Development, Demonstration and Dissemination of Integrated Technology Solutions to Improve Hazardous Materials Transportation Safety and Security

Final Report

prepared for:
U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA)

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LIST OF ACRONYMS

AAR – Association of American Railroads

ABD – Acoustic Bearing Detectors

AEI – Automatic Equipment Identification

ALOHA – Areal Location of Hazardous Atmospheres

API – Application Programming Interface

CLM – Car Location Message

EHM – Equipment Health Management

EHMS – Equipment Health Management System

FRA – Federal Railroad Administration

GPS – Global Positioning System

Hazmat – Hazardous Materials

HD – High Definition

LoRa – Low-Power Wide-Area Network

LORF – Line of Road Failure

Mar-HRIS – Maritime Hazmat Risk Information System

NOAA – National Oceanic and Atmospheric Administration

PHMSA – Pipeline and Hazardous Materials Safety Administration

RFID – Radio Frequency Identification

SHRIS – Shipper Hazmat Risk Information System

STU – Solar Tracking Unit

THD – Truck Hunting Detector

USGS – United States Geological Survey

WILD – Wheel Impact Load Detector

WISER – Wireless Information System for Emergency Responders

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EXECUTIVE SUMMARY

Many thousands of hazmat shipments occur daily in the U.S., traveling across a vast network of rail, truck, marine, pipeline, air and intermodal transportation systems. While the industry has amassed an impressive safety and security track record, incidents continue to occur, posing risks to the health and safety of hazmat responders, inspectors, carriers, shippers and other transportation stakeholders, as well as the communities through which these shipments travel.

This accentuates the need for research that can advance the development of innovative techniques to further minimize the risks of transporting hazardous materials. One promising area for achieving this goal is through deployment of smart detection systems and corresponding communication technologies to improve the accuracy, timeliness and breadth of communication among stakeholders, with an eye on both incident prevention and consequence mitigation.

Providing the shipper with these capabilities is arguably key to influencing the entire hazmat transportation supply chain. The hazmat shipper loads the product, knows its material properties, often owns the fleet equipment, and never completely relinquishes its custodial role (even when in the hands of a carrier) until the product is successfully delivered to the customer.

The objective of this research project was to study how the integration of a number of readily available technologies can be leveraged by hazmat shippers to achieve enhanced hazmat transport safety and security across various freight surface transportation modes. The project embodied four principal tasks, which are described below along with corresponding findings and recommendations:

Design and Implementation of an Integrated Technology System for Rail Shipper Safety & Security
The objective of this task was to produce a description of the design and application of an existing integrated rail technology system utilized by Olin Corporation, for the purpose of making it available to other rail hazmat shippers for implementation consideration.

A conceptual design was prepared for the deployment of this system by rail hazmat shippers, and given the acronym SHRIS (**S**hipper **H**azmat **R**isk **I**nformation **S**ystem). Included are schematics showing individual system components (hardware and software) and their interoperability, as well as a narrative describing how each component is utilized and the means by which information is transmitted to the rail hazmat shipper and subsequently merged into an integrated database. Guidance is also provided as to setting thresholds, triggering alerts/notifications, and communicating these alerts/notifications to appropriate hazmat transportation stakeholders.

Since implementing SHRIS for its high-hazard rail shipments, Olin Corporation has experienced a dramatic reduction in the risk of transporting hazardous materials and also realized cost savings. The existence of this proven and affordable system offers an opportunity for hazmat rail shippers of all sizes to leverage this capability, and not just a

select few within the industry. Such widespread adoption will benefit not only each individual shipper, but the industry as a whole.

Feasibility Test of Low-Power Wide-Area Network Long Range Gateway Modems in Deploying an Integrated Technology System for Rail Shipper Safety & Security

This activity focused on the design, application and efficacy of a modified integrated technology system, hoped to be a lower cost alternative, that could be utilized by smaller sized rail shippers or for less hazardous rail hazmat shipments.

With GPS-based, cellular technology systems proving to be effective in managing the safety and security of high-hazard shipments via rail, a natural extension is to consider the deployment of a technology system with similar capabilities to be used in managing the safety and security of other hazardous materials that are not considered as dangerous. For these materials, a technology-based solution may not require real-time anomaly reporting and offers a potentially lower cost may be more appropriate. In such cases, anomalies can be detected while the shipment is en-route, with the information stored until reaching a location that is more conducive to taking risk mitigation actions (e.g., shipper facility), at which time the information is retrieved and acted upon.

In this task, the study team evaluated a system of sensors installed on the rail car to record and store messages, which relies on the use of Low-Power Wide-Area Network Long Range (LoRa) gateway modems as a means of communication. Gateways then pass along the messages with cellular, satellite, Ethernet, or wifi to a network server.

In the past, many hazmat shippers have avoided implementing GPS-based, cellular technology systems because of the monthly overhead costs of cellular or satellite provider fees. The LoRa configuration, if proven, could eliminate this concern by limiting the cost to the device purchase and avoiding monthly fees by allowing a trip history to be offloaded once a car returns to a gateway facility.

However, we found that the LoRa units were unable to provide consistent and reliable messaging as intended by its functional design. There are several potential explanations for such performance, among them being: 1) drain on the solar batteries, 2) drops in coverage, and 3) other design and construction features of the units that render them inoperable in the environment (e.g., climate) in which they must perform. As a result, the study team concluded that this particular LoRa-based technology solution should not be considered for active deployment.

If there is a silver lining, it comes with the knowledge that the cost for cellular service has dropped precipitously of late. Olin, for example, has experienced a roughly 50% reduction in the cost of its cellular service to support GPS-based, cellular technology system over the past six years. Given this development, what was thought to be a cost-prohibitive solution for some hazmat shippers to deploy a GPS-based, cellular technology solution for managing the safety and security of their shipments is now within economical reach.

Feasibility Test of Implementing Digital Mechanical Locks

A much-discussed topic among shippers has been the potential for installing digital mechanical locks that cannot be opened unless the shipment is located inside a defined geo-fence or is unlocked via a pass code. To date, this technology has not been applied to railcar shipments. This task consisted of identifying, demonstrating and evaluating this capability to open/close rail tank car dome hatches using a commercially available technology.

