

Low-Comotovation: System Design Document

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0.1 Versioning & Authorship

Version 0.1

Low-Comotovation ©

Software Design Specification: Low-Comotovation

Status: Preliminary Release: Software Design Review

0.2 References

During the development of this document, IEEE 1016 was utilized.

0.3 Purpose

This document will specify the architecture and design of the Low-Comotovation train system. It shall discuss the structural and design and considerations of the train system and the accompanying subsystems of the train system. It shall also detail design considerations in vital subsystems.

0.4 Stakeholders & Concerns

The stakeholders of this document are anticipated to be the following:

- Future Design Teams: Future design teams are anticipated to utilize this document to guide their usage of the track controller system
- Pittsburgh Rail Company: The rail company utilizing the Software Design Specification (SDS) to guide the development of physical systems associated with the software

Future design teams associated with the continued development benefit from increased documentation of the original system by allowing for more efficient software design procedures in future revision by potentially unrelated developers.

The benefits to the Pittsburgh Rail Company from a detailed software design specification are twofold. First, a detailed SDD provides developers of railway hardware the information required to produce a paired system. Second, a documented SDD allows the Pittsburgh Rail Company to evaluate the designs ability to meet specifications for vitality.

1 Introduction

To ensure safe, predictable, and reliable operation of the system, there are three primary considerations:

1. *Vitality*: Vitality of a system within this document refers to a safety-critical system.

2. *Testability*: Any system implemented must be easily tested to ensure reliability
3. *Modularity*: Any system designed must reuse code wherever possible

2 System Design Use Cases

In this section, we detail the use cases of each subsystem. The use case of each subsystem is accompanied by brief descriptions of the use cases.

2.1 Track Model

In this subsection, the use cases of the train model are provided.

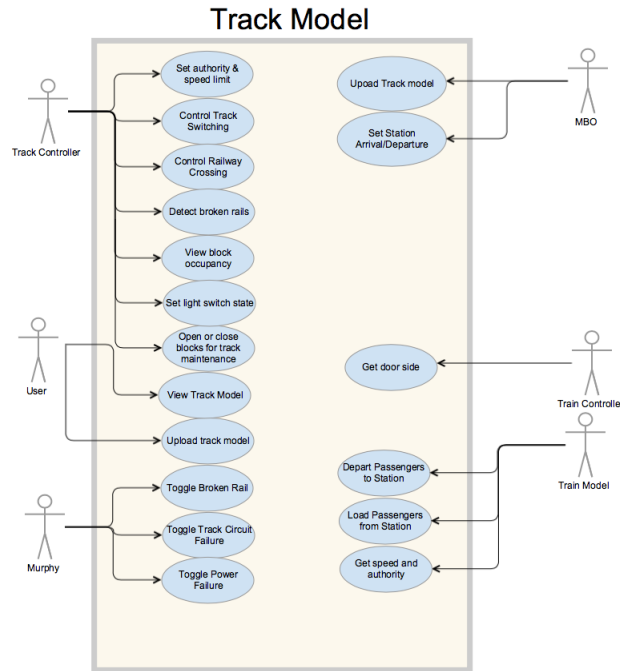


Figure 1: Track model use case diagram

Table 1: Set Speed and Authority

Actors	Track Controller
Description	The track controller shall be capable of setting a speed and authority via the track circuit modeled by the track model
Data	Speed and authority for the trains
Stimulus	None. The speed and authority are set externally
Response	The track model possesses the attributes set.
Comments	The track model only exists as a passthrough for this information

Table 2: Set Switch State

Actors	Track Controller
Description	The track controller shall be capable of setting the switch of a given state
Data	A boolean statement for the state of a switch
Stimulus	The Track Controller signal
Response	Setting the state of the switch
Comments	These are set simultaneously with no delays

Table 3: Control Railway Crossing

Actors	Track Controller
Description	The track controller shall be capable of setting the railway crossing to a given state
Data	A boolean statement for the state of a railway crossing
Stimulus	The Track Controller boolean signal
Response	Setting the state of the railway crossing
Comments	These are set simultaneously with no delays

Table 4: Detect Broken Rails

Actors	Track Controller
Description	The track controller shall be capable of detecting broken rails
Data	A boolean statement for the state of a block
Stimulus	A track controller query
Response	A return of the boolean broken state of the blocks on a track
Comments	The track controller calls the track model in this case

Table 5: View Block Occupancy

Actors	Track Controller
Description	The track controller shall be capable of viewing block occupancy
Data	A boolean statement for the occupancy of the block
Stimulus	A track controller query
Response	A return of the boolean occupied state of the blocks on a trackl
Comments	The track controller calls the track model in this case

Table 6: Set Light Switch State

Actors	Track Controller
Description	The track controller shall be capable of setting the light states
Data	A boolean statement for the next light switch state
Stimulus	A track controller function call
Response	A setting of the light switch state to that set by the track controller
Comments	

Table 7: Set Light Switch State

Actors	Track Controller
Description	The track controller shall be opening or closing a given block for maintenance
Data	A boolean statement for if a given block is open or closed due to maintenance
Stimulus	A track controller function call with a boolean variable
Response	A setting of the blocks open state
Comments	This block will not be considered "open" for planning purposes in new path. This is reflected in the nextBlock functionality

Table 8: Upload Track Model

Actors	User
Description	The user shall be capable of uploading track models to the track model
Data	The track model given in a .csv form. This may be provided by Excel "save as" function or similar.
Stimulus	None
Response	The user loads the files in
Comments	This will require multiple csv files in practice

