Revision History
09/29/15
09/30/15
10/3/15
10/4/15
10/7/15
10/22/15
12/04/15: Added History of Dates where document was modified.

Problem
In a real-word train environment, trains often carry very valuable assets: people, oil, merchandise, etc. It is important for railway system to be able to track the location of each train in order to prevent collisions and to monitor the state of trains in the event of attack.

Vision:
The purpose of this project is to develop a system that can pinpoint the exact location of each train in the rail system so that trains can follow each other closely enough that they may operate on the same track segment.

Existing System:
The current system, including the train set, can only detect if one or more trains are on a particular segment of track. This limits the efficiency of the use of the railway since the system must ensure that only one train can ever be on one particular segment of track at any time. The railway system in the lab has been fitted with a system, that can track each train and determine it's location by track. It uses a MySQL database that is hosted on a test machine outside of the lab. It, however, only has connectivity information how the track is organized. Data from the IMU car and information from the connectivity database are used to determine the train location. As with all IMUs, the information provided by it drifts and becomes increasingly less accurate over time. The particular IMU in the train car is noisy enough that after a few minutes of operation, the location of the car can only be reckoned to a general area (within a few inches instead of within a few centimeters). At it's best, it has been reported by the customer (Dr. Kulick) that the location of the train could be determined within 0.5 centimeters. The primary board of navigation system is a custom board, and it operates off o nof a 9 V battery that is housed inside of the train car. The navigation system is able to operate for about 30 minutes using this battery. An ArduIMUv3 hardware module is the acting IMU for this system. Wireless communication from the train to Train Monitor Terminal is accomplished using Zigbee. Off the shelf, XBee modules were chosen for implementing ZigBee support.

Stakeholders
- Train Operator
    - A train operator is a person or machine that controls one or more of the trains on the Positive Train Control Test Bed. The operator's primary responsibility is to

ensure that trains reach their destination in a timely manner and to prevent collisions with other trains.

- Train Technician
  - A train technician is a person who maintains the Positive Train Control Test Bed. The technician ensures that the train track is in a state for trains to operation along and that trains are in a state to be able to move along the track and be controlled by train operators.
- Railway System Owner (UAH CPE Department)
  - A railway system owner is the entity that owns Positive Test Control Test Bed. The owner is responsible for providing all of the resources necessary for the Positive Train Control Test Bed to operate. This includes assigning and providing resources for Train Operators and Train Technicians.
- Train Monitor Development Team
  - The Train Monitor Development Team is 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.

Actors

- Train Operator

Use case

- Monitor train
- Control switches on the Track
- Learn geometry of railway
- Detect movement of location markers

Monitor Train

Assumption: Train Database already has information about all of the train markers on the test bed.

Assumption: Train is already moving

A Train Operator is currently controlling a moving train. While the train is moving, the Train Operator launches the Train Monitor GUI from the Train Monitor Terminal to find the current location of the train that he/she is controlling. When the GUI launches, the layout of the track is displayed, including icons of all of the switches that are apart of the track. Also on the display is an icon that represents the current position of the train on the train track. It also displays the current speed of the train.

Exception (Estimate of position is calculated to be too inaccurate):

When the GUI launches, the layout of the track is displayed, including icons of all of the switches that are apart of the track. Also on the display is an icon that represents the current position of the train on the train track. The icon is highlighted to indicate that there is some kind of error with the train. Also on the display is text that reports that there is a failure to determine the current position of the train with details on the nature of the failure.

Control Track Switch
Assumption: Train Database already has information about all of the switches on the test bed. Train Database already has information about the geometry of the train track.

A Train Operator, Ned, wants to configure the switches on the track for an upcoming train departure. Ned launches the Train Monitor GUI from the Train Monitor Terminal. The layout of the track is displayed, including icons of all of the switches that are apart of the track. Each switch icon displays the current state of the switch that it represents.Ned then presses on a track switch icon that corresponds to the switch that he wants to change. The GUI acknowledges immediately that the icon has been pressed. When the switch change has been completed, the switch icon is updated to reflect the new state of the switch.

Exception (Failure to send switch change to Train Controller):
After Ned presses the switch, the switch icon is highlighted to indicate that there is some kind of error with the switch. From the display, Ned can see an alert that reports that there was a failure with the request to change the switch with details on the nature of the failure.

Record Track Geometry
Assumption: Train Database already has information about all of the train markers on the test bed.
Assumption: No trains are moving on the track.
Assumption: A single train is placed on a known position of the track.
Assumption: Track has been preconfigured to navigate one of the loops of the track.

