**Light Rail System**

**Software Requirements Specification**

**Version <1.0>**

**Revision History**

|  |  |  |  |
| --- | --- | --- | --- |
| **Date** | **Version** | **Description** | **Author** |
| <02/09/23> | <1.0> | SRS 1.0 | Group-4 |

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**Software Requirements Specification**

# 1. Introduction

The introduction of the Software Requirements Specification (SRS) provides an overview of the entire SRS with purpose, scope, definitions, acronyms, abbreviations, references and overview of the SRS. The aim of this document is to gather and analyze and give an in-depth insight of the completely **renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System** by defining the problem statement in detail. Nevertheless, it also concentrates on the capabilities required by stakeholders and their needs while defining high-level product features. The detailed requirements of the **renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System** are provided in this document.

## 1.1 Purpose

The purpose of this system is to implement a functional central traffic control (CTC) office, train and track controllers with simulation abilities, and establish communications between each of these modules. Each module will also have a UI to allow for user interaction with the system. This system is intended for the PAAC to create a light rail transit system running from downtown Pittsburgh to the North Shore.

## 1.2 Scope

Our primary focus is describing this product’s features and functionality. This is meant for the user who will use this management software to understand the full details of what they have purchased. Moreover, this is a description of how the team developed the product. Specifically, it will describe the user specification and requirements needed to complete the product. It will also give the specifications and requirements the team decided to include. Furthermore, this SRS will also specify why different approaches were discarded or chosen to best satisfy the customer.

## 1.3 Definitions, Acronyms, and Abbreviations

|  |  |
| --- | --- |
| Configuration | It means a product which is available / Selected from a catalogue can be customized. |
| FAQ | Frequently Asked Questions |
| CRM | Customer Relationship Management |
| RAID 5 | Redundant Array of Inexpensive Disk/Drives |
| IEEE | [Institute of Electrical and Electronics Engineers](https://www.bing.com/work/search?msbd=%257B%2522intent%2522%253A%2522None%2522%252C%2522triggeringMode%2522%253A%2522Explicit%2522%257D&q=Institute%20of%20Electrical%20and%20Electronics%20Engineers) |
| PAAC | Port Authority of Allegheny County |
| UI | User Interface |
| PI | Proportional Integral |
| PLC | Programable Logic Controller |

## 1.4 References

* Project’s GitHub Page: <https://github.com/Tlalvani/ECE1140>
* IEEE template for Software Requirement Specification Document: <https://goo.gl/nsUFwy>
* Project information:

<http://www.flexity2.bombardier.com/swf/index.html>

[www.ansaldo-sts.com](http://www.ansaldo-sts.com/)

<http://www.rssi.org/index.html>

<http://www.apta.com/Pages/default.aspx>

<http://www.fra.dot.gov/>

<http://www.nrcma.org/ps.home.cfm?ID=155>

* Suppliers:

<http://www.ansaldo-sts.com/en/company/our_companies/asts_usa.html>

<http://www.phwinc.com/home>

<http://www.railsim.com/>

## 1.5 Overview

The remaining sections of this document provide a general description, including characteristics of the users of this project, the product's hardware, and the functional and data requirements of the product. General description of the project is discussed in section 2 of this document. Section 3 gives the functional requirements, data requirements and constraints and assumptions made while designing the demonstration of the control center, communications,   
train and track control system and simulator for the renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System. It also gives the user viewpoint of the product. Section 3 also gives the specific requirements of the product. Section 3 also discusses the external interface requirements and gives detailed description of functional requirements.

# 2. Overall Description

This document contains the problem statement that the current system is facing which is hampering the growth opportunities of the company. It further contains a list of the stakeholders and users of the proposed solution. It also illustrates the needs and wants of the stakeholders that were identified in the brainstorming exercise as part of the requirements workshop. It further lists and briefly describes the major features and gives a brief description of each of the proposed systems.

The following SRS contains the detailed product perspective from different stakeholders. It provides the detailed product functions of the renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System with user characteristics permitted constraints, assumptions and dependencies and requirement subsets.

2.1 Product Perspective

The renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System was developed for everyone who commutes via the train as well as those employed by Light Rail Transit responsible for controlling and maintaining communications between the train and track controllers. The renovations will upgrade Light Rail Transit’s current and outdated controls system. It can handle Python files in its database and supports communication between sub-modules such that the entire system is fully operational for demonstration purposes.

