



IEEE Recommended Practice for Communications-Based Train Control (CBTC) System Design and Functional Allocations

IEEE Vehicular Technology Society

Sponsored by the
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Sponsor

IEEE Rail Transit Vehicle Interface Standards Committee

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Abstract: This recommended practice for communications-based train control (CBTC) system design and functional allocations builds on IEEE Std 1474.1 by decomposing each identified automatic train protection, automatic train operation and automatic train supervision function to a level where each subfunction can be allocated to one of the CBTC subsystems.

Keywords: automation, communication, signaling, train control, function

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Introduction

This introduction is not part of IEEE Std 1474.3-2008, IEEE Recommended Practice for Communications-Based Train Control (CBTC) System Design and Functional Allocations.

IEEE Std 1474.1-2004 establishes performance and functional requirements for communications-based train control (CBTC) systems. Although there could be many possible system designs to achieve these performance and functional requirements, the current state-of-the-art and industry trends reflect that in many areas there is a preferred approach to allocating the functional requirements to the individual CBTC subsystems. This recommended practice for CBTC system design and functional allocations documents these preferred approaches as current best industry practice. In those areas where there are no clear-cut recommendations, alternative approaches may be described. In such cases, however, it is not the intent to provide any recommendation or guide as to which alternative approach should be selected for a specific application. This decision would typically be made by the CBTC system supplier, in association with the authority having jurisdiction.

The approach adopted in this recommended practice is to build on IEEE Std 1474.1-2004 by decomposing each identified automatic train protection, automatic train operation, and automatic train supervision function to a level where each subfunction can be allocated to one of the CBTC subsystems.

In addition to capturing best industry practice, this recommended practice is intended to be of value in providing a means for interested parties to gain a better understanding of CBTC system architectures and principles of operation.

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1. Overview

1.1 General

This recommended practice establishes the system design and functional allocations for a communications-based train control (CBTC) system. It is divided into nine clauses, as follows:

- Clause 1 describes the scope and purpose of this recommended practice.
- Clause 2 lists normative references that are useful in applying this recommended practice.
- Clause 3 provides definitions that are either not found in other IEEE standards or have been modified for use with this recommended practice.
- Clause 4 provides a top-level description of operations and train operating modes to be supported by CBTC systems.
- Clause 5 defines the general system architecture and principles of operation for CBTC systems.
- Clause 6 defines the detailed automatic train protection (ATP) functional requirements for CBTC systems, including allocation of subfunctions to CBTC subsystems.
- Clause 7 defines the allocation of automatic train operation (ATO) subfunctions.
- Clause 8 defines the allocation of automatic train supervision (ATS) subfunctions.
- Clause 9 summarizes the primary data flows between CBTC subsystems.

1.2 Scope

This recommended practice establishes a preferred system design and functional allocation for CBTC systems.

1.3 Purpose

The purpose of this recommended practice is to define a preferred CBTC system design/system architecture to achieve the CBTC performance and functional requirements of IEEE Std 1474.1TM-2004,¹ and to allocate functions to the major CBTC subsystems.

1.4 Application

The extent to which this recommended practice would be applicable to a specific CBTC installation/project should be determined by the authority having jurisdiction.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

APTA RT-S-RGC-004-03, Standard for Rail Transit Grade Crossing Warning System Design Criteria, Installation and Operation.²

IEEE Std 1474.1TM-2004, IEEE Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements.^{3, 4}

IEEE Std 1474.2TM-2003, IEEE Standard for User Interface Requirements in Communications Based Train Control (CBTC) Systems.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this recommended practice, the following terms and definitions apply. See also IEEE Std 1474.1-2004 for other CBTC-related definitions. *The Authoritative Dictionary of IEEE Standards Terms* should be referenced for terms not defined in this clause.

¹ Information on references can be found in Clause 2.

² APTA standards are available from the American Public Transportation Association, 1666 K Street NW, Suite 1100, Washington, DC 20006, USA (<http://aptastandards.com/>).

³ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

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3.1.1 authorized speed: The speed limit at any point along the authorized path of travel up to the target point.

3.1.2 limit of movement protection: A precise location reference point along the authorized path that marks the absolute limit to which train movement is protected.

3.1.3 target point: A location reference point along the authorized path of travel to which train movement is currently controlled and supervised.

3.2 Acronyms and abbreviations

ATC	automatic train control
ATO	automatic train operation
ATP	automatic train protection
ATS	automatic train supervision
CBTC	communications-based train control

4. General requirements

4.1 Range of applications

The CBTC system design defined in this recommended practice is intended to be applicable to the full range of transit applications, including light rail, heavy rail, and commuter rail transit systems, and should also be applicable to other transit applications such as automated people movers if CBTC is used for automatic train control (ATC).

The CBTC system design should include the capability for providing ATP, ATO, and ATS functions as defined in IEEE Std 1474.1-2004.

This recommended practice recognizes that different configurations of CBTC systems are possible, depending on the specific application. For example, a CBTC system may:

- a) Provide ATP functions only, with no ATO or ATS functions.
- b) Provide ATP functions, as well as certain ATO and/or ATS functions, as required to satisfy the operational needs of the specific application.
- c) Be the only train control system in a given application or be used in conjunction with other auxiliary wayside systems.

Functions identified in this recommended practice are classified as either “Mandatory” (applicable to all CBTC applications) or “Optional” (applicable to only a subset of CBTC applications, depending on the specific operating requirements), as referenced in IEEE Std 1474.1-2004. “Optional” functions required by the authority having jurisdiction become “Mandatory” for that application.

4.2 Operating modes

CBTC-equipped trains may be operated by either a single-person or a multiperson crew. A CBTC system may also be required to support the operation of trains without crews.

CBTC-equipped trains operating in CBTC territory would operate, within ATP limits, under the protection of the CBTC system. The train may be controlled manually by a train operator or automatically by the CBTC system (supervised by the train operator, if present), as specified by the authority having jurisdiction. When operating automatically, some functions (such as door operation and train departure initiation) may continue to be the responsibility of the train operator and/or conductor(s), if present.

Trains not equipped with CBTC train-borne equipment and/or trains with inoperative CBTC train-borne equipment that are operating in CBTC territory would operate under the protection of an auxiliary wayside system and/or operating procedure, as specified by the authority having jurisdiction.

