"We pledge our honor that we have abided by the Stevens Honor System."

CS 347: SOFTWARE DEVELOPMENT PROCESS
INTERNET OF THINGS:

HUGS THE RAIL

The Little Engineers That Could

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1: INTRODUCTION

Locomotives used by Hugs the Rails should aim to get every package onboard as quickly and efficiently as possible so that the people and companies can get to their parcels in a timely manner. They should also be ensured that all systems are updated for their safety alongside the new protocols.

1.1 PROBLEM STATEMENT

Currently, the train system involved with the Hugs the Rail system is completely reliant on the internet and network connection it has. If a scenario occurred where the internet / network connection was lost, however, the trains would be lost with no idea on where to go or what to do incase of an emergency. This is precisely the problem at hand. The Hugs the Rail system will implement sensors into these trains, which function locally, not relying on a network connection with the outside world, so that the trains will function in a scenario where there is no possible way to connect to the internet.

1.2 PURPOSE

Internet of Things: Hugs The Rail is a project that will produce a product to railroad users and supporters to enhance the ride. These changes will include being able to make decisions locally in absence of cellular and wifi connectivity back the offices, being able to capture data from the locomotives and its surrounding environment, issuing an analytic engine on board to process as much information to safely guide passengers as well as the conductor on their destination, make decision that is passed on the locomotive control system, providing room for the operator to enter commands to receive status, and the ability to download the latest rules from the cloud into the engine. The Little Engineers That Could, Team Eight is a talented team filled with curiosity, structured by organized members, and constructed with knowledge to perform these tasks.

2: OVERVIEW

An important fact to note in regards to the Internet of Things / Hug the Rail project is that the trains involved depend on a wireless / cellular network to receive live data about the environment around them and their surrounding traffic. While we don't want the train to lose connection to the internet, there are sometimes unexpected problems that occur resulting in a loss of connectivity from the train to the rest of the world. When this happens, the trains need to have a fallback in order to operate safely in a local setting. To understand how the trains operate locally, it's important to understand and have knowledge of potential hazards the train could face.

2.1 PROCESS MODEL

Umbrella OR WaterFall OR Unified

2.2 TIMELINE

Event	Deadline
Template	02/16/2020
Choose Process Model	02/16/2020
Planning	02/25/2020
Modeling	02/28/2020
Construction / Testing / Prototypes (?)	03/29/2020
Deployment	03/30/2020
Software Increment	--

2.3 ROLES

We have a talented team of individuals, each with a background and drive to succeed in the computer science field. With our combined experiences and effort, our project will get off the ground and onto the rails with no problem.

Name	Role	Responsibilities
Cindy	Member / Developer	Complete Task, Communicate, Address Problems If Needed, Organize
Jack	Leader / Developer	Complete Task, Communicate, Initiate Motivation, Making sure we meet our deadlines.
Hao	Member / Developer	Complete Task, Communicate, Address Problems If Needed
Peter	Member / Developer	Complete Task, Communicate, Address Problems If Needed

2.4 PROBLEMS

Trains can face a number of unexpected problems when being used on railroads:

- Some of these problems have to do with the weather. Various weather conditions can cause trains to slow down or completely stop altogether. These weather conditions in particular include snow, rain, or ice on the track. While one would think an operator could see these conditions themselves, there is a slight possibility that it could be something like black ice, or the conductor could just be distracted. That's why it's important we have sensors to check for these conditions.
- Other hazardous conditions could be an object or animal on the rail, or even hanging above the rail, having a potential to fall onto the train / train track.
- High wind is also a very dangerous hazard, as it could cause the train's speed to alter from its normal trajectory.
- The last important hazard to realize is other trains themselves on the track. These are a *very* dangerous hazard, as if another train is not sensed on the rails, a horrible accident could occur, causing the train to derail and hurt other people involved in the ride.

Because of these hazards, it's important to have sensors that check for these problems.

2.5 EXTERNAL SENSORS

Outside of the locomotive are some unpredictable objects. That's why IoT can help us "see" these problems that the train could potentially run into. A locomotive has a cab also known as the driver's compartment. This part of the train is the control room. Establishing sensors and connecting them to the control room can help the engineer (train drive) to know what is going on. Having proximity sensors can detect motions between each train as well as if the train could approach some unknown object. Proximity sensors usually emit electromagnetic fields or beams of radiation such as infrared. Another sensor are level sensors, as the name in the title, level sensors are used to detect the level of substances including liquids, powders and granular material. This can help with detecting the surroundings and help what could possibly happen but easily avoidable. Gyroscope sensors measure the angular rate or velocity. This can stabilize the locomotive to ensure a safe ride to go fast but not too fast.

2.6 INTERNAL SENSORS

Inside of the locomotive is just as dangerous when it comes to unpredictability. Just as a computer has a BIOS when booting to ensure that the system is booting up properly to the preset settings, sensors of the locomotive can be implemented to do the same things. IoT can give the locomotive a temperature sensor to make sure nothing in the locomotive is overheating or if something is frozen they should be able to detect it. Locomotives are mainly diesel-electric, where the diesel engine is connected to the main generator which converts the engine's mechanical power to electric. It is important to make sure that you are not running low on fuel or anything other important valuables to ensure the train runs smoothly.