A Train Technician, Bob, has been tasked to configure Train Trax to work with Positive Train Control Test Bed that he is responsible for maintaining. Bob launches the Train Monitor GUI from the Train Monitor Terminal. From the display, he chooses the ‘Discover Track Layout’ option from the menu. The GUI then prompts Bob for the current position of the test train on the track. Bob enters the location of the test train. Next, the GUI shows a window with a button that says ‘Start Recording Layout’. Bob presses the button and the button toggles to say ‘Stop Recording Layout’. Then, Bob starts the train with commands to the Train Controller. The train begins to move along the track. As the train moves along the track, the Train Monitor Terminal begins to display a line showing the path that the train has moved along. Once the train completes moving along the entire loop, a prompt appears on the terminal asking if the the user is done recording the train layout. Ned selects yes. The display then asks for a name to associated with the layout. Ned fills in the name.
Exit: ‘Save Track Geometry’ Use Case

Exception (Loss of Contract with Train) Use Case: While the train is moving, communication is lost with the Motion Detection Unit. The Train Monitor GUI displays a prompt explaining that communication has been lost with the train. Ned acknowledges the prompt then the GUI displays another prompt asking if he/she wants to save the existing layout or abort. Ned chooses to abort, and the GUI is returned to the main screen without any changes to the layouts displayed.

Alternate Flow:
While the train is moving, communication is lost with the Motion Detection Unit. The Train Monitor GUI displays a prompt explaining that communication has been lost with the train. Ned acknowledges the prompt then the GUI displays another prompt asking if he/she wants to save the existing layout or abort. Ned chooses to save, and 'Save Track Geometry' Use Case is performed.

Save Track Geometry
Assumption: A train layout has already been created from performing the 'Record Track Geometry' Use Case

The Train Monitor GUI places a prompt to determine whether he/she wants to save the layout. Ned selects yes. The display then acknowledges that the route is saved. The layout is now setup to be included in the display of layouts on the main screen.

Alternate Flow:
The display then asks for a name to associated with the layout. Ned fills in the name. Then the display places another prompt to determine whether he/she wants to save the layout. Ned selects no. The recorded layout is discarded. The display then returns to the main screen without any changes to the layouts displayed.

Exit: 'Repeat Track Layout Recording' Use Case

Repeat Track Layout Recording
The Train Monitor GUI presents a prompt asking whether another layout is desired to be recorded. Ned then answers no. The display then returns to the main screen.

Alternate Flow:
The Train Monitor GUI presents a prompt asking whether another layout is desired to be recorded. Ned then answers yes. The 'Record Track Geometry' Use Case is performed.

Prior Art to Look for Inspiration:

- The Existing Train System for the Model Train Railway
- Existing Train Navigation Systems for Model and Full-Size Trains
- GPS Navigation Systems
- UAV Navigation Systems
- Automotive Navigation Systems

Expected Features

- Report the current position of each train on the rail system.
- Report the history of each train's movements along the rail system.
- Control switches on the rail system.
- Collect information to describe the shape and geometry of the track.
- Collect raw measurements used to estimate each train's position.
- Alert when trains are too close together.
- Alert when there is a system failure.

Tools

- Word (Primary tool for creating documentation such as the test plan, test description document, requirements specification, and design document)
- Eclipse (Used for developing the software)
- Jet Brains You Track (Project Tracking, Configuration Management?)
- Git Hub (Version Control, Configuration Management?)
- Automated test framework like junit
- Continuous integration framework like Jenkins or Team City

Equipment

- Hardware for the project will be provided.
- Additional hardware may be provided to allow for remotely working.

Train Lab

- The team now has access to the train lab.
- Currently 24/7 access with keycode or UAH card
    - Access at some point will change to only within the hours of operation of the school (business hours)

Train Lab Computers:

- HP Tablet
    - No special credentials required.
    - Nothing has been done with it.
    - HP All-In-One
    - Runs Android
    - Made in dec 2013
    - Serial Number: Liz111
    - Model: Ep219ap
    - HP Slate 21
- Linux Boxes
    - Have a standard unix account.
    - Can be requested at http://labs.ece.uah.edu
- Windows Boxes
    - Standard ECE Department account
    - Contact Jason Winningham if you don't have access

Train Control Software:

- JMRI
    - http://jmri.sourceforge.net/

Matlab

- Available on Windows Machines
- Older version is available on Linux Machines
    - Version was defunded, so it may not be very useful if we require any add-ons or newer capabilities.

