**System Requirements Specification Document [IEEE 830]**

**ECE 1140 - Group: Tovarish**

Jonah Belback, Lucas Connell, Devin James, Noah Lichstein, Elizabeth Novikova, Robert (Sam) Pratley, Daniel Richardson

**Change Log**:

| **Change Date** | **Person** | **Affected Sections** | **Version** |
| --- | --- | --- | --- |
| 02/08/24 | Lucas Connell | Document creation | *1.0.0* |

**Table of Contents**

1. **Introduction**
   1. Purpose
   2. Scope
   3. Definitions, acronyms, abbreviations
   4. References
   5. Overview
2. **Overall description**
   1. Product perspective
   2. Product functions
   3. User characteristics
   4. Constraints
   5. Assumptions and dependencies
   6. Apportioning of requirements
3. **Requirements**
   1. Functional Requirements
   2. Non-Functional Requirements
   3. Design Constraints
   4. Other Requirements
4. **Introduction**
   1. **Purpose**

This document serves as the set of records that describes the features and behavior of our application for the ECE 1140 Systems Engineering Course. It shall serve the Tovarish group as the source for all requirements related information. This document shall describe what our software will do and the acceptance criteria for how it will be expected to perform. It will also describe the requirements the product will need to fulfill the needs of our stakeholders.

* 1. **Scope**

The development team will design and implement a new Centralized Traffic Control (CTC) Center and Signaling System for Light Rail Transit system. Out for bid is the control center, communications to and from the territory as well as the train and Track Controllers.

Additionally, the system shall produce a fully operational demonstration of the control center, communications, train and track control system with a simulator for the transit system for review by the PAAC procurement committee

PAAC Demonstration Modules include:

* Train Model (Software)
* Track Model (Software)
* Train Controller (Software & Hardware)
* Track Controller (Software & Hardware)
* CTC Office (Software)

Overall, the system aims to solve the problem of efficiently managing a Light Rail Transit system. Above all, the product will enhance the safety of the transit system, but will also improve reliability and overall passenger throughput.

* 1. **Definitions, acronyms, abbreviations**

The following terms and phrases appear within the text of this standard:

* "Authority" - Length train is allowed to travel
* "Beacon" - Holds static information to be scanned from track to train
* "Block" - Section of track layout
* "Boolean" - A binary variable, with two possible values; "true" or "false."
* "Baud" - A unit of transmission speed measured in signal changes per second. Three (3) baud is equivalent to three bits per second.
* "Commanded Speed" - The safe speed given by train controller
* "Current Speed" - The speed that the train is traveling at a given time (Actual speed)
* "Emergency Brake" - Brake for emergencies (used by driver or passengers) (2.73 m/s^2)
* "Ethernet" - A common technology used to connect devices in LANs
* "Integral Gain" - Determines how fast the steady-state error is eliminated
* "Proportional Gain" - Determines how fast the engine responds
* "Service Brake" - Brake for operational tasks (used by driver) (1.2 m/s^2)
* "Suggested Speed" - The un-vital speed set and given by the CTC
* “The Product” The final top-level deliverable for this project (The system)
* "Train Throughput" - The throughput of trains moving through the system per hour
* "Vital" - Safety critical, function on which life is directly dependent

The following acronyms and abbreviations appear within the text of this standard:

CTC - Centralized Traffic Control

CSV - Comma-Separated Values

EXE - Executable

LAN - Local Area Network

PAAC - Public Administration and Appropriations Committee

PLC - Programmable Logic Controller

SRS - System Requirements Specification

* 1. **References**

Any documents referenced within the SRS shall be detailed here. Each reference should include the title of the document, date, publisher, and source.

* 1. **Overview**

The remainder of this document shall comprise of two main parts, overall description and requirements. The overall description section shall provide a general description of the product, along with a background basis for the requirements to be detailed in the following section. The final section, requirements, shall be comprised of interface requirements in addition to functional and nonfunctional requirements of the product.

1. **Overall Description**
   1. **Product Perspective**

This Train System (transit system) is a standalone simulation of an entire transit system, including the control systems, (simulated) track, and (simulated) moving train. The system runs as-is, without any systems depending only on a computer running Windows 10 to run the system.