Table 9: Set Light Switch State

Actors	Track Controller
Description	The track controller shall be capable of setting the light states
Data	A boolean statement for the next light switch state
Stimulus	A track controller function call
Response	A setting of the light switch state to that set by the track controller
Comments	

Table 10: Toggle Broken Rail

Actors	Murphy
Description	A test environment shall be provided to toggle the rail broken state for testing
Data	A boolean statement to set the rail to
Stimulus	External user testing stimulus
Response	Setting a given block to broken or fixed
Comments	This should be considered for test purposes of other modules

Table 11: Toggle Track Circuit Failure

Actors	Murphy
Description	A test environment shall be provided to toggle the circuit failure state for testing
Data	A boolean statement to set the track circuit functionality
Stimulus	External user testing stimulus
Response	Setting the track circuit to broken or functional
Comments	This should be considered for test purposes of other modules

Table 12: Toggle Power Failure

Actors	Murphy
Description	A test environment shall be provided to toggle the power failure state for testing
Data	A boolean statement to set the power failure state of a rail to
Stimulus	External user testing stimulus
Response	Setting a broken or fixed power state to
Comments	This should be considered for test purposes of other modules

2.2 Track Controller

In this subsection, the use cases of the track controller are provided.

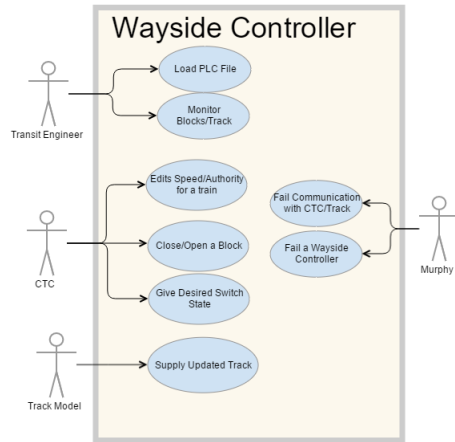


Figure 2: Track controller use case diagram

2.3 Train Model

In this subsection, the use cases of the train model are provided.

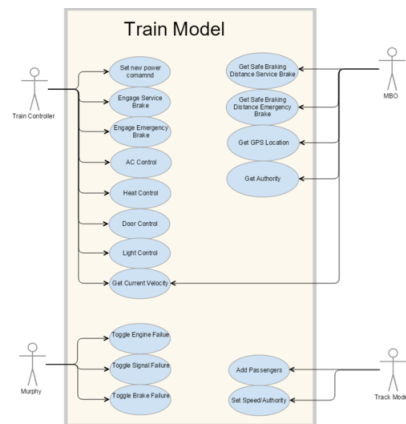


Figure 3: Train model use case diagram

Table 13: Set New Power Command

Actors	Train Controller
Description	Train Controller will set a new power command based on the current velocity of the train and the new setpoint speed set by the driver. This power command will be used to determine the force applied to the train and thus compute the new current velocity.
Data	Power Command issued to the train
Stimulus	When a setpoint speed is provided to the train controller, a Power command is computed using the current velocity and sent to train
Response	New current velocity is returned to actor at the end of the computation.
Comments	

Table 14: Engage Service Brake

Actors	Train Controller
Description	Train controller will engage or disengage the service brake in order to slow down or stop the train for any given reason. Once engaged the power command will be set to zero and the train will begin to decelerate
Data	Service Brake command
Stimulus	Service brake will be engaged under the following conditions: 1) Service brake button is manually pressed by the driver via the train controller 2) Failure occurs in the train that requires the train to stop, this will engage the service brakes unless failure is caused by service brakes 3) Train is set to slow down and service brakes are applied to reduce speed
Response	Service brake status is set to engaged and train begins to decelerate at service brake deceleration rate.
Comments	The service brake can either possess the status of on, off, or failure.

Table 15: Engage Emergency Brake

Actors	Train Controller
Description	Train controller will engage or disengage the emergency brake in order to slow down or stop the train for any emergencies that may occur. Once engaged the power command will be set to zero and the train will begin to decelerate
Data	Emergency Brake command
Stimulus	Emergency brake will be engaged under the following conditions: 1) Emergency brake button is manually pressed by the driver or passenger via the train controller 2) Failure occurs in the service brakes and the emergency brakes are required to stop the train
Response	Emergency brake status is set to engaged and train begins to decelerate at emergency brake deceleration rate.
Comments	The Emergency brake can either possess the status of on or off. For this model we are assuming that the emergency brakes never fail

Table 16: Air Conditioning (AC) Control

Actors	Train Controller
Description	Train controller will activate or deactivate the Air conditioning unit onboard the train to decrease the current temperature of the train.
Data	Air conditioning command
Stimulus	The air conditioning will be turned on or off by the train controller. This will either be performed manually by the driver using a button or automatically by the train controller based on current temperature and thermostat setting.
Response	AC control set to on will result in a gradual decrease of the current train internal temperature.
Comments	The AC can either possess the status of on, off, or failure.

Table 17: Heater Control

Actors	Train Controller
Description	Train controller will activate or deactivate the heating unit on-board the train to increase the current temperature of the train.
Data	Heater command
Stimulus	The heating unit will be turned on or off by the train controller. This will either be performed manually by the driver using a button or automatically by the train controller based on current temperature and thermostat setting.
Response	Heater control set to on will result in a gradual increase of the current train internal temperature.
Comments	The heater can either posses the status of on, off, or failure.