NOTE— This recommended practice does not address requirements for any auxiliary wayside system that may be used in conjunction with a CBTC system for the protection of trains not equipped with CBTC train-borne equipment and/or trains with inoperative CBTC train-borne equipment.⁵

4.3 Failure management

A CBTC system should be designed to support degraded modes of operation to permit the continued movement of trains in the event of CBTC equipment and/or data communication failures. A combination of functional elements of the CBTC system itself, an auxiliary wayside system (if specified by the authority having jurisdiction), and/or operating procedures should provide for the safety of train movement under such failure conditions, including failure recovery.

5. CBTC system design

5.1 CBTC system architecture

A CBTC system should comprise the following major subsystems, as shown in Figure 1:

- a) CBTC ATS equipment
- b) CBTC wayside equipment
- c) CBTC train-borne equipment
- d) CBTC data communications equipment

For the purposes of this recommended practice, the CBTC system is assumed to interface with an external separate interlocking subsystem, and possibly other external wayside equipment, as shown in Figure 1. See also 5.3.1. Interlocking functions may be incorporated within the CBTC wayside equipment, where permitted by the authority having jurisdiction.

The recommended allocation of ATP, ATO and ATS subfunctions to the above major CBTC subsystems is defined in Clause 6, Clause 7, and Clause 8, respectively. Where there is no clear-cut recommendation to a given functional allocation, alternative approaches to good practice are described.

⁵Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the recommended practice.

5.1.1 CBTC ATS equipment

The CBTC ATS equipment includes equipment installed at central and/or wayside locations responsible for ATS (nonvital) functions such as identifying, tracking, and displaying trains, providing manual and automatic route setting capabilities, and regulating train movements to maintain operating schedules.

5.1.2 CBTC wayside equipment

The CBTC wayside equipment consists of a network of processor-based, wayside controllers installed at central and/or wayside locations. Each wayside controller interfaces to the CBTC train-borne equipment via the CBTC data communication equipment and may also interface to external interlockings and CBTC ATS equipment.

The wayside intelligence for CBTC-related ATP functions, such as movement authority setting based on the tracking of both CBTC-equipped and unequipped trains, as well as other allocated wayside ATP, ATO, and ATS functions resides in the wayside controllers. (Train location determination is a train-borne function for CBTC-equipped trains and a wayside function for unequipped trains.)

The CBTC wayside equipment also includes any track-based equipment necessary to provide a unique absolute positioning reference to the CBTC train-borne equipment.

5.1.3 CBTC train-borne equipment

The CBTC train-borne equipment consists of one or more processor-based controllers and associated speed measurement and location determination sensors.

The CBTC train-borne equipment interfaces to the train subsystems (including train operator displays) and also interfaces to the CBTC wayside equipment and the CBTC ATS equipment via the CBTC data communication equipment.

The CBTC train-borne equipment is responsible for CBTC train location determination, the enforcement of permitted speed and movement authority limits, and other allocated train-borne ATP and ATO functions.

5.1.4 CBTC data communications equipment

The CBTC data communications equipment includes equipment located at central and wayside locations, as well as on-board trains, to support both wayside-to-wayside and wayside-to-train data communications (as well as intra-train data communications for those applications where the train-borne equipment consists of multiple processor-based controllers). The datalinks between the major CBTC subsystems should support bidirectional data transfer and should have sufficient bandwidth and exhibit sufficiently low latency to support all defined ATS, ATP, and ATO functions. The datalinks should include a protocol structure to support timely and secure delivery of train control messages.

The CBTC data communications equipment should not of itself perform any CBTC functions and is not required to be vital.