A search was conducted for digital mechanical lock technology that might be feasible for implementation on rail tank car dome hatches. This resulted in the identification and selection of the Power-In-Lock system, developed by QProducts and Services, which had been successfully outfitted on trailers in the trucking industry. The vendor designed a configuration that would be compatible with a rail tank car dome hatch, and this device was subsequently installed on a rail tank car located at Olin's Charleston facility.

Following product installation, the system was tested under a variety of operating conditions (e.g., temperature, atmospheric conditions) over a period of several weeks. The results showed that the digital lock successfully performed its stated function under these conditions, confirming that an opportunity exists to improve rail tank car safety and security with this innovation.

Extensive approval requirements have been established by the Association of American Railroads (AAR) to modify rail tank car equipment. Based on demonstration results, it is now possible for the AAR, in concert with the Pipeline and Hazardous Materials Safety Administration (PHMSA) and other industry stakeholders, to proceed with the steps to obtain preliminary approval to modify rail tank car equipment to allow the use of digital mechanical locks on rail tank car dome hatches.

Assessing System Transferability to Truck and Barge Modes

The final aspect of this research project was to examine the transferability of integrated technology solutions developed for rail hazmat safety and security to other freight surface transportation modes (i.e., truck and barge). This effort considered both opportunities and challenges for adaptation, and the extent to which a feasible implementation pathway could be identified.

The assessment was performed by examining the adoption value and feasibility within the barge and trucking industries, respectively, of the most significant feature elements contained within SHRIS. It was concluded that both the barge and truck modes can benefit from the implementation of a SHRIS-type system, and that the vast majority of highly-valued features can either be adopted directly using technologies embedded in the SHRIS system, or can be implemented by making modifications to SHRIS system elements. There are not dramatic differences in the development effort involving implementation of such a system for either mode, but rather certain feature elements appear to add greater value for one mode and vice-versa.

While development of a SHRIS-type system to hazmat movements by either the truck or barge mode is likely to offer safety and security benefits, a greater need and opportunity appears to exist for developing and deploying such a system in the barge domain. This rationale rests with the communication technology gap found in the maritime industry created by the dependence on a paper-based system kept onboard each vessel. Further, the significantly larger cargo volumes per barge shipment creates the potential for a more consequential impact in the event of a material release.

Consequently, a framework was developed for the design and implementation of a SHRIS-like system in the barge domain, using both the innovative technologies demonstrated in rail combined with a comprehensive electronic maritime hazmat communication system. Coined the Maritime Hazmat Risk Information System (Mar-HRIS), it is highly recommended that PHMSA sponsor a Mar-HRIS demonstration, particularly given the extensive paper practices currently used in the industry and the concomitant risks associated with Covid-19 transmission.

1. INTRODUCTION

Our nation's economy relies heavily on hazardous materials (hazmat) in the manufacture and delivery of products to meet societal needs. Many thousands of hazmat shipments occur daily, traveling across a vast network of rail, truck, marine, pipeline, air and intermodal transportation systems. In doing so, the industry has amassed an impressive safety and security track record. Nevertheless, incidents continue to occur, posing risks to the health and safety of hazmat responders, inspectors, carriers, shippers and other transportation stakeholders, as well as communities at large. This accentuates the need for research that can advance the development of innovative techniques to minimize the risks of transporting hazardous materials.

One promising area for achieving this goal is through greater use of emerging technologies. A primary consideration in this regard is the development of smart detection systems and corresponding communication technology to improve the accuracy, timeliness and breadth of communication among stakeholders, with an eye on both incident prevention and consequence mitigation.

Providing the shipper with these capabilities is key to influencing the entire hazmat transportation supply chain. The hazmat shipper loads the product, knows its material properties, often owns the fleet equipment, and never completely relinquishes its custodial role (even when in the hands of a carrier) until the product is successfully delivered to the customer. In this respect, it is the shipper who is at the helm of implementing the technology solution that collects vital monitoring/detection information, assesses it, and communicates what other stakeholders need to know in a timely fashion in order to ensure that the safety and security of the hazmat shipment is highly coordinated and effectively managed.

This project focused on integrating a number of technologies to leverage their combined capabilities to achieve enhanced hazmat transport safety and security across freight surface transportation modes. The project had several objectives: 1) transferring product knowledge of a recently developed and operational system to hazmat shippers who use the rail mode, 2) testing new functionality for rail system application using additional technologies, and 3) exploring the transferability of the rail system application to hazmat shipments by barge and truck.

The work was performed as a set of independent tasks, each of which is covered as a separate narrative in the ensuing chapters:

Task 1. Design and Implementation of an Integrated Technology System for Rail Shipper Safety & Security
The objective of this task was to produce a description of the design and application of an existing integrated rail technology system utilized by Olin Corporation, for the purpose of making it available to other rail hazmat shippers for implementation consideration. The narrative includes schematics showing individual system components (hardware and software) and their interoperability, as well as a description of how each component is configured and the means by which information is transmitted to the hazmat shipper and subsequently merged into an integrated database. Guidance is also be provided as to setting thresholds, triggering alerts/notifications, and communicating these alerts/notifications to

appropriate hazmat transportation stakeholders compatible with their information receiving devices. A case study is included that provides examples of how the system output is used by Olin Corporation in making improved risk-informed decisions.

Task 2. Feasibility Test of Low-Power Wide-Area Network Long Range Gateway Modems in Deploying an Integrated Technology System for Rail Shipper Safety & Security

This activity focused on the design, application and efficacy of a modified integrated technology system, purported to be a lower cost alternative, that could be utilized by smaller sized rail shippers or for less hazardous rail hazmat shipments.

Task 3. Feasibility Test of Implementing Digital Mechanical Locks

A much-discussed topic among shippers has been the potential for installing digital mechanical locks that cannot be opened unless the shipment is located inside a defined geo-fence or is unlocked via pass code. To date, this technology has not been applied to railcar shipments. This task consisted of demonstrating this capability and evaluating its performance.