Table 18: Door Control

Actors	Train Controller
Description	Train controller will open and close the doors on the left and right side individually using individual commands for each side.
Data	Left door command, Right door command
Stimulus	The left or right doors will be opened or closed by the train controller. This will either be performed manually by the driver using a button or automatically by the train controller upon arrival and departure at each station.
Response	If the right door command is passed, all doors on the right side are opened. If the left door command is passed, all doors on the left side are opened.
Comments	The Left and Right doors can either posses the status of open, closed, or failure.

Table 19: Light Control

Actors	Train Controller
Description	Train controller will turn the interior lights onboard the train on and off based on time of day and location of train (e.g. within tunnel or not)
Data	Interior Light command
Stimulus	The lights will be toggled on and off by the train controller. This will either be performed manually by the driver using a button or automatically by the train controller based on time of day and upon entering and exiting a tunnel
Response	If the light command is passed, all lights onboard the train are turned on.
Comments	The interior lights can either posses the status of on, off, or failure.

Table 20: Get Current Velocity

Actors	Train Controller, MBO
Description	A call will be made to request the current velocity of the train and this will be passed back to the actor which required it. The train controller will request the current velocity in order to compute the power command to send to the train model. The MBO will request the current velocity in order to compute the variation between the suggested speed and the actual speed of the train.
Data	Current Velocity value
Stimulus	A request will be sent to the train model to obtain the current velocity of the train at that given moment
Response	The current velocity of the train will be returned to the caller in MPH.
Comments	

Table 21: Toggle Engine Failure

Actors	Murphy
Description	Murphy is able to toggle the engine failure status in order to disrupt the train's engine. Once engaged the train will be required to stop until the issue is resolved.
Data	Engine Failure command
Stimulus	A command will be sent to the train model from the Murphy console to toggle the failure status of the train's engine.
Response	The engine failure status will be toggled as a response to the command. When an engine failure occurs the service brakes are also engaged to bring the train to a stop until issues are resolved.
Comments	The engine failure status will toggle between failure, and non-failure.

Table 22: Toggle Signal Failure

Actors	Murphy
Description	Murphy is able to toggle the signal failure status in order to disrupt the train's signaling and communication abilities. Once engaged the train will be required to stop until the issue is resolved.
Data	Signal Failure command
Stimulus	A command will be sent to the train model from the Murphy console to toggle the failure status of the train's signaling system.
Response	The signal failure status will be toggled as a response to the command. When a signal failure occurs the service brakes are also engaged to bring the train to a stop until issues are resolved.
Comments	The signal failure status will toggle between failure, and non-failure.

Table 23: Toggle Brake Failure

Actors	Murphy
Description	Murphy is able to toggle the brake failure status in order to disrupt the train's service brake. Once engaged the train will be required to stop until the issue is resolved.
Data	Brake Failure command
Stimulus	A command will be sent to the train model from the Murphy console to toggle the failure status of the train's service brake
Response	The brake failure status will be toggled as a response to the command. When a service brake failure occurs the emergency brakes are also engaged to bring the train to a stop until issues are resolved.
Comments	The brake failure status will toggle between failure, and non-failure.

Table 24: Get Safe Braking Distance (Service Brake)

Actors	MBO
Description	In order to better determine the train's footprint the MBO will call to obtain the safe braking distance of the Train. This will be the distance required to bring the train to a complete stop using the service brake deceleration rate. This distance will vary based on the number of passengers on board the train and the current velocity of the train.
Data	Safe Braking Distance for Service Brake
Stimulus	Command will be requested from the MBO to get the current safe braking distance using the service brakes which would be computed based on the current velocity and mass of the train.
Response	The safe braking distance using the service brakes will be returned to the MBO.
Comments	

Table 25: Get Safe Braking Distance (Emergency Brake)

Actors	MBO
Description	In order to better determine the train's footprint the MBO will call to obtain the safe braking distance of the Train. This will be the distance required to bring the train to a complete stop using the emergency brake deceleration rate. This distance will vary based on the number of passengers on board the train and the current velocity of the train.
Data	Safe Braking Distance for Emergency Brake
Stimulus	Command will be requested from the MBO to get the current safe braking distance using the emergency brakes which would be computed based on the current velocity and mass of the train.
Response	The safe braking distance using the emergency brakes will be returned to the MBO.
Comments	

Table 26: Get GPS Location

Actors	MBO
Description	The MBO will elect to receive the current GPS location to determine the train's current location to the nearest meter. This will be determined by calculating the distance traveled by the train and compute the distance into the current block to return to the MBO
Data	Current Block, Distance Into block
Stimulus	Command will be requested from the MBO to get the current GPS location from the train
Response	GPS location will be returned providing the current block the train is in as well as the distance into that current block to the nearest meter.
Comments	

Table 27: Get Authority

Actors	MBO
Description	The MBO will request to receive the current Authority of the given train. This will be used in conjunction with the suggested authority to determine the variation between suggested authority and actual authority for the train.
Data	Current Authority
Stimulus	Command will be requested from the MBO to get the current Authority from the train
Response	Current authority will be returned for that given train
Comments	

Table 28: Add Passengers

Actors	Track Model
Description	The track model will randomly generate a number of passengers to wait at a station then upon arrival to a station a random number of passengers will board based on space available on the train. This number will be sent to the train model to modify passenger count and mass of train based on capacity.
Data	Number of passengers boarding
Stimulus	Command will be requested from the MBO to get the current Authority from the train
Response	Based on space on board, a random number of passengers between 0 and amount of space will be passed to the train model
Comments	

Table 29: Set Speed/ Authority

Actors	Track Model
Description	The track model will pass the speed and authority to the train model. This speed and authority will then be passed to the train controller with no variation.
Data	Speed, Authority
Stimulus	Command will be sent to train model with speed and authority
Response	Speed and authority will be passed to train controller.
Comments	

Table 30: Set Current Block

Actors	Track Model
Description	The track model will pass the current block the train is on as the train enters each new block area. This current block object will provide the train with the block's grade as well as its length, to be used by the train's GPS
Data	Current Block
Stimulus	Command will be sent to train model with current block
Response	Block length will be extracted for train GPS, and Block grade will be extracted for train movement calculations
Comments	

2.4 Train Controller

In this subsection, the use cases of the train controller are provided.