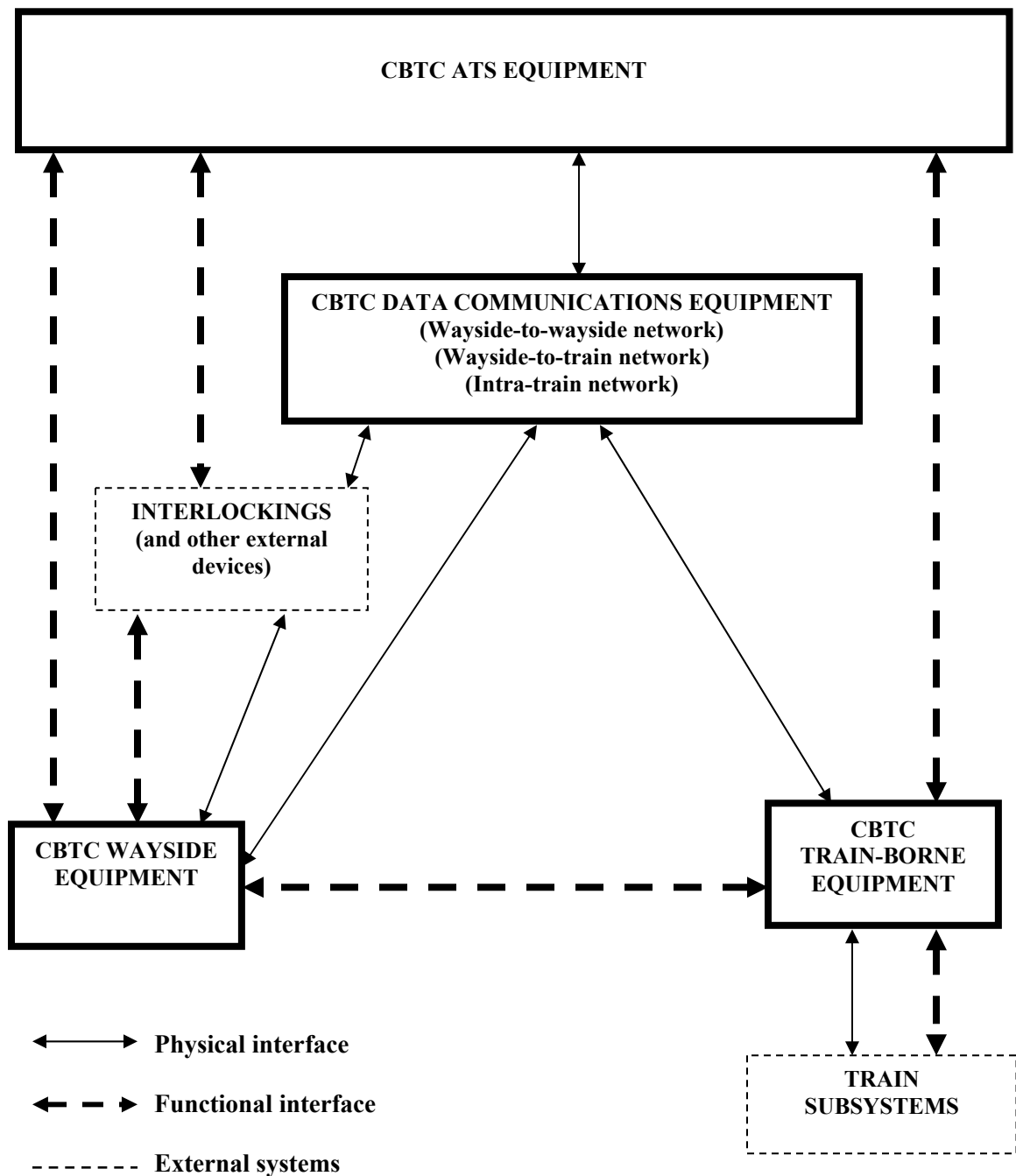


Figure 1—Major CBTC subsystems

5.2 Principles of operation

The principles of operation of a CBTC system should include:

- a) High-resolution train location determination, by CBTC train-borne equipment, independent of track circuits.
- b) Communication of this train location information, and other train status data, to CBTC wayside equipment over the CBTC train-to-wayside data communications link.
- c) Determination of the movement authority for each CBTC-equipped train, by the CBTC wayside equipment, based on train location information and inputs from external interlockings (including the secondary train detection system, if provided) and other external devices capable of detecting hazards that affect train operations.
- d) Communication of the movement authority, and other train control data, to the appropriate train over the CBTC wayside-to-train data communications link.
- e) Determination and enforcement of the ATP profile by the CBTC train-borne equipment.
- f) Communication of required commands from the CBTC wayside equipment to external interlockings (to modify interlocking functions), and status from external interlocking to CBTC wayside equipment to support CBTC operations.
- g) Communication of necessary information from one CBTC wayside controller to a neighboring wayside controller to support the hand-off of train control.
- h) Communication of necessary information between multiple sets of CBTC train-borne equipment, within a train, to support CBTC operations.

5.3 External interfaces

5.3.1 Interlockings

For the purposes of this recommended practice, it is assumed that an external interlocking subsystem provides the conventional interlocking functions based on train position established by a secondary train detection system. These functions include Approach Locking, Route Locking, Detector Locking, Traffic (Direction) Locking, and Time Locking. These interlocking functions ensure that switches cannot be moved under a train and train-to-train collisions (rear-end, side-swipe, head-on) do not occur.

The CBTC system interfaces to and may modify these conventional interlocking functions based on train position established by the CBTC train location determination function, to enable the enhanced performance capabilities of a CBTC system to be realized.

Information that flows between the wayside CBTC equipment and the interlocking subsystems includes:

- a) *Indications* from the interlocking subsystem to the wayside CBTC equipment, including each switch status, each track circuit status, each signal status, and so on.

- b) *Controls* from the wayside CBTC equipment to the interlocking subsystem, including modification of interlocking functions and signal aspects based on CBTC train location reports and limits of movement authority, and so on.

5.3.2 Other external wayside equipment

The interlocking functions described in 5.3.1 should also apply to moveable bridges, and similar right-of-way apparatus that may be required to interface to the CBTC wayside equipment.

CBTC wayside equipment may also interface to intrusion detection devices, platform edge doors, highway grade crossing warning devices, and/or other wayside devices capable of detecting hazards affecting train operation.

5.3.3 Train subsystems

CBTC train-borne equipment should interface to the train's emergency braking subsystem and may also interface to the train's propulsion and service braking subsystems, door subsystem, passenger information subsystem, fault reporting subsystem, and other train-borne subsystems depending on the specific application.

It is the responsibility of the authority having jurisdiction to define integration requirements for CBTC train-borne equipment for the specific application.

5.3.4 User interfaces

CBTC user interface requirements for both CBTC train-borne and non-train-borne user interfaces are defined in IEEE Std 1474.2-2003. This referenced standard provides for consistent user interfaces that take advantage of the characteristics of CBTC systems to enhance service effectiveness of a rail transit system. The standard defines specific operational and maintenance user interface requirements, including what information should be displayed, and guidelines as to how this information should be displayed.

5.4 Integration with other systems

To exploit the operational and safety capabilities of CBTC systems, the design of a CBTC system and the design of other fixed operating elements of a rapid transit system should be carefully integrated.

It is the responsibility of the authority having jurisdiction to define such integration requirements for the specific application. Systems to be considered should include:

- a) CBTC system (including interlockings and other external devices)
- b) Traction power systems
- c) Tunnel and station ventilation systems
- d) Passenger information and security systems
- e) Backbone communications networks

Consideration should be given to the following characteristics of CBTC systems when optimizing the overall transit system design with respect to passenger safety and operational flexibility:

- Real-time availability of precise location, speed, and operational status of CBTC-equipped trains.
- Ability to communicate train health status and other system alarms to a central control location.
- Real-time ability to restrict train movements in response to detected hazardous or other conditions.
- Inherent bidirectional capability and ability to reroute and reverse train movements either automatically or in response to user inputs.
- Ability to predict train arrival times at downstream stations for schedule regulation and other purposes.
- Ability to coordinate multiple train movements for junction management and/or energy optimization purposes.

6. ATP functional allocations

For the purposes of this recommended practice, ATP requirements, as defined in IEEE Std 1474.1-2004, have been grouped under the following primary functions:

- a) Train location determination
- b) Limit of safe route determination
- c) Limit of movement protection and target point determination
- d) ATP profile determination
- e) Authorized speed determination
- f) Actual train speed/travel direction determination
- g) Supervise/enforce authorized speed
- h) Door control interlocks
- i) External interlocking commands
- j) Highway grade crossing warning device control/supervision
- k) Train-borne ATP user interfaces
- l) Fixed ATP data management

Figure 2 summarizes the general relationship between these primary ATP functions as an aid to the understanding of the clauses below. Figure 2 does not include ATO/ATS functions (which are described in Clause 7 and Clause 8, respectively).

