Train Trax: Train Monitor for Positive Train Control Test Beds

Software Design Specification

# Revision History

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| --- | --- | --- | --- |
| Version | Date | Description | Author |
| 1.0 | 10/25/2015 | Initial Version. Created temporary template for software design specification. | Stephen Jalbert  Rashad Madyun  Corey Sanders |
| 1.1 | 11/9/2015 | Added definitions to document. Updated document with overview information about the system. Updated the Train Navigation Database design section with details of track geometry collection. | Corey Sanders |
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# **1. Introduction**

## 1.1 Purpose of this document

The computer engineering department owns a Positive Train Control Test Bed that is intended to mirror a typical train environment. The purpose of the train track is to be a teaching tool for instructing students on creating safety critical software. It is desired for the department Positive Train Control Test Bed to be able to track the location in for each train for this reason. Like subway trains, the department Positive Train Control Test Bed is completely indoors, so a Global Position System (GPS) is not possible.

The purpose of this document is to describe the design for the Train Trax Train Monitor to assist the department with tracking trains as they move along the Positive Train Control Test Bed. It will cover the design for both the desktop application and the embedded system software.

## 1.2 Scope of the development project

Train Trax's primary purpose is to estimate the position of each train operating along the Positive Train Control Test Bed accurately enough to allow Train Operators schedule trains to run close enough to operation on the same section of track with minimal risk of collision. Additionally, Train Trax provides a means for Train Operators to easily control switches on the train track without the need to using any additional train control software. Train Trax is only a monitor for trains, not train controller software. Train Trax consists of hardware that is equipped onto either the train engine or rail cars to measure train movement, software that will run on existing equipment within the department to graphically display train positions and to control movement. Furthermore, the development team is to assist the department with any modifications necessary to the Positive Train Control Test Bed to support proper operation of Train Trax, including the placement of markers on the track at pre-designated locations.

## 1.3 Definitions, acronyms, and abbreviations

**Positive Train Control Test Bed**

A model train system designed to scale to represent actual railway systems. Its purpose is to facilitate the testing, design, and training of train control systems without the risk of associated performing these activities on live trains, such as bodily injury and costs for scheduling and operating full scale trains.

**Train**

A to-scale model of a commercial train engine. It is the primary vehicle used to move along the test bed.

**Rail Car**  
Simple wheeled container that is attached to the train to carry cargo.

**Track**  
The track is a pair of metal rails that the train runs on top of to move. It provides both power and control signals to the train. It is divided into different physical pieces called sections to simplify its assembly.

**Track Section**

A segment of track that is designed to link with other segments to create the track.

**Track Marker**  
Special hardware placed at different spots on the track to highlight places of interest on the track. Examples of train markers include RFID tags that are read by the train as it moves along the track, and track sections that signal when one or more trains are present.

**Train Controller**

A hardware device that is attached to the track that translates requests from operators to control the train to control signals that the train understands.

**Train Monitor Terminal**

The display equipment, such as a laptop, used by the system visually display to operators information about the test bed.

**Track Switch**Devices on the track to control the direction of train engine movement by changing the sections of track that are connected together.

**Train Operator**

A person or machine that controls one or more of the trains on the Positive Train Control Test Bed.

**Train Technician**

A train technician is a person who maintains the Positive Train Control Test Bed.

**Railway System Owner**

The entity that owns Positive Test Control Test Bed.

**Train Monitor Development Team**

A group of people who have been commissioned by the Railway System Owner to create a system for tracking the movement of trains along the railways system real time.

**Position**

A description of where a given object is located on the Position Train Control Test Bed. It uses a relative coordinate system based on the distance from a fixed point on the table.

## 1.4 References

IEEE Standard 1016: Software Design Specification

## 1.5 Overview of document

The remainder of the SDS will provide an overview of the system architecture and then describe the detailed design of each of the system components.