* 1. **Product Functions** 
     1. **CTC Office**

The CTC Office dispatches trains according to a schedule followed by a dispatcher. The CTC Office routes trains through the transit network by sending authority and suggested speed directions to the Track Controller, monitors the transit network, opens/closes blocks for maintenance, and moves switches for maintenance.

* + 1. **Track Controller**

A safety critical (vital) piece of infrastructure. Track controllers exist along sections of the track and control traffic on the tracks. This includes asserting authority based on block occupancy and controlling switches based on routing information from the CTC Office. The Track Controller also controls the activation of several pieces of infrastructure on the Track Model: signal lights, railroad crossing, and switches.

* + 1. **Track Model**

A development tool for testing other modules. This module will be a simulation of a physical transit system track layout. This model will consider grade, elevation, directions of travel, branching, and speed limits. Additionally, track layout will be configurable. Block size will also be shown and configurable. This model will also consider signals, switch machines, and railway crossings and include stations (with heaters) for loading and unloading passengers. Users will also be able to test failure modes including broken rail, track circuit failure, and power failure.

* + 1. **Train Model**

A development tool for testing other modules, primarily the Train Controller. This module will be a simulation of a train and shall be capable of doing physics calculations in response to commands from the Train Controller, facilitate state changes to the train such as the state of the doors in response to commands from the Train Controller, receive data from the Track Model for physics calculations and communication to the Train Controller, and apply the emergency brake at the request of the passenger and change failure state at the request of murphy.

* + 1. **Train Controller**

A safety critical (vital) piece of the train. This module exists to simulate the actual functioning of the train with the combination inputs of the whole rest of the system and the driver inside. With information like the actual speed, authority, station beacons, track state, emergency brake buttons, and failures; this module needs to regulate the speed of the train, lights, doors, announcements, and temperature. The front-end of the system to the public.

* 1. **User Characteristics**
     1. **Dispatcher**
        1. **Responsibilities:** The Dispatcher is responsible for dispatching trains according to a schedule and overseeing the overall transit system.
        2. **Technical Skills:** The Dispatcher must be skilled in system management, time management, and scheduling.
        3. **Education Level:** University degree.
        4. **Training Requirements:** Must have gone through transit dispatcher training, as well as have been trained on the specifics of the system which the Dispatcher is overseeing.
     2. **Train Driver**
        1. **Responsibilities:** The Train Driver is responsible for the safe and punctual operation of the transit vehicles (trains).
        2. **Technical Skills:** The Train driver must be trained in the safe operation of the trains used in the transit system.
        3. **Education Level:** High school minimum
        4. **Training Requirements:** The Train Driver must be trained on the safe operation of the rolling stock used in the system (see **Section 2.4 Constraints**) and on the transit system and routes operated.
     3. **Murphy**
        1. **Responsibilities:** Murphy is responsible for testing the safe limits of the system (a.k.a. breaking things).
        2. **Technical Skills:** Murphy must be technologically proficient in breaking transit systems.
        3. **Education Level:** High school minimum.
        4. **Training Requirements:** Murphy must be trained on the points of weakness and failure of the transit system to ensure that he can do an effective job of breaking the transit system.
     4. **Passenger**
        1. **Responsibilities:** The Passenger is responsible for utilizing the transit system by riding a train from an origin to a destination. The passenger adds revenue to the system by purchasing tickets.
        2. **Technical Skills:** Navigation of a transit system
        3. **Education Level:** No education necessary
        4. **Training Requirements:** The Passenger must be familiar with their origin and destination locations in order to board the correct train and disembark the train at the correct destination
     5. **Track Builder**
        1. **Responsibilities:** The Track Builder is responsible for building and maintaining the tracks within the system.
        2. **Technical Skills:** The Track Builder must be proficient in railway track design and construction, as well as comfortability with using point-and-click software to monitor and inspect the system.
        3. **Education Level:** University degree in Civil Engineering
        4. **Training Requirements:** In addition to the Track Builder’s university training in civil engineering, the Track Builder must be trained in railway construction, NTSB and DOT requirements and regulations for building rail transit systems, and must be trained on the requirements of the system that they are building.
     6. **Transit Programmer**
        1. **Responsibilities:** The Transit Programmer is responsible for configuring the Track Controllers based on the system’s route specifications. The Transit Programmer programs the Track Controllers via a PLC configuration.
        2. **Technical Skills:** Must be proficient in computer programming with specific knowledge of transit PLC programming.
        3. **Education Level:** University degree in Computer Engineering or Computer Science required.
        4. **Training Requirements:** Must be trained on the routing details of the transit system such that the transit programmer and accurately program the functionality of each track controller in the system.
     7. **Train Engineer**
        1. **Responsibilities:** The Train Engineer is responsible for the initial configuration of the transit vehicles in the transit system.
        2. **Technical Skills:** The Train Engineer must possess knowledge about the rolling stock used in the system. The Train Engineer must also have exceptional system testing skills and have mastered PID control concepts.
        3. **Education Level:** University degree in engineering
        4. **Training Requirements:** The Train Engineer must be trained on the operation of the transit vehicles used in the system, as well as how to configure the vehicle.
  2. **Constraints**
     1. Each sub-module shall only communicate as outlined in Section 3.3.1
     2. The project shall be delivered on time according to the agreement made between the customer and the manufacturer.
     3. The transit system shall utilize Bombardier Flexity tram rolling stock of both single set (5-car) and double set (10-car).
  3. **Assumptions and Dependencies**
     1. Any assumptions made will be guided by a) previous consultations with the customer and b) any documents/materials/literature/information previously provided by the customer Any further ambiguities will be consulted on with the customer.
  4. **Apportioning of the Requirements**
     1. The integration of each sub-module shall not be necessitated until “Iteration #3”
     2. Otherwise, no requirements shall be apportioned to a later date, as this product is due on April 25 and will not be iterated upon after this. All requirements must be completed by this date.