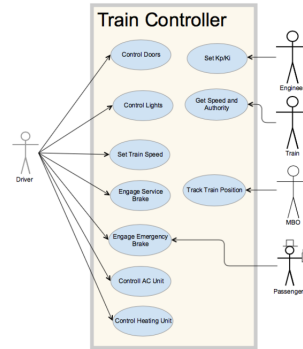


Figure 4: Train controller use case diagram

2.5 Moving Block Overlay

In this subsection, the use cases of the Moving Block Overlay (MBO) are provided.

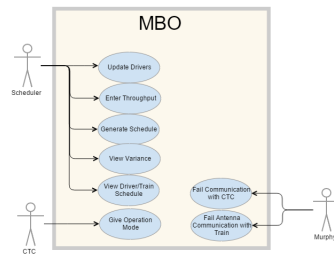


Figure 5: Train controller use case diagram

Table 31: Update

Actors	Scheduler
Description	The Scheduler is able to update the list of drivers. This will change whether or not a driver is able to be scheduled.
Data	filename
Stimulus	Click drivers button
Response	Loops through a CSV file to add all the drivers to the list of drivers. When adding a driver, a driver object will be created with the entered properties. This object will then be added to the Driver Schedule where it can be accessed as part of the list.
Comments	There will be a default file so that it can be saved between sessions.

Table 32: Enter Throughput

Actors	Scheduler
Description	The Scheduler enters the number of trains they would like to be on the track at a certain point in time.
Data	number of trains
Stimulus	Click submit button
Response	The number of trains is entered by the scheduler. This is used to generate both the train and driver schedules for both MBO and FB modes.
Comments	

Table 33: View Train/Driver Schedule

Actors	Scheduler, CTC
Description	Scheduler can see a list of all trains, as well as their station arrival times. Scheduler can see a list of all current drivers, as well as their corresponding break times and current train.
Data	train ID, arrival times, driver name, ID, break times
Stimulus	Updates triggered by clock
Response	Two tables will be displayed, one for the train schedule, and one for the driver schedule. The train schedule will list IDs as the rows and station names as the columns. Each cell will contain the time that train will arrive at that station. The driver schedule will show what train they are on at what times. It will also show whenever they start and stop work and when they are on breaks.
Comments	The table that is displayed will automatically update itself when triggered by the clock.

Table 34: View Variance

Actors	Scheduler
Description	Scheduler can see a list of all trains, as well as their corresponding speed and current position. The suggested speed and authority will be displayed as well as the variance between the two.
Data	train ID, speed, suggested/actual position/authority, variance
Stimulus	Updates triggered by clock
Response	In Fixed Block mode the current block will have to be kept track of based on past block occupancy. In MBO mode the position can be gotten through GPS.
Comments	In Fixed Block mode the position is denoted as the current block. In MBO mode the position is denoted as the current block and the distance into that block.

Table 35: Generate Schedules

Actors	Scheduler
Description	When required a schedule will be generated based on the input data. This will then be displayed for the scheduler/CTC. It is used to dispatch trains and calculate a path for a train.
Data	number of trains, track data
Stimulus	On launch, change in number of drivers, clock triggered
Response	A schedule will be generated for trains and drivers. It will have to take into account the mode of operation (MBO or FB), speed limits, track occupancy, drivers break times, and other variables.
Comments	Can only happen in automatic mode - schedule will be either fixed block or MBO depending on dispatcher's selection of mode.

Table 36: Give Operation Mode

Actors	CTC
Description	The CTC sends the mode of operation whenever it is changed.
Data	mode
Stimulus	CTC changes the mode.
Response	The mode is updated in the MovingBlockOverlay class. Any shut-down procedures to switch between modes are performed.
Comments	The default mode will be manual.

Table 37: Fail Communication with CTC

Actors	Murphy
Description	Murphy breaks communication between CTC and MBO.
Data	communication failure
Stimulus	CTC clicks Fail Communication with MBO button.
Response	Since scheduling will be unavailable without communication with the MBO, the CTC will be forced into manual mode and let the dispatcher know with a message.
Comments	

Table 38: Fail Communication with Train

Actors	Murphy
Description	Murphy breaks communication between Train and wayside.
Data	communication failure
Stimulus	Click Fail Communication with Train button.
Response	The MBO can no longer receive the GPS position of individual trains and is therefore unable to safely operate in MBO mode. So a transition must be made to either Fixed Block mode or to manual mode.
Comments	

2.6 Centralized Train Control

In this subsection, the use cases of the Centralized Train Control (CTC) are provided.

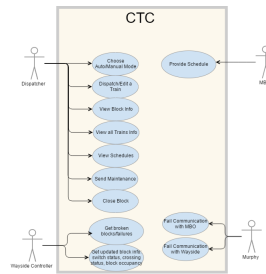


Figure 6: Centralized Train Control use case

3 Class Diagrams

In this section, we detail the use class diagrams for each subsystem..