Purchased RFID Products

- RFID Reader
    - https://www.sparkfun.com/products/11827
- RFID tags
    - https://www.sparkfun.com/products/9416

Model Trains and Rail Cars

- All should be located in the lab.
- Any that are not in the lab on on a wheel cart in room EB209.
- http://modeltrains.about.com/od/operatingmodeltrains/a/Scale-Speed-For-Model-Trains.htm
- Rail Cars that are 1.5 times longer than normal have been purchased
    - They are rated for a maximum of 15 degree turns.
        - Since, there are some 20 degree turns on the track, this means that there are some portions of the track that the car may not be able to traverse.
    - They are flat and metal.
    - Should be long enough for the IMU, RFID Reader, and any additional Motion Detection Unit hardware to fit together on a single car.

Equipment Available For Team to Use:

Measurement devices (obtained from home depot)
Ryobi Phone Works Laser Distance Measurer (Rated at 1/16th of an inch)
- Can be used to measure devices and record it to iPhone or Android.
- Creates a new file for each measurement

Bosch GLM 30 Laser Measure
- (Rated at 1/16 th of an inch)
- 5 mW Laser

Approx 10 Rechargeable 9V batteries are available.

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Power Sources

- Approx 10 Rechargeable 9V batteries are available.

Detailed System Information

Train Track Geometry

- https://en.wikipedia.org/wiki/Track_geometry
- The geometry data is needed because it is desired to setup the system to have trains following closely together on the rail system.
    - Close enough that they can be operating on the same section of track. [Implied with minimum risk of collision]
- Must identify areas where two train segments meet
- Must identify where rail switches are located.
- Must know geometry of individual tracks
    - Must know at least the info for the ones long enough for multiple trains to run along.
- Must collect enough information to render the entire rail system.
- Connectivity information is available with the database for the existing train monitor system.
    - Mentioned that the data could easily be recreated with the work necessary to collect geometry data.
    - To measure position, we can create an app to record measurements and have prenumbered label to mark RFID positions
    - Place command strips on rail car
    - Fix card board to car for measurement
    - Draw marker to target measurement on card board
    - Adhere clip to measurer
    - Create rod that can be attached to table
        - Be sure that rod can swivel from table attachment
    - Screw plate to rod
    - Attach measurer clip to rod

Train Collision Prevention

- The train monitor needs to work well enough for train controllers to move train on the same track accurately enough for them to prevent collisions.
    - Customer estimated that at least 1-2 centimeters of separation between the trains must be maintained.

RFID Tags

- It is acceptable to have multiple tags on a track section.
- Customer is willing to acquire more RFID tags.
- Confirmed that RFID tags are intended to be used to correct IMU data than to be used to determine the position of the train at any time.
- It is desired to know what section of track that it belongs to.
- Position of tag can also be used to validate the orientation of the train since it is bound to track.

- The development team is responsible for determining the placement of RFID tags on the track.
  - We need to have justification for placement of RFID tags. (It is acceptable for the reasoning to be obtained experimentally).
- Approximately 128 tags are available
- Each already programmed with a unique ID.
- The RFIDs are small cylinders that may be placed flat so that the base of the cylinder is centered between both rails.
  - It has been confirmed that 2 RFIDs can be placed along two parallel sections of track without any crosstalk issues.
- These RFIDs are typically used for identify pets (i.e. dog chips).
- The RFIDs have a range of about 2 cm.
- The tags should be able to be attached to the track using clear glue.

Motivations for Project

- A far reaching goal would be for the train to operate without the need of any wiring.
  - This includes wireless determination of position of the train as a first stage.
  - The next stage is wireless control of the train.
  - This include running the train on an alternative power source, such as hydrogen fuel cells.

Train System Configurations

- The only required configuration for the train is where there is a train engine and a single rail car.

Placement of Motion Detection Unit

- The hardware for the navigation system is allowed to be seated vertically within the sensor car.
  - It can be taller than the car as long as it can securely fit within the car and the train can continue to be moved.
- The hardware can span multiple cars.
  - However it is strongly encouraged that a single car be used as stabilizing multiple cars so that they do not affect inertial measurements and train movement across the track is very challenging.
  - Also, synchronizing setting and resetting cars multiple cars onto the track to set up the system is problematic.

Error Notifications

- Users of the system must be notified if the error in position calculations exceeds defined tolerances.