# **2. System architecture description**

## 2.1 Overview of modules / components

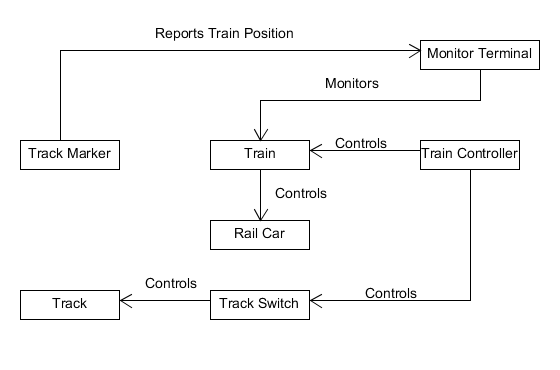
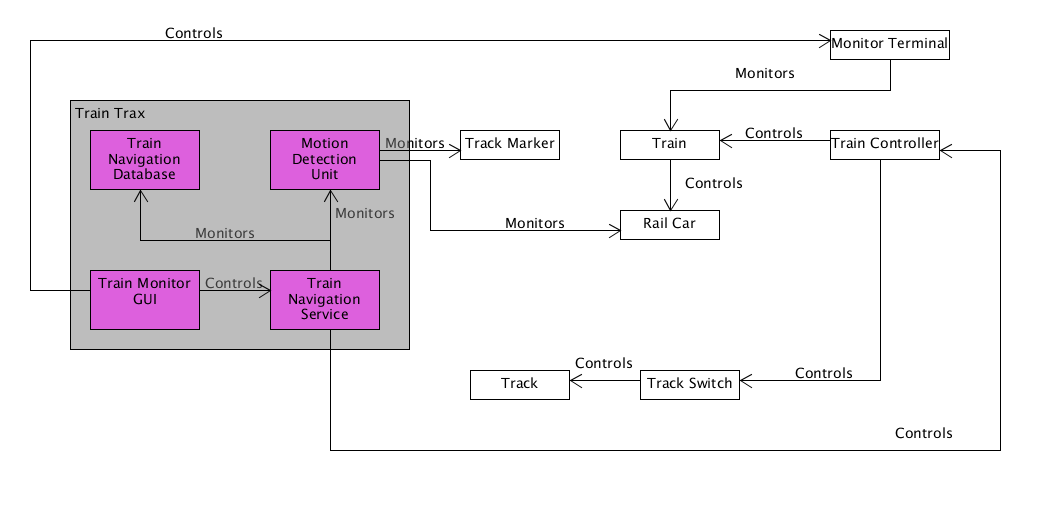


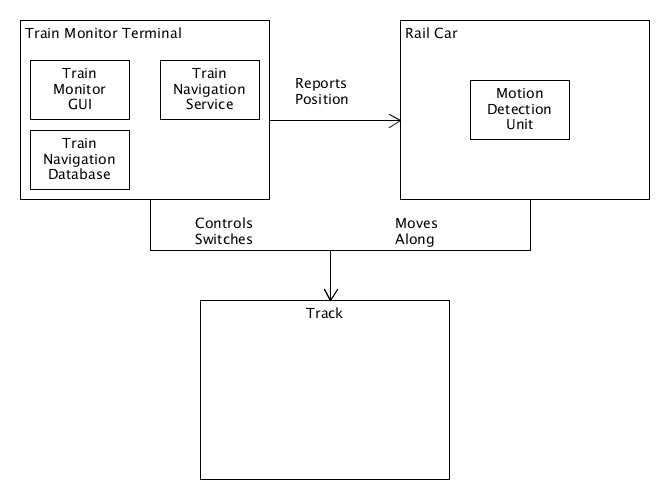
Figure 1 Control Flow of Positive Train Control Test Bed

When the track crosses a track marker, information about the marker that was crossed is relayed to the Monitor Terminal so that it can update the train’s last known position based on the known position of the track marker. Since the rail cars are attached to the train, the train controls where the rail cars move. The Train Controller controls the speed of the train the direction that it moves along the track: either backward or forward. The Train Controller also controls track switches which in turn change the configuration of the track so that the path that the train moves along the track can be controlled. In the existing Positive Train Control Test Bed, Train Markers are actually the sections of track themselves. When a train is on the track, the Train Controller detects the current draw and sends out messaging to report that at least one train is on the section of track.



Control Flow of Train Trax Components with Positive Train Control Test Bed

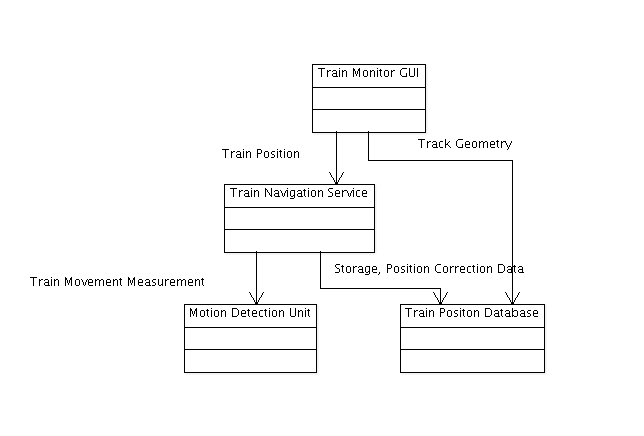
The Train Trax project consists of four top level components: the Motion Detection Unit, Train Navigation Service, Train Navigation Database, Train Monitor Terminal GUI. The Motion Detection Unit is the hardware that is used to measure train movement. It uses sensors to measure acceleration, and orientation of the train as well as crossing of track markers. The Train Navigation Service is a background service that is used to determine the position of each train and to control switches on the track. The Train Navigation Database stores all of the navigation information collected for the track and trains, including details on the geometry of the track (location of switches, sections of track, etc.). The Train Monitor Terminal GUI is the primary display that Train Operators use to interact with the system. It displays the train position of trains on the track and processes requests from users to change track switches.