2.7 CONNECTING TO NETWORKS

After overviewing the variety of helpful sensors, how will they connect to the internet? One way is to have sensors connect to the Low-Power Wide Networks (LPWAN). They can help mitigate the damage and discord if the trains suddenly go offline. LPWAN are optimal because they allow long-ranged communications at a low bit rate. The technology is low-power and low-cost, and since most LPWAN devices are powered by batteries, power outages cannot affect or sever the connection. LoRa (Long Range) is the proprietary of LPWAN. This technology can provide cellular-style communications with the devices that are connected to the network. In our case, data delivery is crucial, so sensors in the LoRa network can traverse below the Radio-Frequency noise floor (noise floor is the measure of the signal created from the sum of all the noise sources and unwanted signals) and transmit large data packets over long distances. We can depend on motion sensors, position sensors, weight sensors, and lidar sensors to relay information back to the control room. These sensors, if able to connect to less-demanding networks, can ensure the train's safety to the next station and allow the system to remain on schedule.

2.8 ONBOARD DECISION MAKING

All of the situational and environmental data collected by these sensors need some way to be processed into a more meaningful and digestible format for the operators. In the event of complete network or power loss, conductors should be able to rely solely on onboard computing and power to process this information. For example, a display in the operator's room - connected to its own power grid, delivering both data and energy to and from the sensors using an existing standard like Power over Ethernet (PoE) - could improve redundancy and provide graphical analytics and last-known train schedules. Most importantly, the system could suggest recommended courses of action. As an example, using the external temperature and humidity sensors to predict the slickness of the tracks, and onboard accelerometers to track the train's velocity, the system could recommend a safe stopping distance to operators. All of these decisions would need to be handled with computers and software running locally in the operator's rooms, but would serve as a list line of defense in the case of multiple system failure.

3: REQUIREMENTS (ANALYSIS)

The end goals of IoT: Hugs the Rail is to deliver a high quality software system. To achieve this, we need to implement requirements.

3.1 FUNCTIONAL REQUIREMENTS

Functional Requirements are the primary way that a customer communicates with the development team. It keeps the project team in the right direction. These requirements specify a behavior or function or what the system should do. In IoT: Hugs the Rail, the functional requirements include:

3.1.1 TRANSACTIONS

Inevitably in a dynamic business environment, requirements will be subject to change with stakeholder expectations and development team capabilities. it is important to define a standard set of procedures for amending the requirements document moving forward and notifying the appropriate parties of changes:

R1. When one or many stakeholders decide a requirement needs updating, the line of communication for making such requests should come in the form of a standalone email address and should be actively monitored.

R2. When the development team has relevant information for the stakeholders, or a request has been fulfilled, they should notify all affected parties directly via their preferred email address.

R3. Only trusted members of the development team should be able to update this document, but all members should be able to read it. The team can use GitLab's group feature for this functionality.

R4. Any and all changes to this document should be tracked automatically using Git source control.

3.1.2 ADMINISTRATIVE FUNCTIONS

When necessary, conductors and engineers should have more complete control than the regular interface provides. Here are some things an administrator of the system would need:

R5. A dense interface with access to all system functions
R6. Terminal to onboard computer
R7. Control of the train's onboard power grid
R8. Physical access to IoT sensors
R9. Uptime logs, error reports, and crash analytics

3.1.3 EXTERNAL INTERFACES

One of the ways to manage a locomotive to the best of its ability is to create an interface that is:

R10. Simple and Compact User Interface.
R11. Easy to the Eye.
R12. Regularly updated with Software Patches.

The interface should be able to:

R13. Expand on the details in case the conductor becomes unavailable and an inexperienced person is needed to take charge.
R14. Prioritize the most important objectives
R15. Alert the conductor when the system is not in homeostatic condition.

3.1.4 HISTORICAL DATA

Historical Data helps the company see what issues come up and what solutions have worked previously. It also helps with any patterns on the routes. Historical Data should be main by:

R16. Station storage will record all stop details. (Problems, Time, and Changes)
R17. Each locomotive will store data on a local drive and then transfers data to the next station.
R18. Data should be uploaded onto the internet to inform customers of the reality of any situation.

3.1.5 LEGAL & REGULATORY REQUIREMENTS

R19. The network nodes should not be able to carry out data analysis.
R20. All the sensors need to do is transmit information through the network to the central server.
R21. Data collection must be kept private and secure by all means.
R22. System should only store data temporarily; this minimizes the damage done if there are ever security breaches.
R23. Trains should be tagged with Radio-Frequency Identification (RFID) technologies recognizable only to the sensors and private domain.