Task 4. Assessing System Transferability to Truck and Barge Modes

The final aspect of this research project was to examine the transferability of integrated technology solutions developed for rail hazmat safety and security to other freight surface transportation modes (i.e., truck and barge). This effort considered both opportunities and challenges for adaptation, and the extent to which those challenges can be overcome. This resulted in the preparation of a document, designed to serve as a "road map", outlining what would be required to make the rail-based system or its functional equivalent affordable, practical and achievable for hazmat truck and barge shippers to make risk-informed decisions and communicate necessary information to appropriate transportation stakeholders.

2. DESIGN AND IMPLEMENTATION OF AN INTEGRATED TECHNOLOGY SYSTEM FOR RAIL SHIPPER SAFETY & SECURITY

This section presents an overview of a system design for addressing critical hazardous materials risks and how key technological components can operate together to improve rail safety and security. It includes the description of the design and application of an existing integrated technology system, for the purpose of making it available to any rail hazmat shipper for implementation consideration. Schematics are presented showing individual system components (hardware and software) and their interoperability, as well as a narrative that describes how each component is utilized and the means by which information is transmitted to the hazmat shipper and subsequently merged into an integrated database. Guidance is also provided as to setting thresholds, triggering alerts/notifications, and communicating these alerts/notifications to appropriate hazmat transportation stakeholders. A case study is subsequently presented that illustrates how system outputs are used in making improved risk-informed decisions.

2.1 System Design Overview

The technology solution utilizes as its foundation an integrated safety/security system for rail shipments of high-hazard cargo that begins inside the shipper's fence line, continues while a shipment is in transit, and does not end until the cargo is successfully delivered to the customer (Figure 2.1).

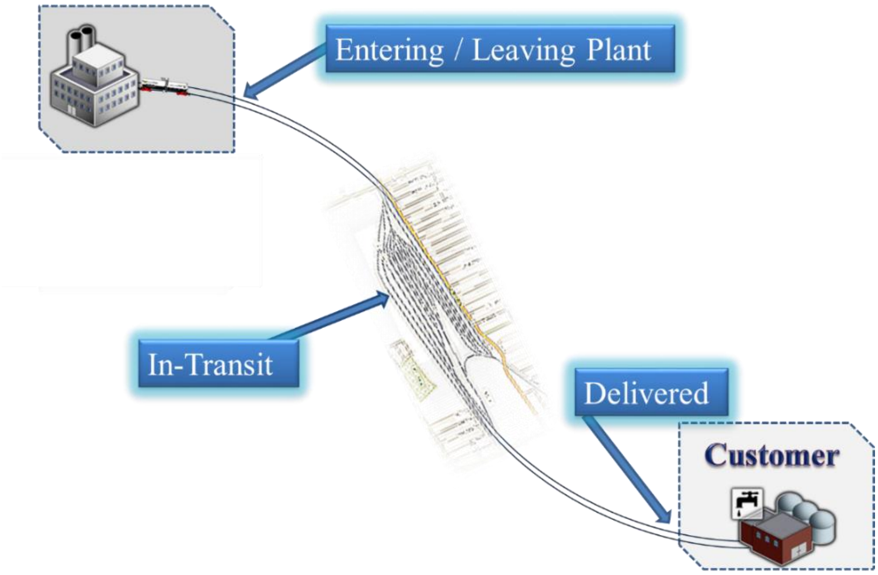


Figure 2.1 - Railcar Shipment Overview

Risk domains of safety and security interest are the health and handling of the railcar, its contents and the railroad infrastructure. A schematic of the developed rail hazmat shipper safety and security system is displayed in Figure 2.2. A variety of operational and spatial information is collected from multiple sources. Natural hazard information is streamed from source data collection agencies to identify extreme weather and earthquake events that may impact the current or future location of a hazmat shipment. Sensors installed on the cargo container enables the shipper to monitor any developing problems, recognize tampering, identify an accident, or perform damage assessment. Sensors installed by the railroad (along the track) provide information on equipment and track health. Finally, the shipment is monitored according to whether its location is within a prescribed geo-fence to ensure that it stays on the desired path.

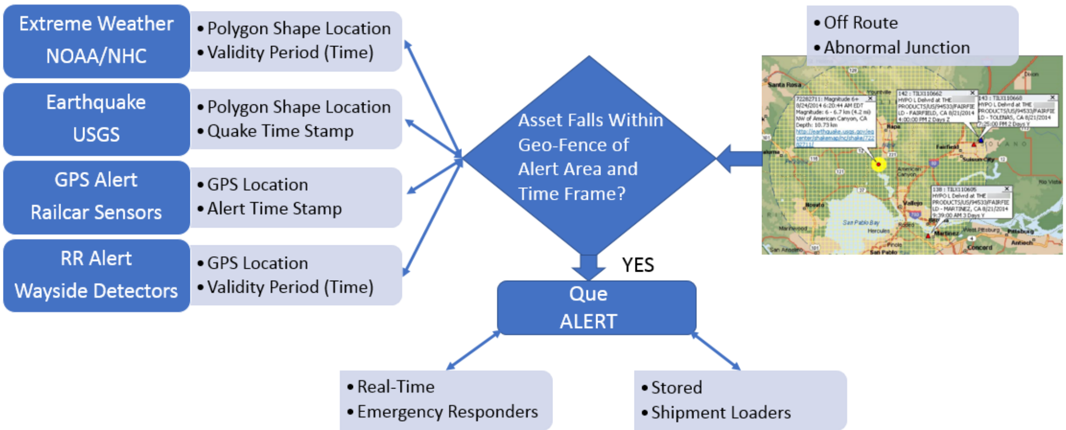


Figure 2.2 - Rail Hazmat Shipper Safety and Security Information System

Figure 2.3 shows a schematic of the preferred location of the GPS device mounted on the cargo container. If the unit contains a camera (which is not wide angle), a distance of 14 feet from the platform on the top of the ladder is a desired installation site in order to capture the image of a seven-foot tall man standing on the platform. The four-foot indicator is the suggested location for a GPS unit install if the device does not contain a camera.