Design Constraints

- Magnetometers cannot be used to assist in determining the location of the train because there is a lot of electromagnetic interference from the powered rails of the system and from the building.

- GPS cannot be used to determine the location of the rail system because it is entirely indoors.

Assumptions

- The system needs to be able to estimate the position of the train at least within inches so that we can measure if one train is close enough to another train to be able to be on the same section of track.
    - Based on customer estimate of the longest section of track being about 14 inches.
        - Feet or Meters would not precise enough.
        - Centimeters are more precise than inches.
- Assuming that a train tested on the Test Bed does not represent a train that can move faster than 200 mph.
- TODO: Measure the curvature of the Positive Test Bed so we can estimate the maximum rad/sec that the train will experience. A ball park estimate is the train taking 3 seconds to move along a 90 degree turn. That amounts to 0.5 radians per second when it is operating near top speed (typical). (This means that we really want at least 0.01 radians per second precision, but not likely to get from gyroscope)

Train Position Measurement

- System must persist train position measurements.
- Accuracy should be within a segment of track.
    - The longest train track is approximately 14 inches long.
        - This means that the system needs to be able to estimate within inches to be able to verify this.
- Elevation of the train does not need to be calculated.
- Only the 2-dimensional position on the table is required.
- Although not required, 3-dimensional positional data was expressed as a bonus that would aid in future layouts for the model train railway system.
- Targeting for 100 HZ for the sampling rate of both the accelerometers and gyroscopes.

System Inertial Motion Unit (IMU)

- The IMU needs to be configured to measure acceleration within 2 g's worth of force.
    - The train cannot generate more than that.
- It is recommended that the accelerometers selected for the IMU be very sensitive to force less than or equal to 2 g.
    - The existing system experienced a lot of noise with their measurements of train movement
- Any IMU package can be used as long as it fits within a train car.
- Reusing software for communication with the existing IMU was not recommended because it was hastily created by the team that created the last monitor system.
- Arduimuv3 is the IMU for the existing system.

Train Monitor Display

- There needs to be a visualization of the position of the train relative to railway system.
    - In other words, a user should be able to see exactly where on the track a train is located.
- The customer did not express any preference on how it was visualized.
- It was mentioned that the UI can be simply as representing the track as a series of curves and that the position of the train can be a bold point on that curve. (Ex. If the train track were a single loop, then the track would be a circle, and the train would be a bold point on it).

Reading RFID Tags

- Consider having multiple RFID readers to measure latency of RFID read
- The original proof-of-concept work that was conducted by Dr. Kulick and Jason Winningham was demonstrated by having the RFID reader tied to USB then tied to a Computer.
- We need to determine the response time of the reader. (i.e. how long it takes between an object being in position to be read by the RFID reader and the reader reporting that the tag has been read)

Testing Train Monitor System

- Not expected for code coverage of libraries.
- He is fine with covering methods invoked on remote machine.
- Recording of system input is acceptable but is extra work.
- Full Statement coverage and branch coverage required.
- Junit can be used potentially for unit testing.
- Suggested Code coverage tools
    - http://sourceforge.net/projects/codecover/
    - EclEmma suggested in class
- Use TeamCity to implement continuous integration
- Determine that the system can operate in an asynchronous mode.
- Include in test plan handling of ranges of input
- Include in test plan scenarios to address risks of the system.
- If code is not covered in a place, we must provide a justification.
- The purpose of the test plan is to demonstrate that we thought about what could go wrong and that we have a way to test it.

Problem Domain:

Train Control Software

- Control software is called JMRI. Open Source.
    - http://jmri.sourceforge.net/
- Train is marked as occupied if power is lost for safety.
- Multiple trains can be linked to throttle with JMRI.
- Monitor Loconet window in JMRI is a loconet sniffer UI.
- JMRI does not have a display to show the position of the train.
    - An image (not to scale) of the train track is loaded in a separate window to help with tracking.

Train Track

The purpose of the train track is to be a teaching tool for instructing students on creating safety critical software. The train track consists of approximately 120 segments of track (rough estimate from observation). According to Dr. Kulick, the maximum length of a segment of track is about 14 inches. There are two completely independent track routes in the set. One set is intended to be an alternate route where a train can potentially circle the entire area of the set indefinitely.