3.2 NON-FUNCTIONAL REQUIREMENTS

3.2.1 HARDWARE USABILITY

R24. The sensor hardware should be durable and easy to implement because frequent maintenance is not ideal.
R25. It should be able to withstand temperatures lower than 0 degrees Celsius in the winter and temperatures above 40 degrees in the summer.
R26. Of course, the sensors should be covered or sheltered so that rodents and other animals cannot tamper with the technology.

R27. Since it is exposed to various weather conditions, the lens should be hydrophobic and protected with a layer of anti-dust coating.

R28. The external structure of the sensors also need to tolerate 60 mph winds just in case there are windstorms.

3.2.2 PERFORMANCE

Hugs the Rails Performance Requirement should include:

R29. IoT HTR should process an event within 3 ms of its occurrence.

R30. IoT HTR sensors should be able to detect an event within 1 ms.

R31. IoT HTR should be able to store 2 TB worth of data.

R32. IoT HTR should have a throughput of 100 gbps.

3.2.3 RELIABILITY

While not technically required to be active 24/7 as the train is ideally going to be connected to the internet for a majority of the time, we need our sensors to be both reliable and accountable.

R33. IoT HTR should have sensors with an uptime of 99.9%.

R34. IoT HTR should have sensors that can reliably reboot if an error occurs.

R35. IoT HTR should have sensors that have a 90% accuracy when sensing the environment, etc.

3.3.4 SECURITY

Physical security may not be a large problem in this project (If anything, we'd need to ensure that no one physically breaks into the compound with the train in it to prevent anyone tampering / breaking the sensors themselves), but cybersecurity can be a big worry in today's world.

R36. IoT HTR needs a security system tight enough to prevent common cyber attacks.

R37. IoT HTR needs a physical security system as well, to prevent break-ins to tamper with the train itself.

R38. IoT HTR should utilize an outside business / system to make a security system on the train.

3.3.5 SCALABILITY

Scalability is a question of whether or not the system in question can handle this growth. In the scope of this project, the "growth" would be defined as getting more train cars, so the question is if the amount of sensors we acquire can handle the amount of trains we acquire.

R39. We should only purchase new trains, new sensors, etc. when we have enough materials to purchase all at once.

R40. To prevent overbuying, only utilize new materials when absolutely necessary.

3.3 FEATURES

Upon meeting the Chief Technology Officer (CTO), we discussed adding four features. These feature include:

3.3.1 STANDING OBJECTS ACTIONS

Detect standing objects on the path with distance and suggest action to the operator to brake or increase/decrease the speed.

R41. Radars or sensors should be able to detect 270 degrees in a fixed 3 meter radius in order to scan or to track crowds. Markers should be placed on the track to alert the technology if there is a disruption in the restricted area. If this is the case, the locomotive should be alerted at least 500 meters away to slow down or stop.

R42. The locomotive should have vibration sensors aboard to detect its displacement. If it passes a certain threshold, precautions should be taken to decelerate the train. This is extremely important on bridges.

3.3.2 MOVING OBJECTS ACTIONS

Detect moving objects and distance ahead or behind and their speed and suggest to the operator branking or changing speed.

R43. If any objects are moving towards the train with no signs of braking or slowing down from the object, then the locomotive interface should alert the operator to move away and increase speed away from the object.

R44. If any objects are moving towards the train with signs of braking or slowing down, then the locomotive interface should alert the operator to slow down.

R45. If a locomotive detects a moving object but the proximity was becoming far too close that could lead to an interception or crash, the locomotive should alert the operator to slow down and possibly a potential brake.

R46. If there is a locomotive behind coming closer to the locomotive, it should alert the operator to speed up to a reasonable pace.

R47. The locomotive should have sensors implemented in the front and in the back of the train to detect proximity of other objects.

3.3.3 GATE ACTIONS

Detect gate crossing open/closed, distance and suggest speed change or brake to stop the operator.

R48. If a detected gate crossing is closed within 100 feet, begin to slow the train down to a stop so the train will not crash into the barrier.

R49. If a gate in front of the train is detected to open, begin to speed up the train so it can start to travel at its normal speed again.
R50. While the train is stopped in front of a closed gate crossing, keep the train stopped. Do not start moving until the gate is detected to have opened once more.
R51. The train should only be moving at maximum speed at a distance of 150 feet from the gate (regardless of whether or not the gate is in front or behind, for the purpose of safety).

3.3.4 WHEEL ACTIONS

Detect wheel slippage using GPS speed data and comparing it with wheel RPM and suggest to operator change speed or brake.

R52. If GPS-based speed data is greater than the calculated speed using the wheels RPM, alert the operator that there is wheel slippage and report the difference in projected and actual speed as a percentage.
R53. When wheel slippage is detected, automatically slow the train until the GPS speed data is equivalent to the speed calculated from the wheel's RPM.
R54. If wheel slippage is detected and the weather data suggests high moisture content in the air, alert the operator that the tracks are wet and suggest slowing.
R55. If still connected to the network, report to the control room at the next station that wheels are slipping and the train may be delayed or off schedule.
R56. The locomotive should have a sensor for every three wheels to check whether there is a dangerous amount of slippage.