Collectively, this information is transmitted to the shipper via GPS vendor application programming interface (API) or read from Internet sources, and merged into an integrated database for each railcar. There are three interdependent dimensions to this information - time, location, and event criticality – which are benchmarked against safety/security performance metrics and corresponding safety/security exceedance threshold values. When a threshold is exceeded, an alert or notification is transmitted to affected parties (Figure 2.4). Alerts are transmitted in real-time when a critical event has been reported or the potential for a time-sensitive, critical event is identified. Otherwise, this information is stored as a notification, to can be acted upon at a more convenient location without jeopardizing immediate safety or security, such as when a part needs to be replaced the next time the railcar arrives at the shipper's facility. In both instances, the relevant information is transmitted to the person(s) with a need to know, formatted to be interoperable with the recipient's device (e.g., smart phone, lap top, etc.).

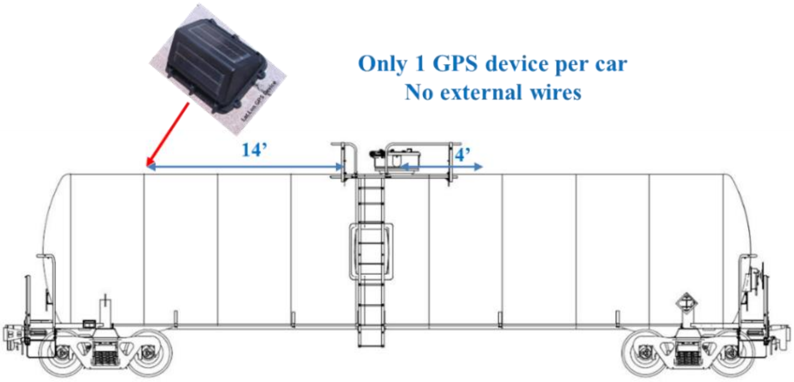


Figure 2.3 - Tank Car Equipped GPS Device

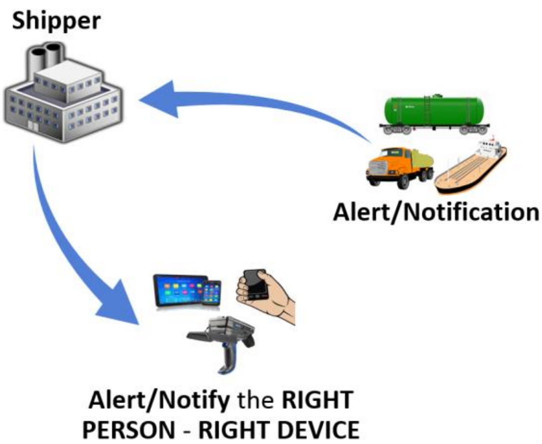


Figure 2.4 - Alert and Notification Protocol

2.2 System Operations

Specific system operating characteristics can be best described and understood as they map to a typical hazardous material shipment, beginning at the shipment origin.

2.2.1 Shipper Facility System Features

When a railcar enters the shipper's facility, it is scanned in multiple ways (Figure 2.5):

1. The unique railcar automatic equipment identification (AEI) tag is read. This electronic tag allows railroads, car owners, and shippers to track information related to each specific railcar. Data-tag readers are also usually tied to a railroad's car location message (CLM) system, where the railroad can opt to share this information with its customers. This system provides a trigger to automate delivery of the alert queue. Alerts gathered during transit are supplied to targeted employees who can act on them.
2. Cameras installed on both sides of the car enable high-definition (HD) image capture. This creates a visual record of the physical status of the railcar upon entering the facility. If any car damage is observed by the technician reviewing the image, this is documented (Figure 2.6) and reported along with the equipment health management (EHM) alerts.
3. Any scheduled maintenance due on the railcar is also identified according to the amount of time/distance it has been in service (Figure 2.7).

Collectively, this information is passed to facility personnel for appropriate action (Figure 2.8). The system also integrates with the facility entrance security system to determine which personnel are working that day to avoid delivery of alert queues unnecessarily.

While inside the shipper facility, cars equipped with GPS can generate and provide alerts to facility employee hand-held devices, reporting and reminding them of an unresolved/unacknowledged alert based upon the employee's proximity to the car.

Prior to departing the shipper facility, maintenance and repair records are checked to ensure that no railcar leaves without work having been completed.