Data flows between CBTC subsystems are provided in more detail in the clauses that follow. All data flows among CBTC ATS, CBTC wayside, and CBTC train-borne equipment should be performed by the CBTC data communications equipment.

In the tables used in the following clauses, for each identified subfunction, the following information is provided:

- A summary definition of the subfunction and the requirements associated with the subfunction
- Whether performing the subfunction is mandatory or optional (see 4.1)
- Whether the subfunction is vital or nonvital
- The CBTC subsystem responsible for performing this subfunction
- The CBTC subsystem/subsystems and/or external equipment providing input data for this subfunction
- The CBTC subsystem/subsystems and/or external equipment receiving output data from this subfunction
- A cross reference to IEEE Std 1474.1-2004 or IEEE Std 1474.2-2003, where applicable
- Any notes to assist in an understanding of the table

As an example, in Table 1, subfunction 6.x.y.z is a mandatory, vital subfunction performed by the CBTC train-borne equipment using input data from CBTC wayside equipment. In this example, output data from the subfunction is received and used by CBTC ATS equipment and CBTC train-borne equipment.

NOTE—Any data communicated to CBTC equipment for display or data logging purposes only, and not used by that CBTC equipment as an input to another CBTC subfunction defined in this recommended practice, is not explicitly referenced in these tables.

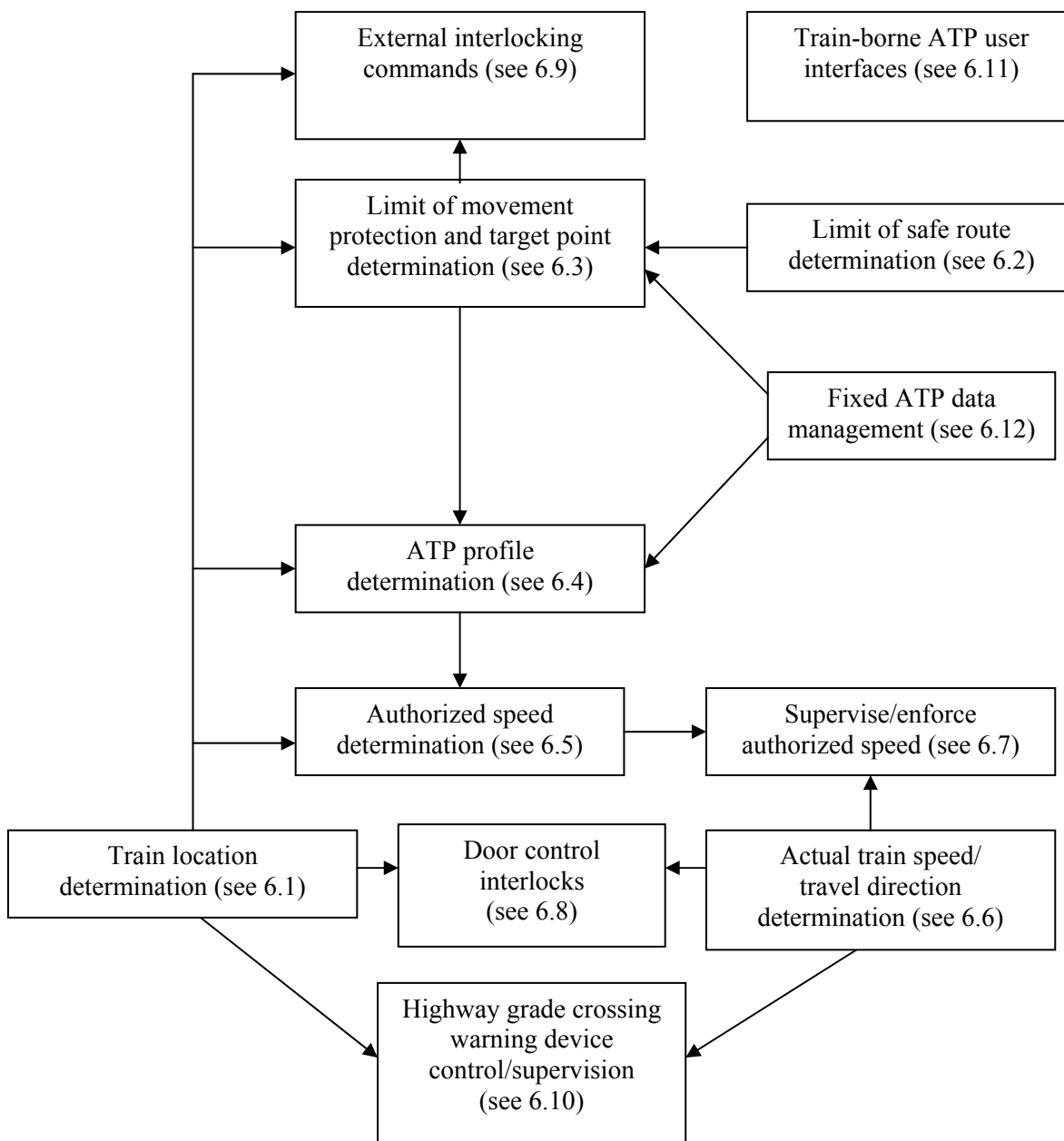


Figure 2—Primary ATP functions

Table 1 —Example of subfunction table

Subfunction #6.x.y.z: Inserted here is the name of the subfunction							
Inserted here is the requirement to be performed by the subfunction, as stated in or derived from IEEE Std 1474.1-2004 or IEEE Std 1474.2-2003.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment					X		
CBTC wayside	X ¹						
CBTC train-borne			X		X		
(External)							
Notes:							
NOTE 1—Inserted here are any notes, where the note is referenced to a superscript in this table.							
References: Inserted here are any references to IEEE Std 1474.1-2004 or IEEE Std 1474.2-2003.							