- 3.1 Track Model
- 3.2 Track Controller
- 3.3 Train Model
- 3.4 Train Controlled
- 3.5 Moving Block Overlay
- 3.6 Centralized Train Controller

4 Sequence Diagrams

In this section, we detail the sequence diagrams each subsystem.

4.1 Track Model

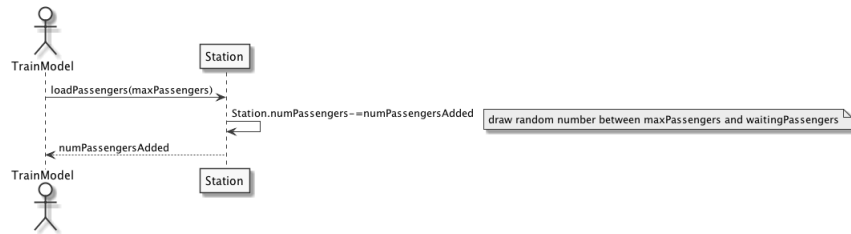


Figure 7: Add Passengers Use Case Diagram

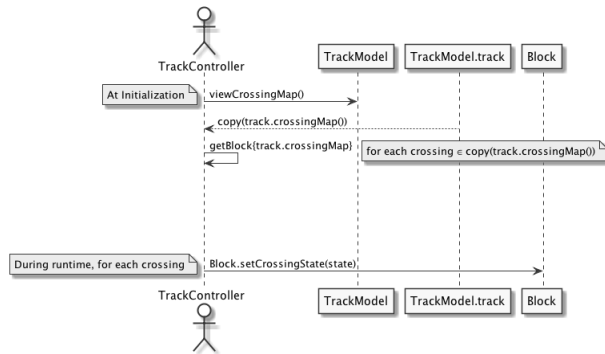


Figure 8: Toggle Crossing State Use Case Diagram

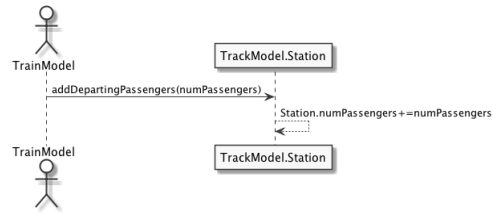


Figure 9: TDeparting Passengers to Station Use Case Diagram

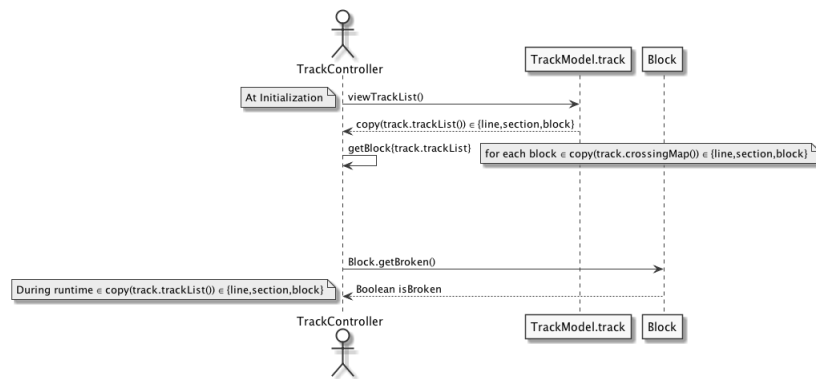


Figure 10: Detect Broken Rail Use Case Diagram

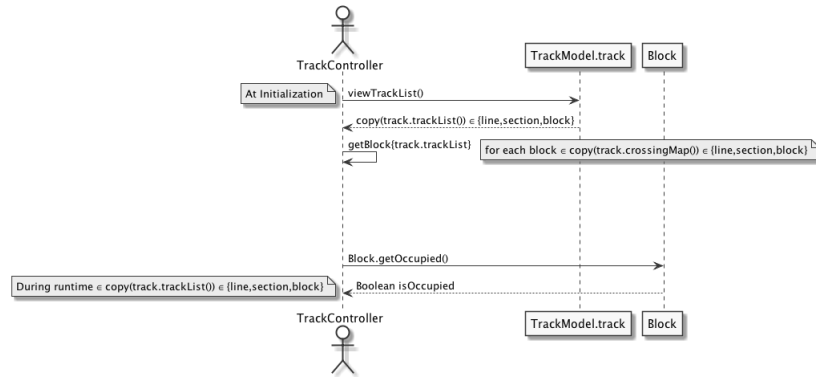


Figure 11: Detect Block Occupancy use Case Diagram

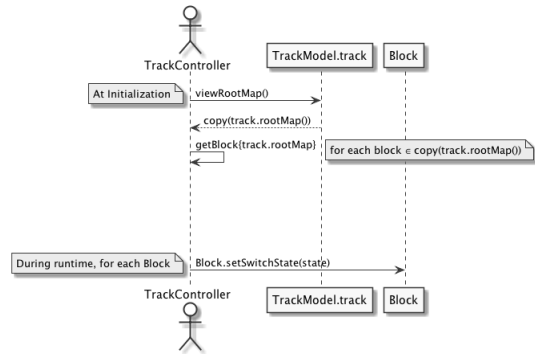


Figure 12: Toggle Switching Use Case Diagram

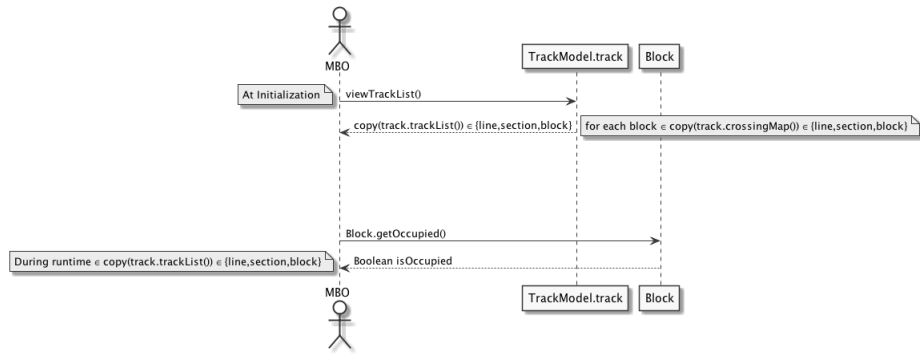