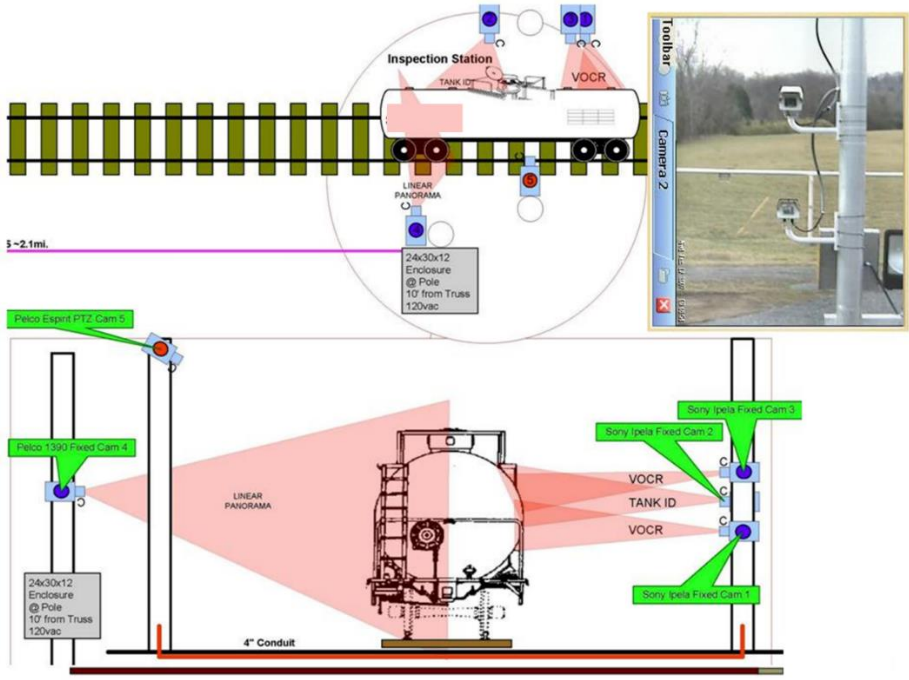


Figure 2.5 - Cameras and AEI Readers at the Shipper Facility

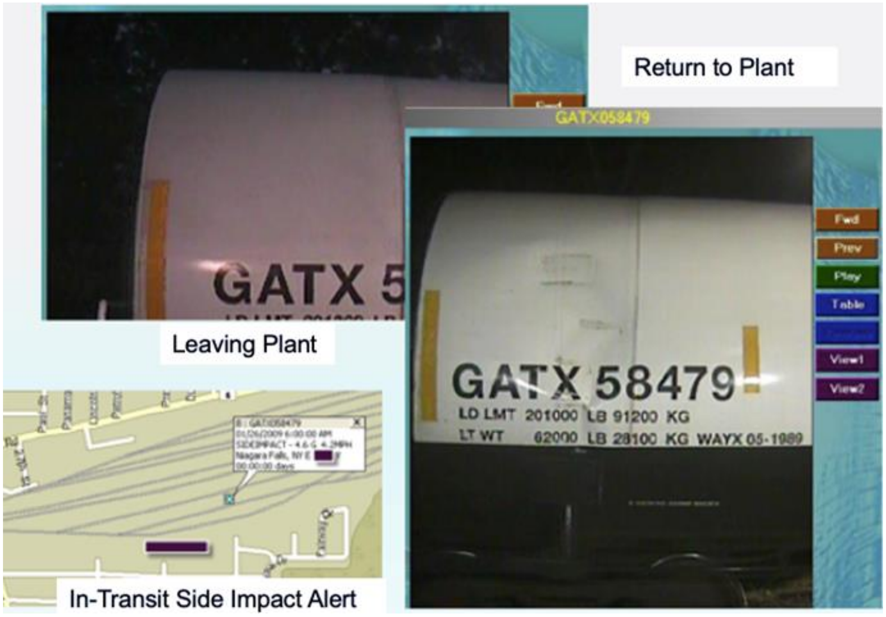


Figure 2.6 - Car Damage Assessment

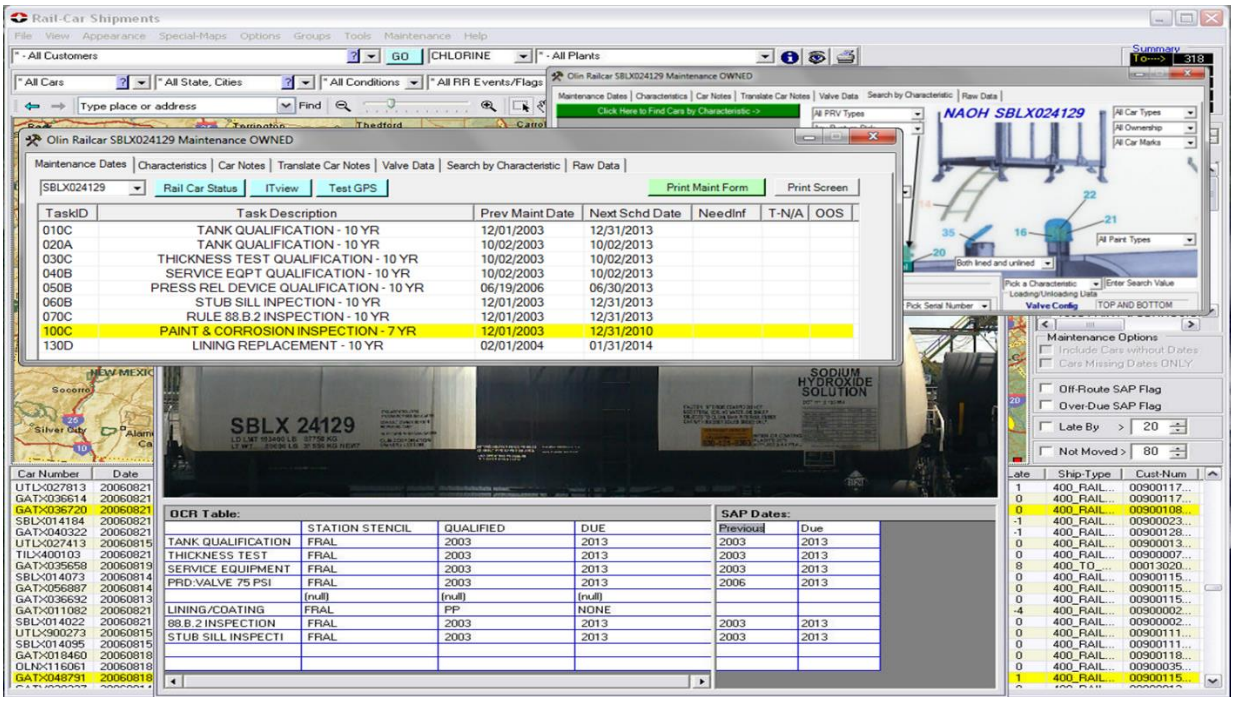


Figure 2.7 - Maintenance and Repair Records

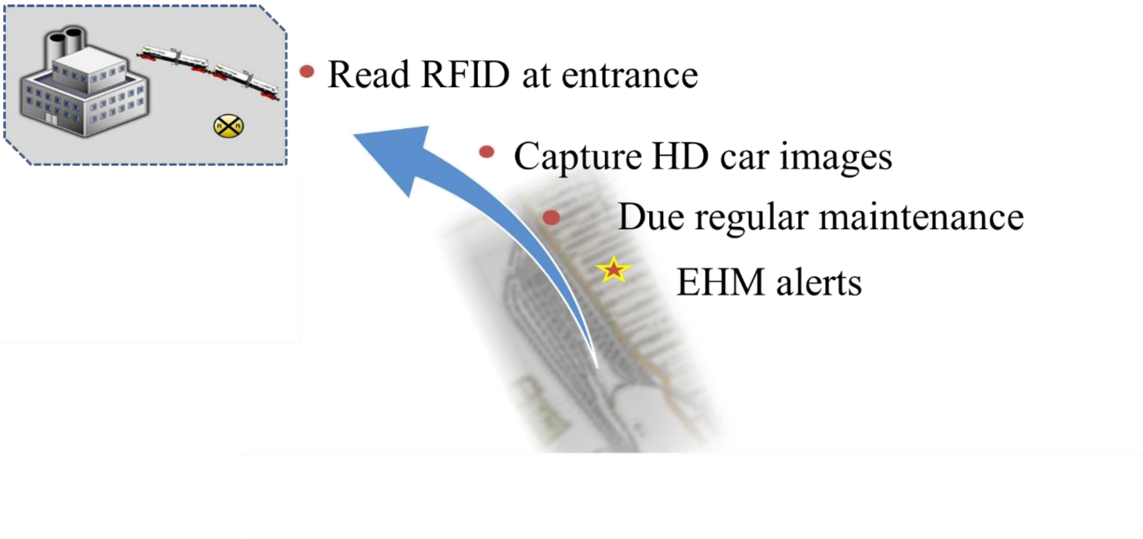


Figure 2.8 - Actionable Facility Information

2.2.2 In-Transit

Once cars are in transit and outside the confines of the shipper's facility, the focus shifts to monitoring the shipment, maintaining vigilance that the cargo is not exposed to unwanted safety or security risk.

GPS Data Collection

Car safety and security is monitored via the GPS unit installed on the top of the railcar. With this technology, the tank car's dome position can be monitored for tampering, ride quality measured by collecting impact and deceleration data, and images captured when any unexpected motion or movement is experienced (Figure 2.9). The criteria are programmable according to the shipper's specification.

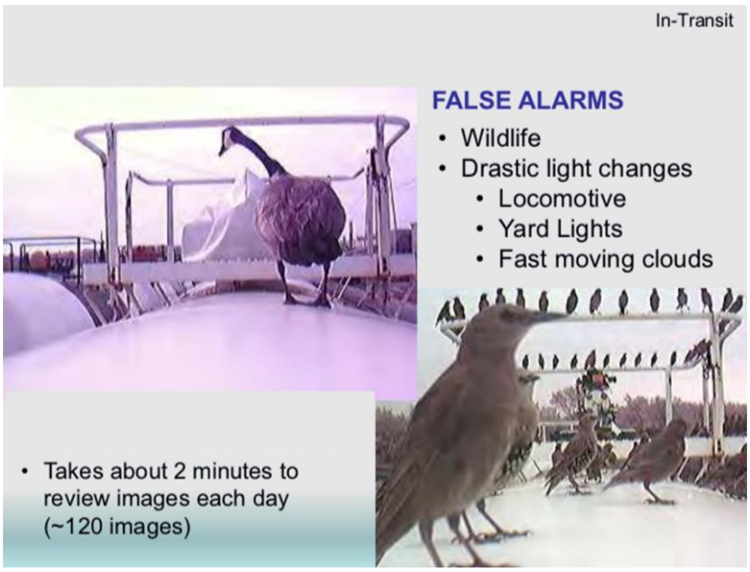


Figure 2.9 - Motion Image Capture

Several techniques are available to determine tampering: 1) motion detection sensors, 2) vibration monitoring (differentiates between normal rail car movement vibrations and footsteps on the car), and 3) a wireless transmitter underneath protective dome housings with an accelerometer that detects opening of the dome lid. Regardless of the technique used, an event will trigger an image capture and data is stored by the GPS unit until it is sent to the shipper via cellular message or offloaded via wireless transmission when the car re-enters the shipper's facility.

The GPS devices also serve a valuable purpose to ensure that the shipment is traveling on its intended route. Route boundaries can be defined by establishing geofences, spatial coordinates that if intersected, infers that the railcar is off-route. If such an event is detected, the GPS device triggers an alarm indicating an off-route situation.

Natural Hazard Information

Natural hazards also pose a potential in-transit threat to the safety of hazmat shipments. Among the data sources regarding natural hazard threats or event occurrences, are information available through the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS). This information can be sourced through the web in real-time, and associated with railcar location and movement.

Real-time satellite imagery and associated information provided by the National Oceanic and Atmospheric Administration's (NOAA), when superimposed on the shipper's railcar locations, provides current information on extreme weather events (e.g., storms, wildfires), such that potentially dangerous locations can be avoided until safe passage can be restored (Figure 2.10). The USGS provides real-time earthquake information, helpful in ascertaining whether a rail car may have incurred damage from being located in the impact zone (Figure 2.11), and if not, whether the railcar's shipment route has been impeded, such that the car must be halted and stored in a safe haven, or re-routed.

In the event of a release, existing weather conditions at the site can be utilized in predicting how a release will propagate over time and what emergency response measures would be appropriate (Figure 2.12). Toxic release modeling can be performed using publicly available tools, such as the Areal Location of Hazardous Atmospheres (ALOHA) model, developed by the U.S. Environmental Protection Agency, and the Wireless Information System for Emergency Responders (WISER), developed by the National Institutes of Health. Predictive information provided by these tools help support timely and effective emergency response.

