in the track database.
- Any of the three alternative broken rail detection architectures considered in the development of the project can support FMB operations.

- 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.
- The need for a standard framework for developing ABRRD hardware necessary to support migration to FMB was identified. Thus, an ABRRD requirement specification document was prepared as part of this project.

FUTURE ACTION

This project focused on fundamental FMB functions and the minimum viable alternative broken rail and rollout detection functionality to support FMB. Validating FMB requirements is planned for a future project.

REFERENCES

1. Kindt, J., Vieira, P. J., & Polivka, A. (In press). *Quasi-Moving Block System Requirements Development.* Federal Railroad Administration.

2. The Association of American Railroads (2020). AAR Manual of Standard and Recommended Practice; Sections K1-K6.

3. Vieira, P., Rosales-Yepez, J., Polivka, A., & Brosseau, J. (2022). Higher Reliability and Capacity Train Control (Report No. DOT/FRA/ORD-22/30). Federal Railroad Administration.

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CONTACT

Francesco Bedini Jacobini
Federal Railroad Administration
Office of Research, Development, and Technology
1200 New Jersey Avenue, SE
Washington, DC 20590
(202) 493-0800
Francesco.Bedini@dot.gov

Veronica Dorsey
Office of Acquisition Services
Supervisory Contracting Officer
U.S. Department of Transportation
Federal Railroad Administration
(202) 493-4239
Veronica.Dorsey@dot.gov

KEYWORDS

Alternative Broken Rail and Rollout Detection (ABRRD), Full-moving block (FMB), Quasi-moving block (QMB), Interoperable Train Control (ITC), Positive Train Control (PTC), communications-based train control (CBTC)