Figure 13: View Block Occupancy Use Case Diagram

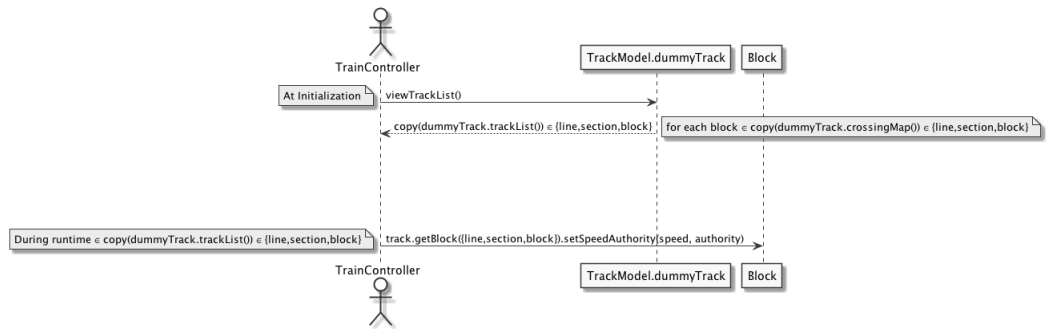


Figure 14: Set Speed and Authority use Case Diagram

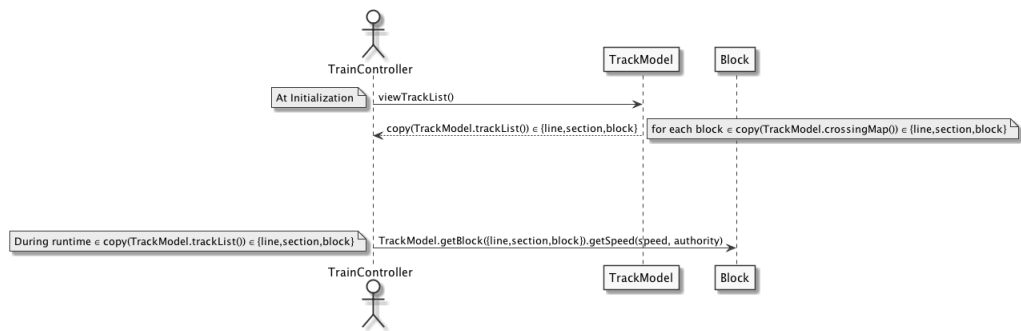


Figure 15: Get Speed Use Case Diagram

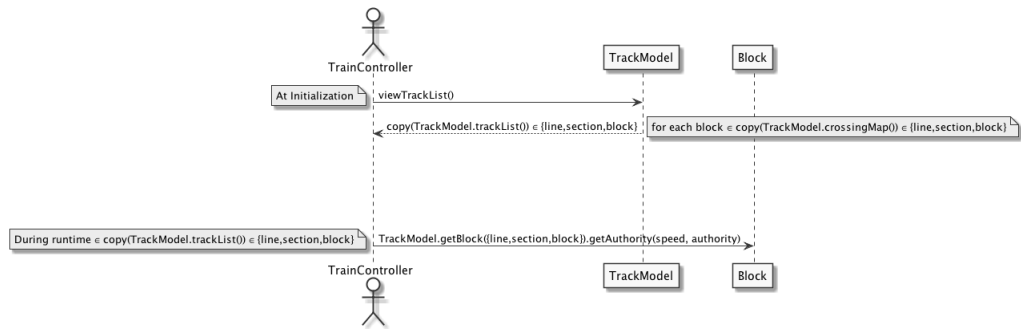


Figure 16: Get Authority Use Case Diagram

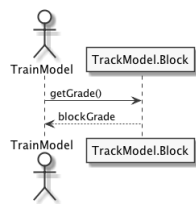


Figure 17: Get Grade Use Case Diagram

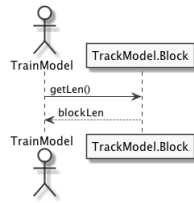


Figure 18: Get Length Use Case Diagram

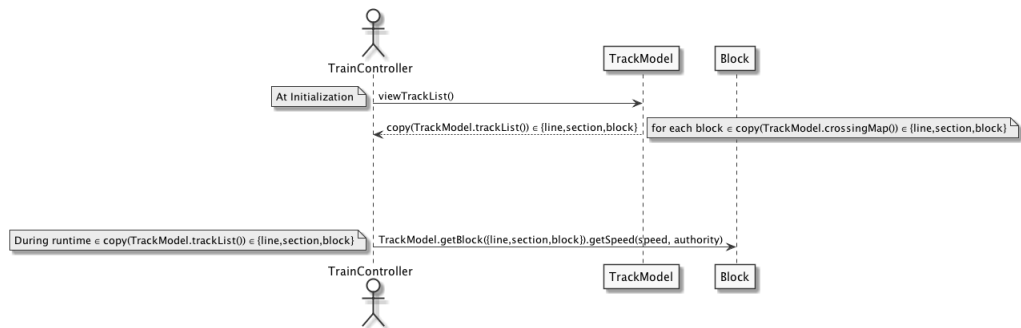


Figure 19: Get Speed Use Case Diagram

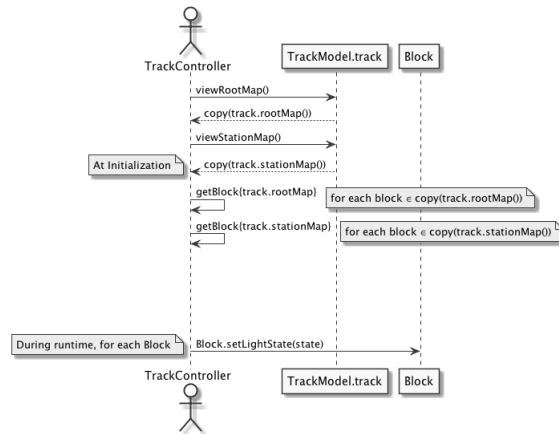


Figure 20: Toggle Lights Use Case Diagram

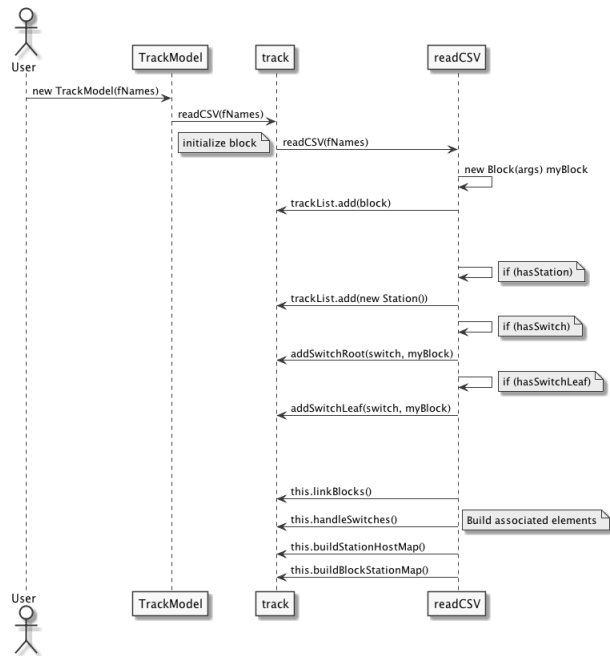


Figure 21: Read File Use Case Diagram

4.2 Track Controller

4.3 Train Model

In this section, we provide the sequence diagrams of the train model.