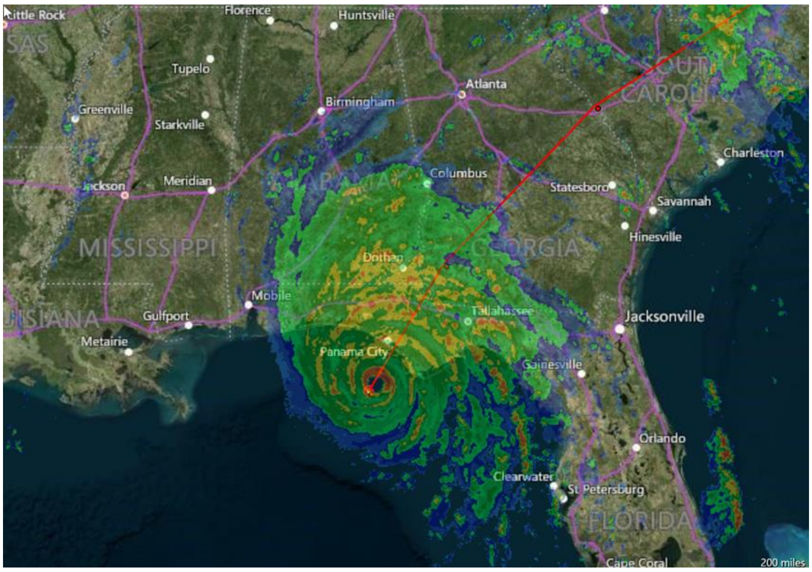


Figure 2.10 - Severe Weather Event

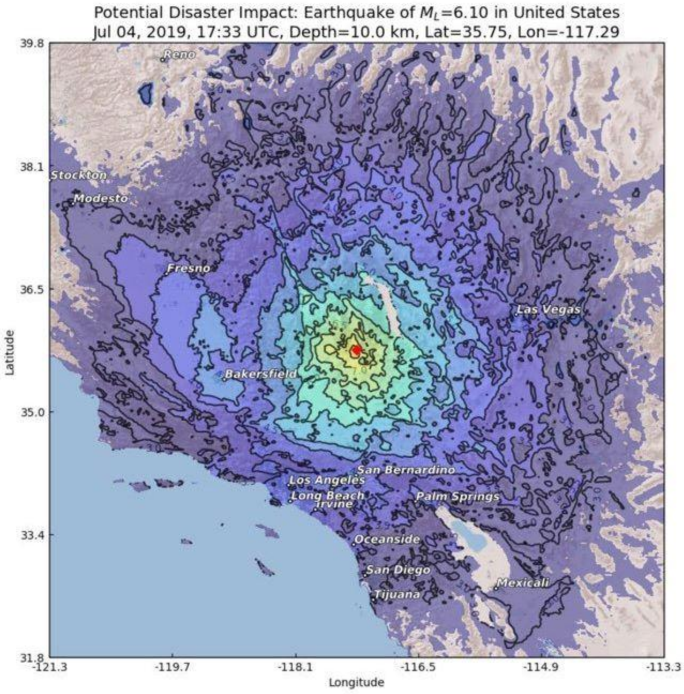


Figure 2.11 - Earthquake Impact Zone

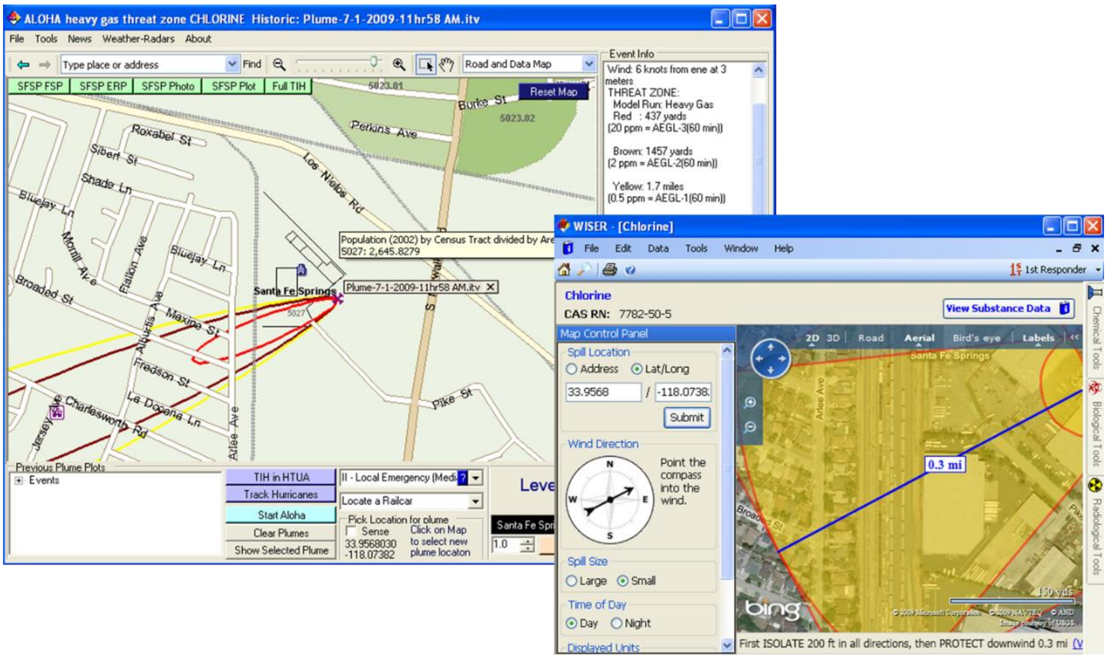


Figure 2.12 - Release Modeling

Railinc

Another important information source is Railinc, a subsidiary of the Association of American Railroads (AAR), whose mission is to provide rail data and messaging services to the North American freight railroad industry. Two services provided by Railinc, equipment health management system (EHMS) and car location messaging (CLM), can be integrated as part of a shipper's safety and security information system.

EHMS is a web-based application that communicates the condition of railroad equipment to rail carriers, car owners and other interested parties, including alerts. The system receives and manages alert data from the following wayside detection devices located at regular intervals along rail track: 1) wheel impact load detectors (WILD), 2) truck hunting detectors (THD), 3) acoustic bearing detectors (ABD), and 4) truck performance detectors (TPD). Collectively, these detectors are designed to reduce risk in railroad operations by identifying poorly performing equipment before accidents occur. Additionally, line of road failure (LORF) notifications are provided, representing a new statistical alert based on data summaries associated with component failure rates.

WILD measures vertical wheel forces via rail-mounted accelerometers or strain gages, searching for defective wheels. THD measures oscillation of the wheelset due to lateral movement in the gauge of the track, where exceedance above a certain threshold (i.e., dynamic instability) can cause wheel flanges to impact the rails, potentially causing damage to both, and increasing the likelihood of a derailment. ABD identifies bearing flaws in railcars by recording audio from a train as it passes by, and using acoustic technology to detect wheel bearing defects prior to failure. TPD evaluates the suspension performance of trucks[1] by measuring the vertical and lateral forces generated by the wheels as a car moves over the detectors that are placed along instrumented track. The following defects can be flagged with TPD: 1) worn friction wedges, 2) broken suspension springs, 3) twisted car bodies, 4) mismatched side frames, 5) hollow/worn wheels, and 6) tight side bearings.