There are several switch on the track that are daisy chained together through an Ethernet-like protocol called (LocoNet) to a controller accepts instructions through USB and forwards necessary traffic to switches. Switches have two modes: pass (normal) and bypass (alternate route). The controller forwards all traffic that is not for any of the train switches to the track controllers which simultaneously send the data to the entire train track so that any trains that are on the track can receive the data. The encoding for this data is the Digital Command Control (DCC) protocol. This is the same protocol being used on modern trains today. Each train is designated a unique Id and listens only to data associated with that ID.

There are approximately four trains that are available for the track. Trains come in two models: modern electric and steam. The characteristics of how quickly the trains move and respond to change instructions vary by model. For example, the steam locomotive will take longer to accelerate than the electric locomotive. When rounding curves of the track, no more than approximately 0.2 g is experienced on the trains as they round corners around the track. The maximum amount of force that will be experience by the train is 1 g.

Several train cars have been equipped with sensors. One car has been equipped with an Inertial Motion Unit(IMU) that measures up to 8 g of acceleration. Collected IMU data relayed from a controller in the car and sent across radio to another controller that sends the data to a PC. Both the IMU board/radio controller and the PC radio controller are off-the-shelf boards, likely purchased from SparkFun. Another car has been fitted with an RFID reader. It uses USB and was wired to the PC for the initial evaluation. A tie sensor is also attached to the IMU car. The tie sensory in theory can be used to estimate speed by counting the number of revolutions that the train wheels in a given period of time. However, the tie sensor is only reliable for areas within a track segment. When the train hits a switch over or bump, the readings get skewed.

RFID tags are available to be placed on the track. Approximately 128 tags are available, each already programmed with a unique ID. The RFIDs are small cylinders that may be placed flat so that the base of the cylinder is centered between both rails. These RFIDs are typically used for identify pets (i.e. dog chips). The RFIDs have a range of about 2 cm. It has been confirmed that 2 RFIDs can be placed along two parallel sections of track without any crosstalk issues. The original proof-of-concept work that was conducted by Dr. Kulick and Jason Winningham was demonstrated by having the RFID reader tied to USB then tied to a Computer. From the experiment, it was determined that when the tags are placed so that they are perpendicular to the rails, a lot of cross-talk is experienced. However, when the tags are aligned parallel to the rails and positioned in the center of the track, there is minimal cross-talk. It is suggested that clear glue be used to permanently attach tags to the track.

Jason Winningham is available for additional questions about the structure of the train track and to assist with any changes to the track or train equipment.
Access to the train system is presently 24/7 provided that you have the keycode or a card. In the near future, the locks in the building will be upgraded and the hours that the system is available will be reduced. The train system should always be available at least during the hours of operation of the building (I think that's the same as normal business hours)
Power can be drawn from the rail system, however there are segments of track where power is not provided. Additionally, there are scenarios where during the operation of the track power is lost. It is recommended to use a super capacitor or some other means of backup power to provide power to the system to protect against power loss. Rechargeable 9V batteries are available for use as an alternative power source.
When setting up the system, each rail car must be set onto the track and reset in order to be used. The standard rail car size is approximately 10 ft x 90 ft. Using the HO scale, this is equivalent to 3.5 cm x 31.5 cm for a model rail car. Rails cars are also available that have no ceiling.

Train Track (Positive Train Control Test Bed)

- Approximately 120 sections of track
  - 4-8 sections of the track in the system are long enough to support multiple trains.
  - Maximum length of a section of track is 14 inches.
- 30-31 switch junctions in the system
- Typically use a joiner for power between the two track sections.
  - Furthest separation between two adjacent sections of track is 2 inches
- Switches are turn right only.
- Inter Urban and Mainline tracks of rail system are independent in rail system except for 4 junctions.
- Yellow tape is used to mark different power sections of the rail system.
- Engines are controlled through a single train controller unit that takes control requests and converts them into Digital Command Control (DCC) signals.
- Communication with the train controller including train engine control requests use the LocoNet Protocol, which is transported across using Ethernet transport.
  - There can only be one train controller in use by the track at any one time.
- Two Models of Engines Used
  - Modern Electric and Steam
- There is a safety relay that switches power off to the track.
  - Current safety system is being overridden so we don't have to worry about for our testing.
  - Used by scheduler to prevent collisions
- There is a unit that detects when polarity is about to be reversed on track and corrects by reversing polarity on the track.
- Trains are currently controlled through command line entry from the train control software: JMRI.