1. **Requirements** 
   1. **Functional Requirements**
      1. **General system requirements**
         1. The system shall be able to operate at 10x wall clock speed.
      2. **CTC Office** 
         1. The CTC Office shall have automatic, manual, and maintenance modes.
         2. The CTC Office shall send the suggested speed and authority to the Track Controller for each train dispatched such that dispatched trains reach destinations at a time set by the dispatcher.
         3. In manual mode only, the CTC Office shall command the Track Controller to open blocks when a dispatcher opens a block.
         4. In manual mode only, the CTC Office shall command the Track Controller to close blocks when a dispatcher closes a block.
         5. In maintenance mode only, the CTC Office shall command the Track Controller to position a switch when a dispatcher positions a switch.
         6. The CTC Office shall report ticket sales per line per hour per line.
         7. The CTC Office shall report trains per hour per line.
         8. The CTC Office shall allow a dispatcher to upload a schedule using a format outlined with system delivery.
         9. The CTC Office shall dispatch trains according to an uploaded schedule.
         10. In automatic mode only, the CTC Office shall dispatch trains from a schedule uploaded by the dispatcher.
         11. In manual mode only, the CTC Office shall dispatch trains manually by the action of the dispatcher..
         12. The mode of the CTC Office shall be switchable from automatic mode to manual mode.
         13. The mode of the CTC Office shall be switchable from automatic mode to maintenance mode.
         14. The mode of the CTC Office shall be switchable from maintenance mode to automatic mode.
         15. The mode of the CTC Office shall be switchable from automatic mode to maintenance mode.
         16. The mode of the CTC Office shall not be switchable into automatic mode from any other mode.
      3. **Track Model**
         1. The Track Builder shall be able to load a Track Model from Excel file
         2. All track properties shall be displayed to the user, including: grade, elevation, length, speed limit, direction of travel, railway crossings, track heaters, beacons
         3. Ticket sales (people waiting at stations) shall be displayed to the user
         4. Number of passengers embarking and disembarking shall be displayed to the user
         5. Block occupancy shall be displayed to the user
         6. Track circuit signals shall be sent to the Track Controller
         7. Track circuit signals shall be received from the Train Model.
         8. The user shall be able to set environmental temperature
         9. The user shall be able to ensure track heaters are operational
         10. Switch positions and light states shall be displayed to the user
         11. Murphy shall be able to test failure modes including: Broken Rail, Track Circuit Failure, and Power Failure
      4. **Train Controller**
         1. The Train Controller shall receive commanded speed and authority from the Train Model.
         2. The Train Controller shall receive current speed from the Train Model.
         3. The Train Controller shall receive a speed limit from the Train Model.
         4. The Train Controller shall not be able to exceed the commanded speed and authority.
            1. The Train Controller should be able to travel below commanded speed and authority.
         5. The Train Controller shall accept a command setpoint speed for the driver.
            1. The Train Controller shall not act on a given speed that exceeds the commanded speed.
         6. The Train Controller shall calculate and output engine power to the Train Model
            1. The Train Controller shall accept proportional gain and integral gain values from the Train Engineer.