Placement of System Components Within the Positive Train Control Test Bed

Train Trax integrates into the existing Positive Train Control Test Bed to function. The Train Navigation Service, Train Navigation Database, and Train Monitor GUI operate as software packages that run from the Train Monitor Terminal. They work together to allow the Train Monitor Terminal fulfill its responsibility to track trains and control switches on the track. Since there is very little space on the train engine itself, the movement of the train must be observed through an attached rail car instead. The Motion Detection Unit is equipped onto the Rail Car so that it can measurement movement of the rail car as it moves along the track.

## 2.2 Structure and relationships



**Figure 1 Train Trax system relationships**

The Train Navigation Service depends on the Motion Detection Unit to provide the raw measurements of train movement for the navigation calculations for each train. It also depends on the Train Position Database to save its calculated train position estimates and to lookup the positions of Track Markers. The Train Navigation GUI depends on the Train Position Database to render the history of each train's movement, and for track geometry information, such as the location of switches, track sections, and track markers. The GUI also depends on the Train Navigation Service to control track switches and to determine the current position of each train.

## 2.3 User interface issues

To be added

This section will present the main principles of the product's user interface. Use the personas defined in section 2.1 of your SRS to make specific examples. This section should not touch on technical details. You may want to include sketches and specific text messages.

# **3. Detailed description of components**

## 3.1 Component template description

This section is not part of your design. It is the pattern you will use to describe the components given in subsections 3.2 - 3.n. Each part of the template will be identified by a label. Here in 3.1, you must briefly explain the purpose of each point. To make the presentation clear, use a table or bullet list. You may adapt the template suggested below to your particular needs (although deviations from the suggested template should be minimal and well-motivated).

## 3.2 Motion Detection Unit

## 3.3 Train Navigation Service

## 3.4 Train Navigation Database

Track Geometry Data:

The primary data that is stored in the Train Navigation Database is track geometry information. Track Geometry information is all of the information necessary to describe the shape and size of the track. It also includes a description of all of the relevant points of the track that are essential to making it function, such as identification of sections of track and the location of switches, power junctions, and track markers.

All of this information is necessary for the database to have enough information for the Train Navigation Service to correct its estimates of train positions as they cross track markers. Furthermore, it is necessary so that there is enough information for Train Operators to have context of where each train is located relative to both the track and each other.

Since this data is not already available, part of the design is to collect the track geometry data required for the database.

The sections below describe details on the type of track geometry information collected as well as the process of collecting it.

**Coordinate System**

* Use a relative coordinate system based on the distance from a fixed point on the table. (For example, the bottom left corner of the table can be 0,0).
  + This was selected because if we have this quality of granularity in measurement. We can still choose to relay the location of the train according to a grid if needed to simplify the problem, but we cannot get further accuracy if all that we collected was grid information.

**Type of Data to Collect**

* Angle of Train from bottom corner of table
* Section of track
* Nearest junction
* Position within track
* Position
* Segments that a junction joins

**Train Geometry Collection Procedure**

Before you start geometry collection, partition the table into 4 sections along the length of the table where the Test Bed is located. Each section will be a phase of where data is collected. This intended to reduce the amount of work necessary for data collection at any one time, and to give us the opportunity to refine the geometry collection procedure before all of the table has been measured.

Tools

* Spreadsheet
  + Used to record the measurement data
* 3 Laser Range Finders
  + Position Measurement
* 3 Pedestals
  + Placement of Laser Range Finders
  + Ensures that Range Finders are High enough to avoid any interference from objects on the track.
* Fabric Tape Measure
* Measurement Rail Car
  + Rail car that has been fitted with two polls each with a marker on the top that is easy for the range finders to align and measure.
    - We need two markers so that we can estimate the orientation of the rail car.