Train Engine

- DCC Signalling is what is used to control the train.
  - DCC Decoder is equipped on the locomotive
    - Looks like a stick of gum.
    - Located at the top of the engine.
  - Signalling works through coding of electric signals from the rails.
  - Control signals are sent simultaneously to the entire rail system

        - Each engine is assigned a unique ID to allow it to discriminate message intended for it versus any other train.
- Train engine gets power from the rails.
- Model locomotives cost $50
- The maximum amount of force that can be experience by one of the model engines is 1 g.
- Rails are how train gets its power.
    - One rail is positive charge, while another rail is negative.

Rail Systems (In General)
- Trains systems are supposed to have no more than 5 degree slope.
- Switches are turn right only.
    - They have two modes: Pass (Normal) and ByPass (Alternate)
- There is no feedback from the switches for what their state is.

Rail Cars (Model Cars)
- Standard Rail car is 3.5 cm x 31.5 cm
- Approximate measurement taken for the current IMU car is 6" x 1 3/8th".
- Model train cars cost $10
- Test Rail Car Exists with an ArduIMUv3 already equipped on it programmed to report from the car via Zigbee
- Test Rail Car Exists with a RFID Reader already equipped.

Expenses
- Model locomotives cost $50
- Model train cars cost $10

Purchases
- Train store in Birmingham is where they buy supplies.

System Features

Customer Expectations for Team and System
- We need the information that a scheduler needs to have multiple trains on a block.
    - Distance down the track that a train is located would be 'ideal'.
- Team will need to provide a way to identify the cars so that we ensure the pairing of the system.
- System needs to operate for when the train is moving both forward and in reverse.
- System needs to estimate the current speed of the train.
- System must be able to have two trains passing each other and it continue to operate.
- No commands are expected to be issued by the navigation system to communicate with the train.
- Visual Display of the Position of Each Train on the Train Track.
    - UI doesn't have to be a tablet.
- Use as much off-the-shelf as possible. It is desired for our project to be able to be reproducible by other organizations.
- Plans to use the existing display to control train and a separate display(ours) to monitor train positions.
- Wants to be able to switches using a single action or ‘touch’ through our display.
    - Needs to be easier than typing in a switch number to control the switching.
    - Current method being used involves typing in a command from the train control software: JMRI.
- Notification of any error in determining the position of the train.
- System must continue to be working even if there are small power disruptions to the rail system power.

Customer Extras Desired for the system

- Notification of when a train is approaching a switch.
- Mobile Support for the Train Monitor Display
- Notification if two trains are too close to each other and in danger of collision.
- Reporting elevation changes of trains
- Extending our solution to support two IMUs being used instead of one to resolve the location of the train.

Prototyping:

- Create a test track where the geometry and the length of the track is already known. Use this as a basis.
    - Use a test train to navigate the track and evaluate it's report of the geometry of the track against the known data. (I recommend that for this experiment we do a circle or a line. Something very simple. (A circle clearly demonstrates x & y, Move to a figure 8 if successful.)

- Use a straight line of track and collect multiple measurements and determine the average amount of error for a fixed distance and fixed time. (If difficult, do a fixed time, and record the final distance each iteration)
- The Nexus 7 has both an accelerometer and a gyroscope. Use data collected from Nexus 7 to conduct experiments previously described and evaluate its performance. It will likely be not precise enough for the track, but it will help test IMU algorithm.
- Collect data to store, then use matlab to test algorithm before implementing

Analysis Models

System Level Entities

- Train
- Train Markers
- Train Track Segments
- Train Monitor Terminal
- Motion Detection Unit

Train Monitor System Entities

- Motion Detection Unit
- Train Navigation Library
- Navigation Database
- Train Monitor Display

Glossary

Railway system = "Positive Train Control Test Bed"
Locomotives themselves have identifications on them, but not the cars.
train car = 'railroad car'
track segment = 'track section'

Motion Detection Unit = hardware provided by the system to measure how an object moves in two dimensional or three dimensional space.
DCC = Digital Command Control protocol which is a electric signaling protocol used to control train engines on a train track through the rails.

Outstanding Concerns / Questions

- What is the minimum resolution that is suitable for finding the train? Within a 7 inch radius? If not, why?
- What are the conditions that the safety relay on the system is triggered when enabled?

Action Items

- Ask about status of getting old system database.
- Double check bandwidth requirements for sampling.
- Ask again about loconet sniff for switch control.
- Ask Dr. Kulick for feedback on testing train movement

Search Terms

Coriolanus Force
Strapdown IMU
Strapdown Inertial Navigation Technology, 2nd Edition

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