Figure 3 provides a summary of the relationships among the various terms used in the following clauses. Specifically, it should be noted that the movement authority limit is represented by two points along the authorized path: the limit of movement protection and the target point. The limit of movement protection is defined for safe train separation and interlocking protection. Train travel beyond the limit of movement protection would represent a safety hazard, and as such, a CBTC system must vitally ensure that a train never travels beyond this limit. This is achieved by controlling train movement along the authorized path to a target point. The distance between the target point and limit of movement protection is a variable safety distance (or overlap), as determined by the safe braking model, to ensure that under no conditions (including all credible failures) will the limit of movement protection be exceeded.

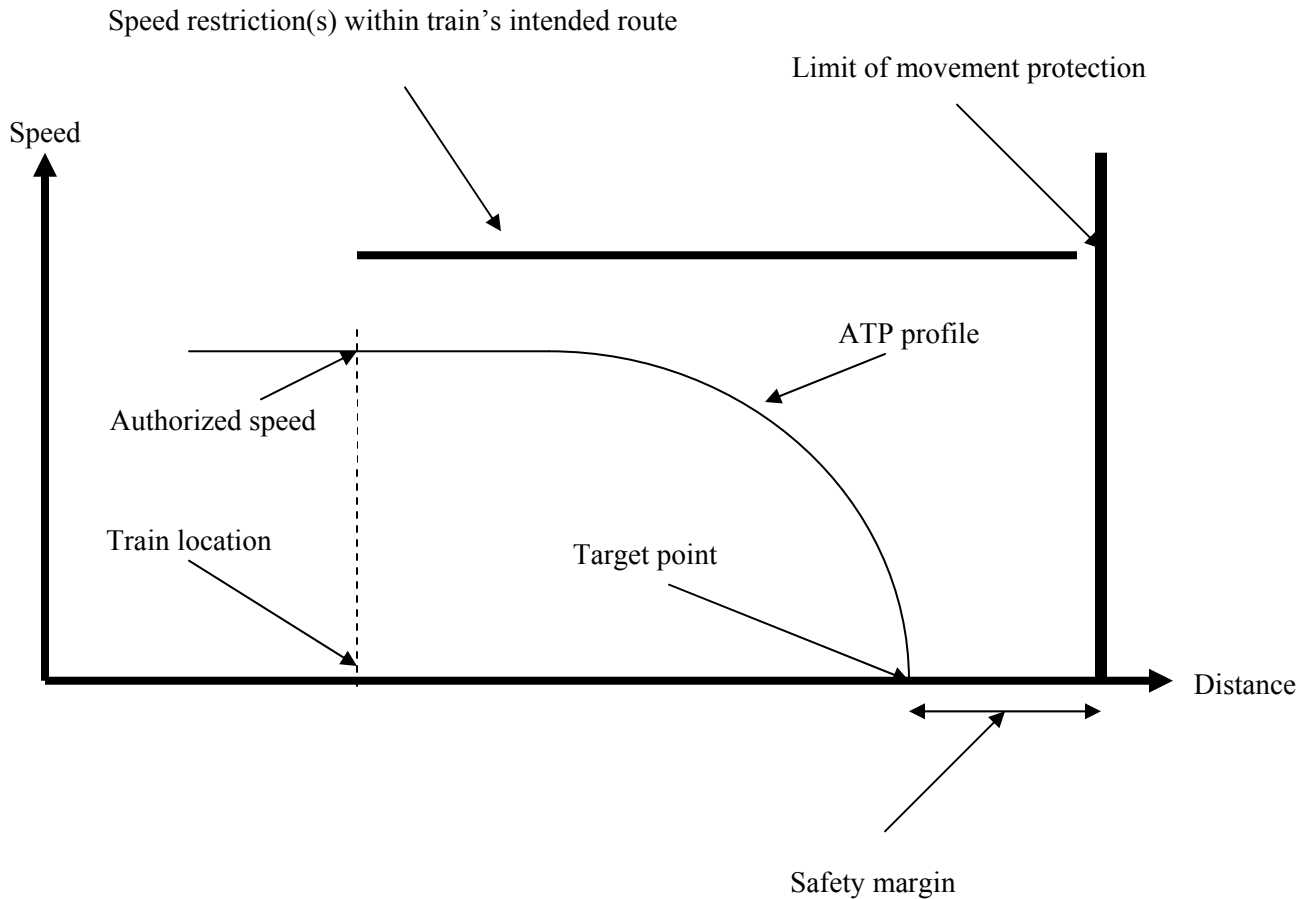


Figure 3—Components of movement authority

6.1 Train location determination

This function determines the locations of all trains (both CBTC-equipped and unequipped) in CBTC territory.

Figure 4 summarizes the interfaces between subfunctions described in this clause (solid boxes), and the interfaces to subfunctions described in other clauses (dashed boxes). Specifically, an arrow between two subfunctions represents a data flow between these subfunctions. External interfaces are not shown.

Within each box, “[A]” indicates that the subfunction is performed by CBTC ATS equipment, “[W]” indicates that the subfunction is performed by CBTC wayside equipment, and “[T]” indicates that the subfunction is performed by CBTC train-borne equipment. “[W/T]” indicates the subfunction may be performed by either CBTC wayside equipment or CBTC train-borne equipment, depending on the specific CBTC system design.

NOTE—The conventions described above are used in all subsequent figures.