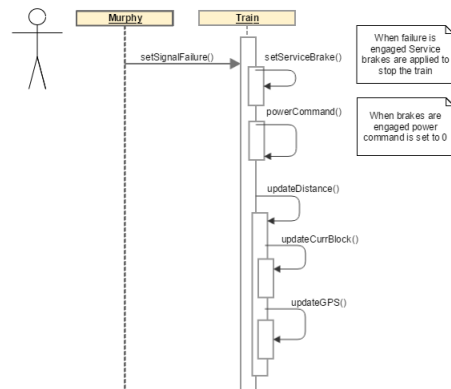


Figure 22: Toggle Signal Failure Use Case Diagram

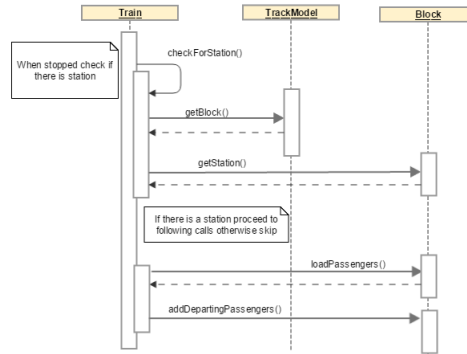


Figure 23: Add Passengers Use Case Diagram

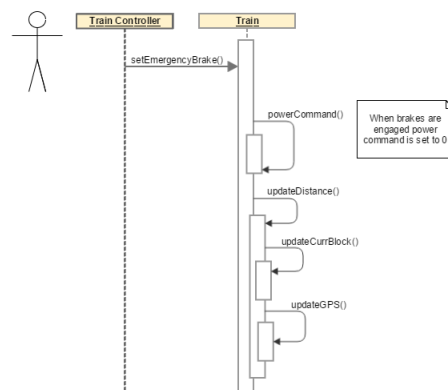


Figure 24: Engage Emergency Brake Use Case Diagram

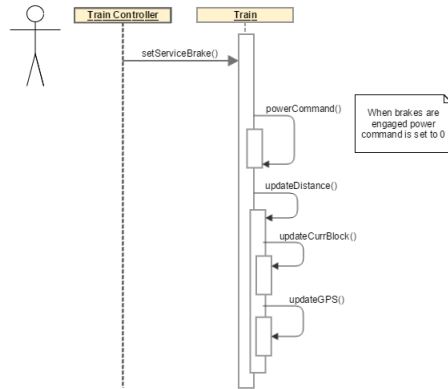


Figure 25: Engage Service Brake Use Case Diagram

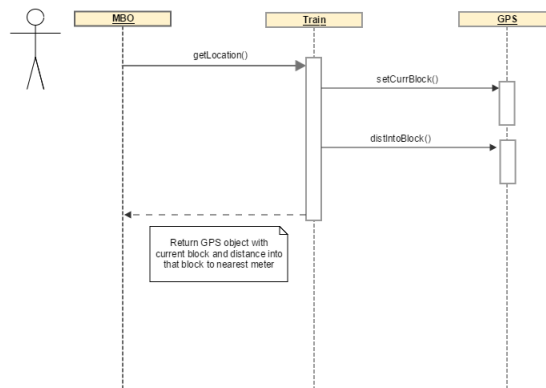


Figure 26: Get Location Use Case Diagram

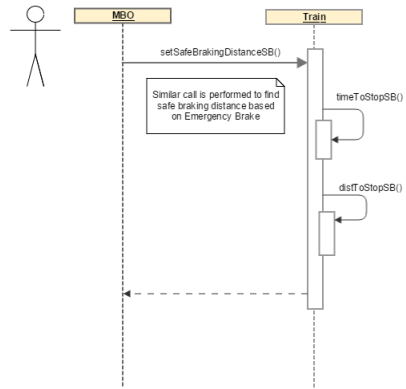


Figure 27: Calculate Safe Braking Distance Use Case Diagram

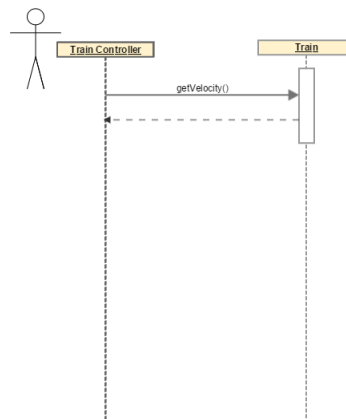


Figure 28: Get Velocity Use Case Diagram

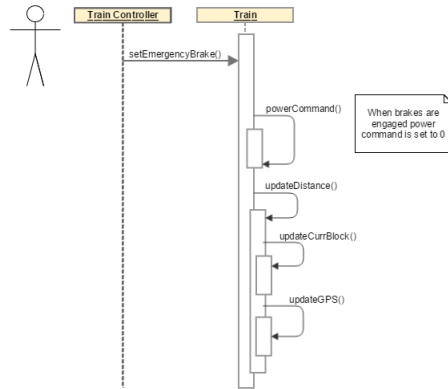