The proportional gain and integral gain values shall not cause the system to become unstable.

* + - 1. The Train Controller shall contain automatic mode and manual mode which can be freely switched to and from by the user.
         1. In automatic mode, all actions are performed solely by the Train Controller. No input from the driver is accepted, unless it is a vital override for the safety of the train. Vital overrides include enabling the emergency brake.
         2. In manual mode, the driver may perform control actions as desired.

It shall be the responsibility of the Train Controller to ensure all actions taken remain vital.

* + - 1. The Train Controller shall initiate the emergency brake on the driver’s input.
    1. **Train Model**
       1. The Train Model shall calculate Newton’s Laws correctly.
          1. For a given commanded power the resulting force shall be applied to reach the desired velocity.
          2. When the service brake is engaged, the correct force shall be applied to achieve the desired velocity.
       2. The Train Model Shall receive commanded authority and speed from the rail signal and communicate it to the Train Controller.
       3. The Train Model Shall receive route information and speed limit from the track beacons and communicate it to the Train Controller.
       4. The Train Model shall receive the state of the left and right doors, the interior and exterior lights, the internal temperature, the announcements, and the driver emergency brake from the Train Controller.
       5. The Train Model shall receive information about the physical world from the track such as grade, elevation, and track circuit state and communicate the circuit state to the Train Controller.
       6. The Train Model shall have three failure modes: Engine Failure, Signal Pickup Failure, and Brake Failure. The state of each it receives from Murphy and communicates it to the Train Controller.
       7. The Train Model Shall receive the emergency brake request from the passenger and communicate it to the Train Controller.
    2. **Track Controller** 
       1. The Track Controller shall receive suggested speed & authority from CTC
       2. The system shall execute a PLC program
          1. The user shall be able to load the PLC program onto the implementation of the Track Controller
          2. The Track Controller shall automatically move switches based on PLC program execution
          3. Track Controller shall automatically set traffic light color (red, yellow, and green) based on PLC program execution
       3. The Track Controller shall receive train presence from Track Model
       4. The Track Controller shall send track occupancy to CTC
       5. The Track Controller shall activate railway crossing lights and gates
       6. The Track Controller shall have both maintenance mode and automatic mode which can be freely switched to and from by the user
          1. In maintenance mode, the user shall be able to manually set a switch position
  1. **Non-Functional Requirements -** Specifications on the system that enable the delivery of functional requirements.
     1. The system shall run as an executable (.exe file) on Windows 10.
     2. Each sub-module shall have a user interface.
     3. Each sub-module shall be delivered as an installable executable.
     4. The whole system shall be delivered as a runnable executable.
     5. For the Track Controller:
        1. The PLC program language for the Track Controller shall be based solely on boolean variables
        2. The Track Controller shall have safety critical architecture
        3. The system functionality shall be implemented in both hardware and software
     6. For the Train Model:
        1. The train shall have a length, height, width, crew count, passenger count, and a mass dependent on the base mass of the train, the crew count, and the passenger count. The train may have more than one car.
     7. All metrics shall be displayed to the user in the imperial format.
  2. **Design Constraints**
     1. Module-to-module communication:
        1. The CTC Office shall only communicate to the Track Controller.
           1. The CTC and Track Controller shall communicate through an ethernet cable
        2. The Track Controller shall only communicate with the CTC Office and Track Model.
        3. The Track Model shall only communicate with the CTC Office, the Track Controller, and the Train Model.
        4. The Train Model shall only communicate with the Train Model, the Track Model, and the Train Controller.
        5. The Train Controller shall only communicate with the Train Model.
     2. The Track Model beacon information shall contain no more than 128 characters
     3. The rate of communication through the rails of the Track Model shall not exceed 3 Baud
     4. Performance - Statistical and qualitative specifications
     5. Data management - Data storage, retention, integrity, access specifications
     6. Design constraints - Customer / user provided constraints
     7. Standards - Industry specific or reporting requirements
     8. System attributes - Reliability, Availability, Security, Maintainability, Portability

1. **Other Requirements**