This is an open-source project with a very active developer team to support it and provide feedback to users. The system is developed to run on Windows.

2.2 Product Functions

*2.2.1 Centralized Traffic Control Office (CTC)*

1. Scheduling and routing trains
2. Providing dispatcher with current state of entire system
3. Provide throughput information
4. Close and open sections of track for maintenance
5. Send authority and suggested speed for trains to Track Controller
6. Receive information from dispatcher about routing or dispatching

*2.2.2 Track Controller – Software*

* 1. Receives suggested speed and authority from CTC office.
  2. Moves switches and sets traffic light color based on PLC program.
  3. Receives track occupancy and broken rail from the Track Model.
  4. Controls railway crossings’ lights and gates.

*2.2.3 Track Controller – Hardware*

1. Receives suggested speed and authority from CTC office.
2. Moves switches and sets traffic light color based on PLC program.
3. Receives track occupancy and broken rail from the Track Model.
4. Controls railway crossings’ lights and gates.

*2.2.4 Train Controller*

1. Receives commanded and actual speed from the train model and sends power back to the train model.
2. Calculates output power using a KI controller, ensuring the train does not exceed authority or the speed limit.
3. Monitors and acts upon faults in a safe manner.
4. Takes input from the train driver in manual mode.
5. Controls other non-vital parts of the train, such as lights and doors.
6. Announces and stops at stations.

*2.2.5 Train Model*

1. Receives commanded power from the train controller and sends actual velocity back to train controller.
2. Calculates the force of the train using a limiter, checking that the commanded velocity received by the train controller is greater than zero.
3. Calculates acceleration using previous value of force and total mass of train.
4. Uses Laplace transform to calculate actual velocity of the train, which gets sent to the train controller.
5. Uses Laplace transform to calculate position of the train using the actual velocity found in previous calculation.
6. Continuously reads input coming from train controller.

*2.2.6 Track Model*

1. Receives suggested velocity from track controller and passes it to train model
2. Sends information including location and speed limits to train when it passes by a beacon
3. Sends occupancy and track information about faults to track model
4. Heats track when too cold, so no freezing occurs
5. Turns on crossing warnings when passing by roads
6. Turns switches as directed by track controller so trains can stay on correct route

2.3 User Characteristics

Typical users include those who need to operate the train and track, such as transit engineers, dispatchers, train programmers and track builders. Users of a High School diploma minimum operate the system via applications that are intuitive with ease of use. Those with disabilities gain the same user experience as typical users would through symbology, representing features in multiple ways, descriptive text for further guidance. Users with more advanced technical backgrounds will find the new system assists in their daily tasks and improves operations. Additionally, users such as hackers will find difficulty in accessing confidential information to decrease the risk of an attack on the system.

2.4 Constraints

This system shall use Windows 10. Each sub-system shall have a user interface with ease of use. The Arduino hardware component must be compatible with Windows 10 with appropriate drivers and libraries installed. System should be less costly than other systems presented to PAAC President. The system should be accessible to the Transportation Security Administration (TSA) as well as the National Transportation Safety Board (NTSB) for monitoring and safety regulation.

2.5 Assumptions and dependencies

The renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System is developed in Python and therefore requires the PyCharm developing environment to be installed on the user’s system for making edits. The latest version of PyCharm compatible with Windows 10 shall be installed on the user’s machine. All user devices must operate on Windows 10 to use the system’s software applications.

2.6 Apportioning of Requirements

|  |  |
| --- | --- |
| Train Model |  |
| Function | Models train movement assuming train is a point mass with acceleration and velocity limits. Movement should account for the terrain of the track. |
| Description | Reads power command from train controller and uses Newton's Laws to calculate force, acceleration, actual velocity and position of the train. |
| Key Inputs | Authority, power, commanded speed, speed limit, acceleration limit, deceleration limit, route information, temperature control, door open/close, beacon, track input, light controls and emergency brake |
| Key Outputs | Actual velocity, position, authority |
| Side Effects | Train engine failure, signal pickup failure, brake failure |
| Condition | Action |
| Power Command > Engine Max | Max Force = Nominal Mass \* Max Acceleration |
| Power Command in Engine Range & Velocity ≠ 0 | Force = Power / Velocity |
| Power Command in Engine Range & Velocity = 0 | Depends on sign of Power Command but degenerates to 1st or 4th condition |
| Power Command < Engine Max | Max Force = Nominal Mass \* Max Deceleration |