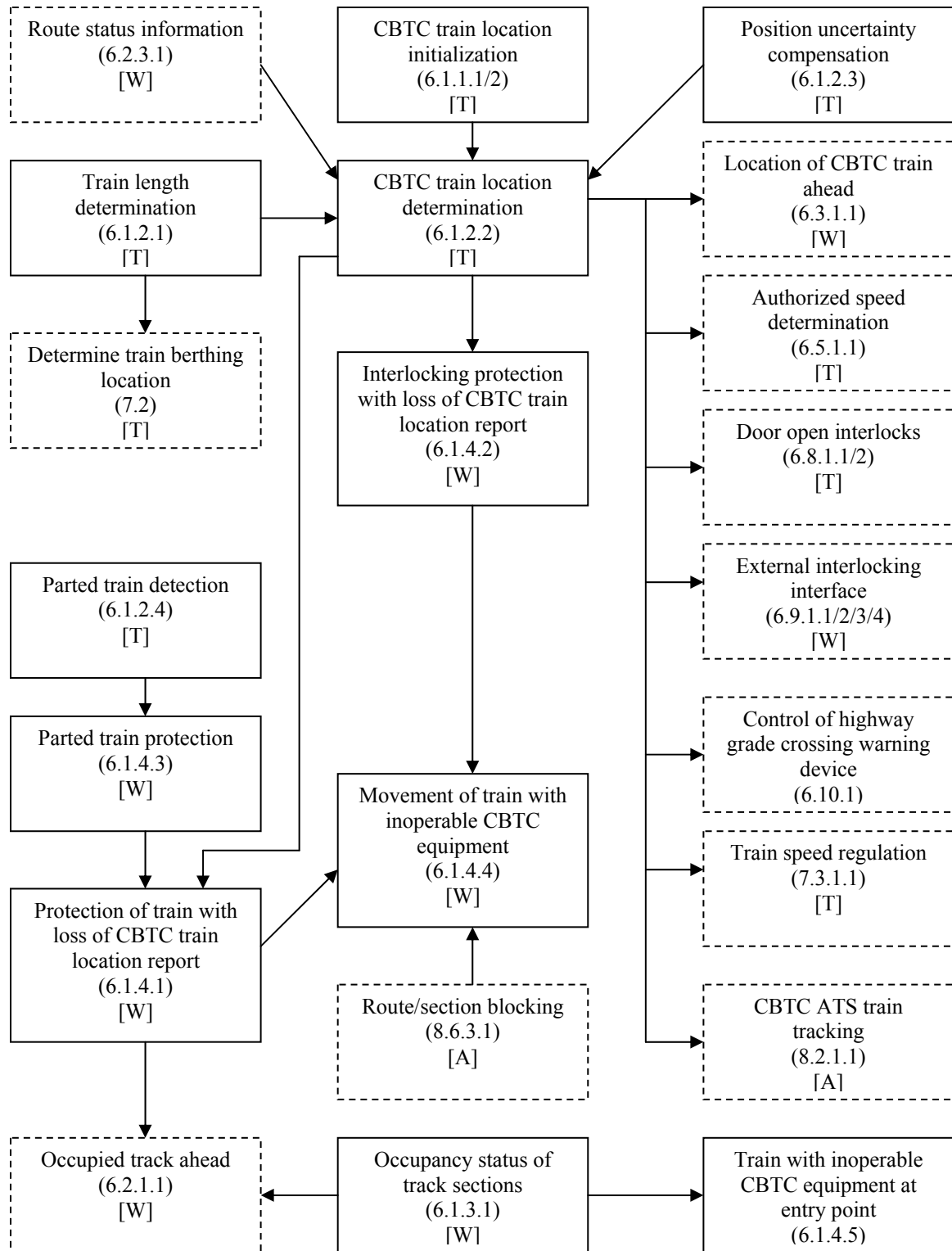


Figure 4—Train location determination

6.1.1 CBTC train location initialization

This function initializes the CBTC train location, i.e., establishes the initial location for a CBTC-equipped train.

Subfunction #6.1.1.1: CBTC train location initialization on entry to CBTC territory							
The CBTC train location determination function shall be self-initializing and shall automatically detect each CBTC-equipped train as it enters CBTC territory without requiring manual input of train location or train length data.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside	X ¹						
CBTC train-borne			X		X		
(External)							
Notes:							
NOTE 1—CBTC wayside equipment (such as transponders or equivalent) will provide unique absolute position references to CBTC train-borne equipment.							
Reference: IEEE Std 1474.1-2004 6.1.1.1							

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Subfunction #6.1.1.2: CBTC train location initialization on recovery from CBTC equipment failure							
The CBTC train location determination function shall be self-initializing and shall automatically detect each CBTC-equipped train on recovery from CBTC equipment failure without requiring manual input of train location or train length data. ¹							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside	X ²						
CBTC train-borne			X		X		
(External)							
Notes:							
NOTE 1—Manual train movement may be required to reestablish train location.							
NOTE 2—CBTC wayside equipment (such as transponders or equivalent) will provide unique absolute position references to CBTC train-borne equipment.							
Reference: IEEE Std 1474.1-2004 6.1.1.1							

6.1.2 Determine location of CBTC train

This function determines the location of the front and the rear of a CBTC train.

Subfunction #6.1.2.1: Train length determination							
CBTC shall determine the length of the train. ¹							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside	X ²						
CBTC train-borne			X		X		
(External)	X ³						
Notes:							
NOTE 1—If specified by the authority having jurisdiction, the CBTC system may assume a fixed, worst-case, maximum train length for a given class of trains operating in CBTC territory, with a reliance on operating procedures to ensure this maximum train length is not exceeded.							
NOTE 2—CBTC train-borne equipment may receive input from the CBTC wayside equipment to validate train length.							
NOTE 3—CBTC train-borne equipment may include interfaces to train subsystems (e.g., couplers) to establish train length.							
Reference: IEEE Std 1474.1-2004 6.1.1.1							

Subfunction #6.1.2.2: CBTC train location determination							
CBTC train location determination shall safely and accurately establish the location of both the front and the rear of the train with sufficient resolution and accuracy to support the performance and safety requirements.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment					X		
CBTC wayside	X ^{1,2}				X		
CBTC train-borne	X ³		X ⁴		X		
(External)							
Notes:							
NOTE 1—CBTC wayside equipment (such as transponders or equivalent) will provide unique absolute position references to CBTC train-borne equipment.							
NOTE 2—CBTC wayside equipment may provide route status input to CBTC train-borne equipment in order for the train to track its location through interlockings (see 6.2.3.1).							
NOTE 3—This requires train location initialization and train length input (see 6.1.1.1/2 and 6.1.2.1).							
NOTE 4— The location of both the front and the rear of the train should include maximum position uncertainty per subfunction 6.1.2.3.							
Reference: IEEE Std 1474.1-2004 6.1.1.1							

Subfunction #6.1.2.3: Position uncertainty compensation							
The CBTC train location determination function shall compensate for the effects of measurement error and shall include an appropriate allowance for position uncertainty. ¹							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside							
CBTC train-borne	X		X		X		
(External)							
Notes:							
NOTE 1—The maximum position uncertainty is required for the safe braking model.							
Reference: IEEE Std 1474.1-2004 6.1.1.1 and 6.1.2.1							

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Subfunction #6.1.2.4: Parted train detection							
The CBTC system shall detect when a train of two or more vehicles or units has parted.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside					X		
CBTC train-borne			X				
(External)	X ¹						
Notes:							
NOTE 1—Train integrity inputs from train subsystems will provide indication of parted consist.							
Reference: IEEE Std 1474.1-2004 6.1.6							

6.1.3 Determine occupancy status of track sections

This function determines the occupancy status of a section of track.