Figure 29: Increase Temperature Use Case Diagram

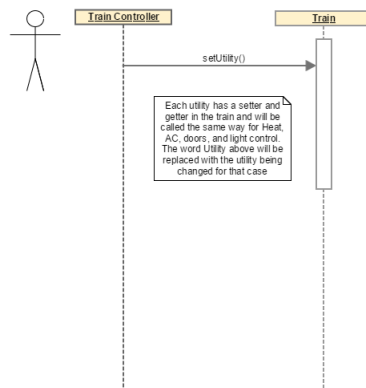


Figure 30: Modify Utilities Use Case Diagram

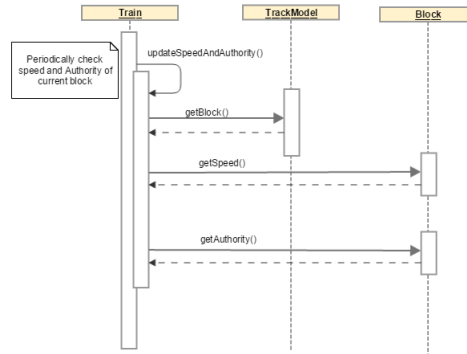


Figure 31: Set Speed and Authority Use Case Diagram

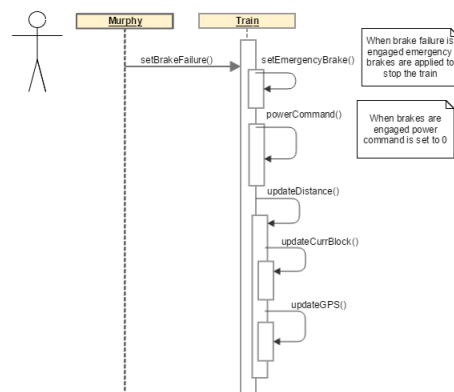


Figure 32: Toggle Brake Failure Use Case Diagram

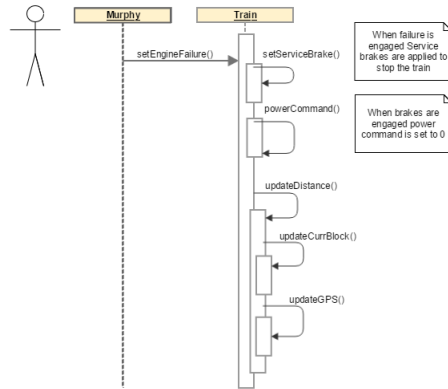


Figure 33: Toggle Engine Failure Use Case Diagram

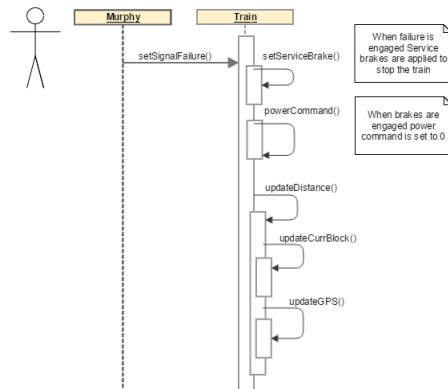


Figure 34: Toggle Signal Failure Use Case Diagram

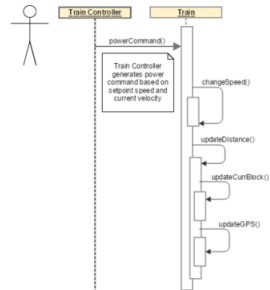


Figure 35: Toggle Signal Failure Use Case Diagram

4.4 Train Controller

4.5 Moving Block Overlay

4.6 Centralized Train Controller