|  |  |
| --- | --- |
| Track Model |  |
| Function | Models track conditions for train to accurately run on. Adjusts switches and lights to model actual terrain of a track. Has stations for passengers to embark and disembark from. |
| Description | Adjusts all physical components of a track to accurately reflect position of trains on the track. |
| Key Inputs | Suggested speed, crossings, switches |
| Key Outputs | Suggested speed, speed limit, track status, track occupancy |
| Side Effects | power failure, broken circuit, broken rail |
| Condition | Action |
| Track temperature < 32 degrees Fahrenheit | Heat track to prevent freezing |
| Track section occupied | Display train is occupying section of track |
| Broken circuit, broken rail, or power failure | Alert track controller |

|  |  |
| --- | --- |
| Track Controller |  |
| Function | Moves switches and sets traffic lights based on PLC program. Control railway crossings’ lights and gates based on PLC program. |
| Description | Receives suggested speed and authority from CTC office, and track occupancy and broken rail from Track Model. Uses Boolean logic to output lights, switch positions and railway crossings. Also, it sends commanded speed and authority to Track Model, as well as track occupancy and broken rail to CTC office |
| Key Inputs | Suggested speed, authority, track occupancy, Track Status (Broken rail, circuit failure, power failure) |
| Key Outputs | Commanded speed, authority, lights, switch positions, railway crossings (lights and gates) |
| Side Effects |  |
| Condition | Action |
| Track block occupied | Set red or yellow light |
| Track unoccupied | Set green light |
| Train presence detected (railway crossing) | Railway crossing light red and gates down (closed) |
| Train presence undetected (railway crossing) | Railway crossing light green and gates up (open) |
| Train presence detected (switches) | Move switch to avoid collision |
| Train Controller | |
| Function | Vital controller that controls the train’s speed according to speed limit and authority. Also allows for train drivers to control the train. |
| Description | Receives actual speed from train model and regulates the train speed using a PI controller to the commanded speed of the driver or CTC office. Acts upon faults in a safe manner using emergency brake. Also controls non-vital components such as lights, doors, and station announcing. |
| Key Inputs | Commanded speed, Actual speed, Authority, Beacon, Speed limit, Brake failure, Engine failure, Signal failure |
| Key Outputs | Train power, Emergency Brake, Service Brake |
| Side Effects |  |
| Condition | Action |
| Brake failure, engine failure, or signal failure | Emergency brake applied |
| Train going too slow | More power applied |
| Train going too fast | Power reduced and service brake applied |
| Train arrives at station | Station announced and appropriate doors are opened |
| CTC Office |  |
| Function | Schedule and route trains, with input from the dispatcher about rerouting based on traffic. Gives overview of entire system to dispatcher |
| Description | Calculate suggested speed and authority for every train to ensure prompt arrival to stations and no collisions. Display all information to dispatcher to allow them to adjust if needed. Allow dispatcher to close portions of the track for maintenance when applicable to prevent trains from using route. |
| Key Inputs | Track layout, Track occupancies |
| Key Outputs | Authority, Suggested speed, Track status |
| Side Effects | Track maintenance |
| Condition | Action |
| Trains are too close to each other on the same line | Decrease suggested speed for the train behind front train |
| Section of track is currently being worked on | Send maintenance info to track controller to close part of the track |
| Dispatcher reroutes a train | Calculate new authority and suggested speed and send to track controller |

# 3. Specific Requirements

This section discusses the general requirements of the overall system. The sub-sections below discuss functional and non-functional requirements of each module in the system.

## 3.1 Functionality

This section contains the functional requirements for the renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System. Below are general requirements for the overall system. The following sub-sections will further explain the functional requirements for each module.

General functional requirements of the overall system include:

1. The system shall have an automatic mode with preset scenarios to demo the system.
2. The system shall be capable of running at least 10 times faster than wall clock time.
3. The system shall be able to pause during simulation.
4. The project shall use at least one or more architectural and design patterns to represent the system.
5. The architectural and design patterns shall be identified in the architecture design documentation.
6. The system shall identify any commercial off-the-shelf hardware components used in the system.
7. The project shall address the vital aspects of the system through the architecture and design of the system.
8. The sub-systems should be implemented correctly such that all modules may communicate with each other to demonstrate functionality of the overall system.
9. Each module shall be testable individually as well as with the overall system.