**Setup**

* Divide table into 4 Regions Along the Length of the Table
* Mark the Beginning and End of Each Region
* Place RFID Tags On Each End of Each Section of Track that is within the region.
  + If there is a section of track that overlaps regions. Only add a tag for the end is with the region.
  + If there happens to be an end that overlaps the region of interest and another region, proceed with adding the tag.
* Select the Corner of the table that will be the origin of the coordinate system.
  + It is recommend to the bottom left corner so that all measurements are positive.
* Place pedestals on the corners of the table that are not the origin.
  + Pedestals are selected because the laser range finders must be level and they need to be high enough for us to be able to measured positions on the track without any risk of interference from objects on the train track.
* Mark on each pedestal. This will be the point where laser range finders will measure from.
  + It is recommended that you try to mark points as close to the table as possible.
* With the fabric tape measure, measure the distance from the origin of each of the measuring points.
  + You can also use a one of the laser range finders to measure distance at that point as well if desired.
  + This is necessary to make any last adjustments.
* Select one of the markers on the measurement rail car to be the primary marker.
  + The primary marker is the marker that is always aligned with the position of the object of interest when measuring.

**Procedure for a Given Partition of the Test Bed**

When searching for an object of interest that has not been measured yet, search from top-to-down and from left-to-right. The x-axis is the edge of the table that is along the length of the table and touches the origin. The y-axis is the edge of the table that is along the width of the table and touches the origin.

**Measuring the Position of an Object on the Track**

* Place or locate the object on the track that you want to measure.
* With the fabric tape measure, measure the distance from the object to the edge of the table that is perpendicular to the x-axis.
* With the fabric tape measure, measure the distance from the object to the edge of the table that is perpendicular to the y-axis.
* Move the measurement rail car into position so that the primary measurement marker of the car is aligned with the position on the track that is closest to the object of interest.
* Adjust the laser range finders on each pedestal so that the finders can measure the distance from the pedestal measurement point to a given measurement rail car measurement marker.
* Record the measurements of the distance from each range finder for each rail car measurement marker.
* Record the section of track that the object belongs to.
* If not already recorded, record the junctions that connect to the section of track.
* If not already recorded, record the two sections of track that are adjacent to the section of track that the object of interest is on.
* If measuring a RFID tag, record the end of the track section that it belongs to by recording the junction that it is closes to.
  + In the event, that the tag is not on an end of the track, record ‘NA’ so that it is known to be not be an end.

**Objects to Measure**

* RFID Tags
* Switches
* Junctions

NOTE: If we record just these things, then we know exactly where each section of track begins/ends. So we can use our train position data to estimate the geometry of each section of track when we begin position estimation.

## 3.5 Train Monitor Terminal GUI

These sections should contain design information for each component. Table included after appendices details contents.

# **4.0 Reuse and relationships to other products**

All software for the Train Trax project will be new development and no reuse will occur.

# **5.0 Design decisions and tradeoffs**

Use this section to motivate any decisions that will help the reader understand the design that your team is using. This section can also capture good ideas that were abandoned and the reasons for leaving them out of the design.

# **6.0 Pseudo code for components**

To be added as developed

# **7.0 Appendices**

To be added as necessary

Content guide for section 3.X (Table to be removed on document completion)

|  |  |
| --- | --- |
| Identification | The unique name for the component and the location of the  component in the system. |
| Type | A module, a subprogram, a data file, a control procedure, a class, etc |
| Purpose | Function and performance requirements implemented by the design component, including derived requirements. Derived requirements are not explicitly stated in the SRS, but are implied or adjunct to formally stated SDS requirements. |
| Function | What the component does, the transformation process, the specific inputs that are processed, the algorithms that are used, the outputs that are produced, where the data items are stored, and which data items are modified. |
| Subordinates | The internal structure of the component, the constituents of the component, and the functional requirements satisfied by each part. |
| Dependencies | How the component's function and performance relate to other  components. How this component is used by other components. The other components that use this component. Interaction details such as timing, interaction conditions (such as order of execution and data sharing), and responsibility for creation, duplication, use, storage, and elimination of components. |
| Interfaces | Detailed descriptions of all external and internal interfaces as well as of any mechanisms for communicating through messages, parameters, or common data areas. All error messages and error codes should be identified. All screen formats, interactive messages, and other user interface components (originally defined in the SRS) should be given here. |
| Resources | A complete description of all resources (hardware or software) external to the component but required to carry out its functions. Some examples are CPU execution time, memory (primary, secondary, or archival), buffers, I/O channels, plotters, printers, math libraries, hardware registers, interrupt structures, and system services. |
| Processing | The full description of the functions presented in the Function subsection. Pseudocode can be used to document algorithms, equations, and logic. |
| Data | For the data internal to the component, describes the representation method, initial values, use, semantics, and format. This information will probably be recorded in the data dictionary. |