Subfunction #6.1.3.1: Occupancy status of track sections			
If specified by the authority having jurisdiction, an auxiliary wayside system may provide a secondary train location determination to establish whether a section of track is occupied by one or more trains, including trains not equipped with CBTC train-borne equipment and/or trains with inoperative CBTC train-borne equipment. ¹			
Mandatory:		Optional:	X
		Vital:	X
		Nonvital:	
Functional allocation:			
	Subsystem providing input	Subsystem performing subfunction	Subsystem receiving output
CBTC ATS equipment			
CBTC wayside		X	X
CBTC train-borne			
(External)	X ²		
Notes: NOTE 1—If no secondary train location determination function is provided, strict adherence to operating procedures will be required to protect the movement of unequipped trains and/or trains with inoperative CBTC equipment (see 6.1.4.4). NOTE 2—Secondary train location determination is typically provided by external track circuits or axle counters as an element of an auxiliary wayside system. The form of the interface to these elements is to be defined by the authority having jurisdiction. It is not necessary to determine the location of unequipped trains, or trains with inoperative train-borne CBTC equipment, to the same accuracy as CBTC-equipped trains.			
Reference: IEEE Std 1474.1-2004 6.1.1.2			

6.1.4 Failure management

As noted in 4.3, a combination of functional elements of the CBTC system itself, an auxiliary wayside system (if specified by the authority having jurisdiction), and/or operating procedures should provide for the safety of train movement under failure conditions related to the train location determination function.

Subfunction #6.1.4.1: Protection of train with loss of CBTC train location report							
In the event of loss of CBTC train location report from a given train, the CBTC system shall prevent movement authorities from being issued to other trains into the section(s) of track that could be occupied by the nonreporting train (see also 6.1.4.4 and 6.2.1.1).							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside			X		X		
CBTC train-borne	X ¹						
(External)							
Notes:							
NOTE 1—The “input” from the CBTC train-borne equipment is the loss of CBTC train location report.							
Reference:							

Subfunction #6.1.4.2: Interlocking protection with loss of CBTC train location report

In the event of a failure of the CBTC train location determination function for a train in or approaching an interlocking, all interlocking functions shall remain in effect until the train is proven to be clear of the interlocking by the CBTC system (i.e., the train is subsequently determined to be clear of the interlocking limits), or through operating procedures, or a combination of both approaches.

Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside			X				
CBTC train-borne	X ¹						
(External)	X ²				X ²		
Notes:							
NOTE 1—The “input” from the CBTC train-borne equipment is the loss of a CBTC train location report.							
NOTE 2—In the event of a failure of the CBTC train location determination function in an interlocking where train location is also capable of being detected by means of a secondary train location determination function (see 6.1.3.1), CBTC system modification of the interlocking functions could be released, provided route and other locking functions are maintained by the auxiliary wayside system so as to prevent the movement of a switch in front of and under the train until the train is proven to be clear of the interlocking.							
Reference: IEEE Std 1474.1-2004 6.1.11.2							

Subfunction #6.1.4.3: Parted train protection							
In the event of a detected parted train, the CBTC system shall prevent movement authorities from being issued to other trains into the section(s) of track that could be occupied by the parted train (see also 6.1.4.1).							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside			X		X		
CBTC train-borne	X						
(External)							
Notes:							
Reference:							

Subfunction #6.1.4.4: Movement of train with inoperable CBTC equipment							
Movement of train with inoperable CBTC equipment shall be protected. ¹							
Mandatory:	X	Optional:		Vital:	X ²	Nonvital:	X ³
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment	X ³						
CBTC wayside	X ²		X		X		
CBTC train-borne							
(External)							
Notes:							
NOTE 1—If no secondary train location determination function is provided, strict adherence to operating procedures will be required to protect movement of trains with inoperative CBTC equipment.							
NOTE 2—If a secondary train location determination function is provided (see 6.1.3.1), movement of a train with inoperable CBTC equipment should be detected and protected from following trains by the CBTC system (see 6.2.1.1)							
NOTE 3—Protection could also be provided by blocking the section(s) of track occupied by the train with inoperable CBTC equipment, through input from the CBTC ATS equipment (see 8.6.3.1).							
Reference:							

Subfunction #6.1.4.5: Train with inoperable CBTC equipment at entry point							
At any entry point into CBTC territory, the CBTC system shall prevent a route being established into the CBTC territory for a train with failed CBTC train-borne equipment, or an unequipped train, unless protected by an auxiliary wayside system, or through operating procedures, or a combination of both approaches.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside	X ¹		X				
CBTC train-borne							
(External)					X ²		
Notes:							
NOTE 1—A train with failed CBTC train-borne equipment, or an unequipped train, should be detected by a secondary train location determination per 6.1.3.1.							
NOTE 2—This function provides an output to external interlockings at entry points to CBTC territory.							
Reference:							

6.2 Limit of safe route determination

This function determines the limits of a safe route for a CBTC-equipped train. The function of route setting is addressed under the function “train routing” (see 8.3). Protection of the route is provided by the interlocking functions.

Figure 5 summarizes the interfaces between subfunctions described in this clause and the interfaces to subfunctions described in other clauses.