*3.1.1* *Centralized Traffic Control Office (CTC)*

1. Module shall schedule and route trains
2. Module shall display the current state of entire system
3. Module shall close and open sections of track for maintenance
4. Module shall send authority and suggested speed to track controller
5. Module shall receive information from dispatcher for routing and dispatching
6. Module should calculate and output throughput information

*3.1.2 Track/Wayside Controller – Software*

1. System shall be a vital controller that controls the track
2. System shall receive suggested speed, authority, track occupancy and broken rail.
3. System shall send commanded speed, authority and shall control light colors, switch positions and railway crossings (lights and gates) to avoid any collision
4. System shall detect track occupancy and broken rails.
5. Module shall communicate with CTC office and Track Model.
6. System shall continuously read input values and update output values sent to CTC office and Track Model
7. Module shall be testable on its own

*3.1.3 Track/Wayside Controller – Hardware*

1. System shall be a vital controller that controls the track
2. System shall receive suggested speed, authority, track occupancy and broken rail.
3. System shall send commanded speed, authority and shall control light colors, switch positions and railway crossings (lights and gates) to avoid any collision
4. System shall detect track occupancy and broken rails.
5. Module shall communicate with CTC office and Track Model.
6. System shall continuously read input values and update output values sent to CTC office and Track Model
7. Module shall be testable on its own

*3.1.4 Train Controller*

1. Module shall be a vital controller that controls the train.
2. Module shall ensure that train obeys speed limit and authority using a PI controller.
3. Module shall take a commanded speed from transit operator or from CTC office, passed in through train model.
4. Modules shall have an automatic and manual mode.
5. Module shall open and close doors at the appropriate times.
6. Module shall turn lights on and off at the appropriate times.
7. Module shall announce stations and stops at the appropriate times.
8. Module shall monitor trains for faults, such as brake failure, engine failure, or signal failure, and act upon them in a safe manner.
9. Module shall receive commanded speed, actual speed, authority, and failures from train model and output power, emergency brake, and service brake back to train model.

*3.1.5 Train Model*

1. Sub-system shall model train movement using Newton’s laws assuming the train is a rigid body point mass.
2. Shall have acceleration and velocity limits.
3. Shall model movement which accounts for the terrain of the track.
4. Should have length, height, width, mass, crew count and passenger count.
5. Inputs shall be authority from wayside controller, setpoint speed command, brake command, speed limit, acceleration limit, deceleration limit, route information, temperature control, door open and close, beacon, track circuit input, light controller for tunnels, and emergency brake from passenger.
6. Shall read commanded power from train controller, and calculate force, acceleration, actual velocity and position of the train.
7. Shall send actual velocity calculation to train controller.
8. Shall alert for the following failure modes: train engine failure, signal pickup failure, brake failure.
9. Module shall be testable.
10. Module shall not communicate directly with other modules besides the track model and train controller.
11. Module shall not directly control signals between track model and track controller as well as the signals between track controller and CTC office.
12. Should include a system architecture designed to structure the above requirements.
13. Module shall continuously read in changes to inputs from track model and train controller and send updated outputs to both modules as necessary.

*3.1.6 Track Model*

1. Sub-system shall model track conditions and train positions
2. Shall send suggested speed to train model
3. Shall have speed limits associated with every section of the track and send them to train model
4. Shall send alert to track controller if there is a power failure, broken circuit, or broken rail
5. Should show how many passengers are on a train and in a station
6. Should send train model details of track environment such as grade and elevation

## 3.2 Non-functional Requirements

This section contains the non-functional requirements for the renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System. Below are general non-functional requirements for the overall system. The following sub-sections will further explain the non-functional requirements for each module.

General non-functional requirements of the overall system include:

1. Shall be executable on a Windows 10 Operating System.
2. Train and track controllers shall have architectures including vital components of the train system for proper operation.
3. Each sub-system shall have a user interface.
4. Each sub-system shall have an installable executable once implemented.
5. The overall system shall have an installable executable once implemented.
6. The system shall run according to the speed, velocity, acceleration and deceleration limits.
7. System shall detect and notify user during failure modes.
8. The system shall detect and notify users regarding important transponder information.
9. Sub-systems should communicate properly with each other for full system integration and demonstration.
10. Implementation shall be relevant to the user, but not shared with users who do not need it such that integrity breaches are avoided.
11. All user devices should be updated with any changes to the system’s software applications for maintainability.
12. The system should be reliable with minimal errors to avoid faults in operation.
13. Programs should be portable for users such that any applications can be used across multiple devices for remote operation.

Sub-systems:

*3.2.1* *Centralized Traffic Control Office (CTC)*

1. Module shall communicate with track controller to relay vital information
2. Module shall use a simple UI that dispatcher can easily understand and use
3. Module shall ensure no collisions occur when routing trains

*3.2.2 Track/Wayside Controller – Software*

1. System shall run a PLC program based on Boolean logic
2. The system should always have a PLC script loaded to allow track control without direct communication with the CTC office.
3. PLC program shall be specifiable separately from the implementation of the track controller
4. Shall collect status from track circuit to determine track occupancy
5. Inputs shall be manually configurable if desired
6. PLC program shall be manually modifiable if desired
7. Sub-system shall have a user interface and shall be easily navigable
8. System should not allow unauthorized users to modify its inputs or the PLC program
9. Wayside should be positioned at determined locations at the side of the track

*3.2.3 Track/Wayside Controller – Hardware*

1. System shall run a on an Arduino
2. Shall collect status from track circuit to determine track occupancy
3. Inputs shall be manually configurable if desired
4. Sub-system shall have a user interface and shall be easily navigable
5. System should not allow unauthorized users to modify its code or configuration
6. Wayside should be positioned at determined locations at the side of the track
7. System should have number of trains permitted in each block at any time
8. System should have minimum distance permitted between two trains at any time

*3.2.4 Train Controller*

1. Module shall communicate with the train model to send and receive vital information.
2. The user interface shall be intuitive and easy to use such that someone who is literate would be able to use it.
3. The module shall have a vital architecture.

*3.2.5 Train Model*

1. Module shall dependently communicate with the track model and train controller both receiving and sending crucial input and output.
2. Corresponding modules which communicate with the train model should notify train model when issues arise.
3. The sub-system shall have a user interface that is intuitive to the user so they can further assist system operations.
4. Module shall minimize communication between components for troubleshooting.
5. Module shall minimize communication between components for repairs during failure modes.
6. Module should include security measures which make it difficult for unauthorized user to access confidential information.
7. The module shall specify who its intended user is through its user interface.

*3.2.6 Track Model*

1. Model shall communicate with the track controller and train model to pass and receive essential information about the system
2. Sub-system shall have a user interface that displays positions of the trains and track components
3. Module shall communicate failure modes to track controller when they occur

## 3.3 Design Constraints

The system shall use a program which allows communication between all modules for the entire system to function properly. The program shall be saved in a repository compatible with Windows 10 for defect tracking and modular design. The system shall use modular design where every feature is wrapped into a separate module and the modules depend on each other through well-written APIs. The system architecture shall convey vital inputs and outputs necessary such that all users can use the system appropriately. The user experience shall be conveyed using uniform symbology for demonstrating workflow and user interaction with each sub-system.

## 3.4 Other Requirements

This section contains the additional requirements for the renovated Centralized Traffic Control Center (CTC) and Signaling System for Light Rail Transit System. Below are general requirements for the overall system involving results of user surveys as well as supporting information about the problems to be solved by the future renovation.

Additional requirements of the overall system include:

1. The system shall display speed limit to user dashboard to assist transit engineers while driving.
2. The system shall include more visual feedback regarding train authority, passengers waiting at stops, and passenger count for assisting dispatchers.
3. The system shall limit the amount of maintenance regarding installation and programming to assist the transit programmer.
4. The system shall be easily configurable and intuitively programmed in a language that is easily understood by users to aid with equipment failure, electrical hardware problems, circuit replacements and maintaining signals between trains.
5. The system should have timely arrivals at junctions and include interactive features in the train for passengers to be aware of incoming stops and other important announcements.
6. The system shall include a user program which assists track builders in viewing entire layouts of transit lines, simplify designing track layout, and support uploading multiple files at once.
7. The system shall clearly indicate where faults occur and which module it corresponds to.
8. The system shall allow testing of each module to fix errors and allow full system operation.
9. The system shall prioritize requirements corresponding to vital functionality and put additional requirements which do not affect vital requirements at a lower priority level.