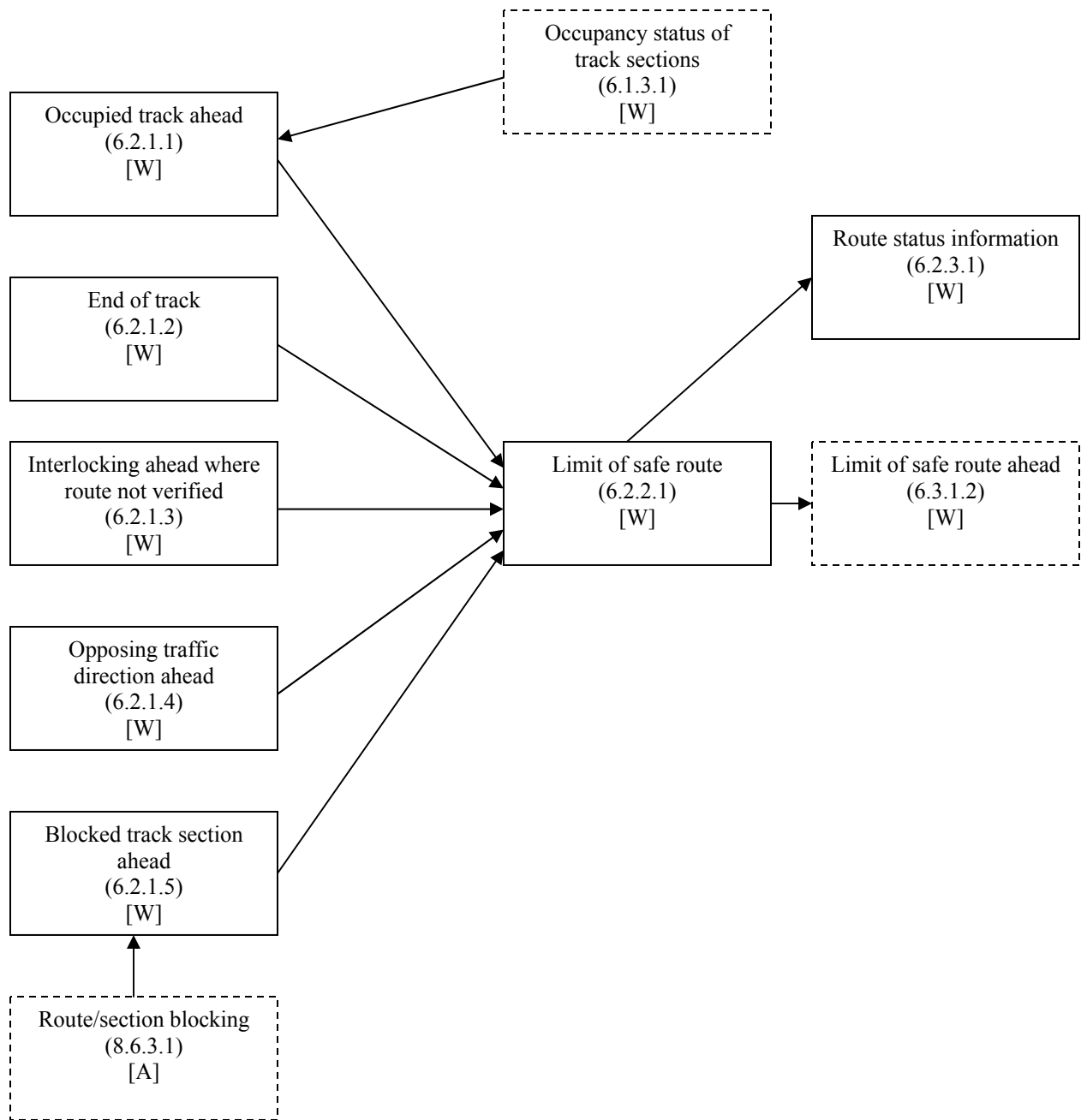


Figure 5—Limit of safe route determination

6.2.1 Determine potential limits of safe route

This function determines the potential limits of a safe route ahead of a CBTC train.

Subfunction #6.2.1.1: Occupied track ahead							
CBTC shall determine the location of the boundary of any section of track ahead of the train that is indicated as being occupied by one or more unequipped trains or trains with failed CBTC train-borne equipment.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside	X ¹		X ²		X		
CBTC train-borne							
(External)							
Notes:							
NOTE 1—Track section occupancy status input may be provided by secondary train location determination per 6.1.3.1.							
NOTE 2—If specified by the authority having jurisdiction, the CBTC system may further limit the boundary to the route entry point of a route occupied by the unequipped train or failed train.							
Reference: IEEE Std 1474.1-2004 6.1.2							

Subfunction #6.2.1.2: End of track							
CBTC shall determine the location of any end-of-track ahead of the train.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside	X ¹		X ²		X		
CBTC train-borne							
(External)							
Notes:							
NOTE 1—From ATP fixed data.							
NOTE 2—End-of-track protection will prevent trains from over-traveling the end-of-track or, if buffers are specified, will prevent trains from exceeding the design limits for impact with an end-of-track buffer.							
Reference: IEEE Std 1474.1-2004 6.1.2 and 6.1.5							

Subfunction #6.2.1.3: Interlocking ahead where route not verified							
CBTC shall determine the location of the entrance to any interlocking ahead of the train where the route is not verified as aligned and locked in the required position.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside			X		X		
CBTC train-borne							
(External)	X ¹						
Notes:							
NOTE 1—Route status information will be provided by external interlockings. Form of interface to be defined by the authority having jurisdiction and may include switch position/lock status and/or wayside signal status.							
Reference: IEEE Std 1474.1-2004 6.1.2							

Subfunction #6.2.1.4: Opposing traffic direction ahead							
CBTC shall determine the location of the boundary of any section of track ahead of the train with an opposing traffic direction or no traffic direction established.							
Mandatory:	X	Optional:		Vital:	X	Nonvital:	
Functional allocation:							
	Subsystem providing input		Subsystem performing subfunction		Subsystem receiving output		
CBTC ATS equipment							
CBTC wayside	X ¹		X		X		
CBTC train-borne							
(External)	X ¹						
Notes:							
NOTE 1—Traffic status information will be provided by external interlockings and internally within the CBTC wayside equipment for CBTC traffic sections. Form of interface to external interlockings to be defined by the authority having jurisdiction.							
Reference: IEEE Std 1474.1-2004 6.1.2 and 6.1.12							