CLM delivers complete information on the car location and its shipment. CLM has many event codes which help summarize and provide data on the car and its cargo. Examples include departure and arrival times, current location and estimated arrival time, interchanges between railroad carriers, intermodal transfers, and equipment in storage or deemed currently defective.

2.2.3 Customer Delivery

At the final destination, once the shipment has arrived inside the customer's fence line, the shipper remains concerned that no accident occurs at this location. The previously described technologies and information system remain active during this time and until the shipper's equipment leaves the customer's facility. It is also possible that the technologies described in Section 2.2.1 could be installed at the receiving facility as well.

2.2.4 Information Transmission and Database Management

Data collected by the GPS units can be transmitted using cellular service or via long range wireless communication. The data is received and stored at a central server maintained at the shipper's facility where cars enter or leave. The data is further enriched by combining it with information provided by Railinc and natural hazard web services, resulting in a comprehensive health, maintenance, inspection and damage assessment of each rail car entering the facility for further action. The data collected from various sources can be analyzed based on the thresholds and decision criteria established by the shipper, consistent with any Federal Railroad Administration (FRA) requirements and AAR standards/guidance.

The process can be aided considerably by utilizing Early Warning, a web-based application/service provided by Railinc that acts as a hub for communications about rail equipment from which maintenance advisories and early warning notices can be issued. Early Warning enables railroads, equipment owners, and repair shops to have visibility into defective equipment and components, identify when tests are past due, and report when a car has been inspected or repaired so that equipment can be removed from notices.

Every source of data has a relevance period, defined as the time between the ship date and the delivery date. All GPS readings and alerts that occur between these dates belong to that shipment. Events that occur during transit can also have a relevance period, and sometimes a geo-coordinate shape such as a tornado warning. All GPS readings from a car inside the geo-coordinate shape that occurred within the event relevance period can be flagged for inspection once the car arrives back at the shipper facility. Events such as earthquakes may have a short relevance period, but depending upon the magnitude and regional location, can have a large geo-fence radius. All GPS readings reported within the geo-fenced area and timing within one update cycle would be flagged for inspection.

[1]In the rail industry, the term "truck" refers to the structure underneath the railcar to which axles (and wheels) are attached.

2.3 Case Study: The Olin Experience

Olin Corporation is a large multinational petrochemical company with a substantial North American presence as one of the largest producers of chlorine, industrial bleach and on-purpose hydrochloric acid. As a shipper of hazardous materials, Olin is committed to ensuring the safety and security of these shipments through active monitoring and active engagement with carriers, incident responders and other transportation stakeholders as an essential part of its risk management program.

Olin developed and has implemented the aforementioned integrated technology system, equipping a portion of its railcar fleet used for shipping high-hazard cargo with GPS devices, and establishing criteria for triggering alerts and notifications. In the discussion to follow, the Olin experience is described in terms of how the system is operated and utilized. Hereafter, we refer to this system using the acronym SHRIS (**S**hipper **H**azmat **R**isk **I**nformation **S**ystem).

2.3.1 Olin System Data Sources

As described in the prior discussion and shown in Figure 2.13, Olin sources data via GPS, the Internet, and Railinc to form a comprehensive information system from which risk-informed safety and security decisions can be made. The GPS unit is utilized for dome open/close detection, motion detection image capture, and collection of impact and deceleration data. Web services are sourced for recognizing natural hazard threats and events, whereas Railinc provides EHM and CLM data.

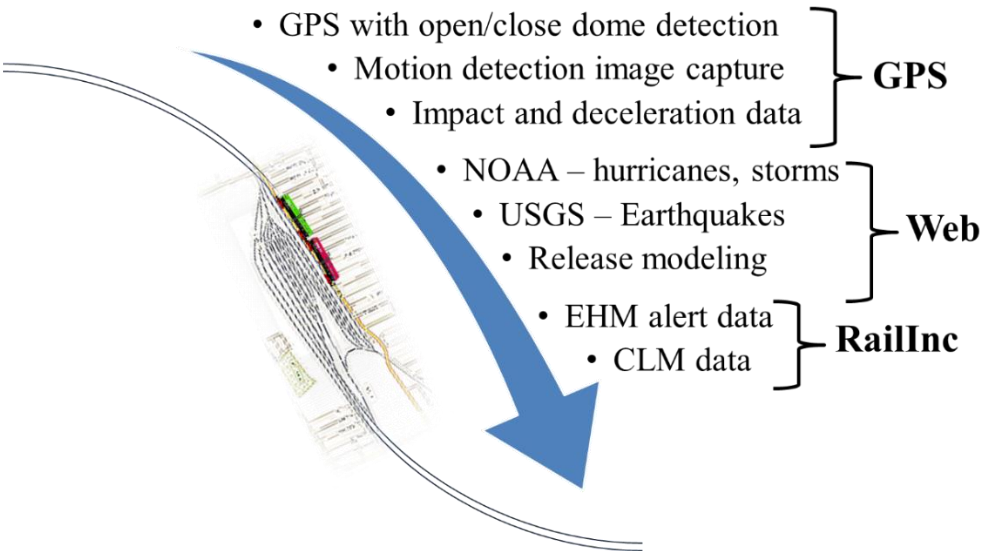


Figure 2.13 - Olin System Data Sources

2.3.2 Anomaly Alerts

As shown in Figure 2.14, collectively this information enables Olin to assess a multitude of system performance considerations and evaluate whether alerts are warranted. Any alerts are recorded and transmitted to the plant rail crew for maintenance and repair (Figure 2.15)[2]. These notifications are managed within an alert management system, wherein the plant crew

[2]The reference to SAP in Figure 2.15 represents Olin internal digital platform.

has complete visibility over each railcar and its corresponding safety and security needs (Figure 2.16).

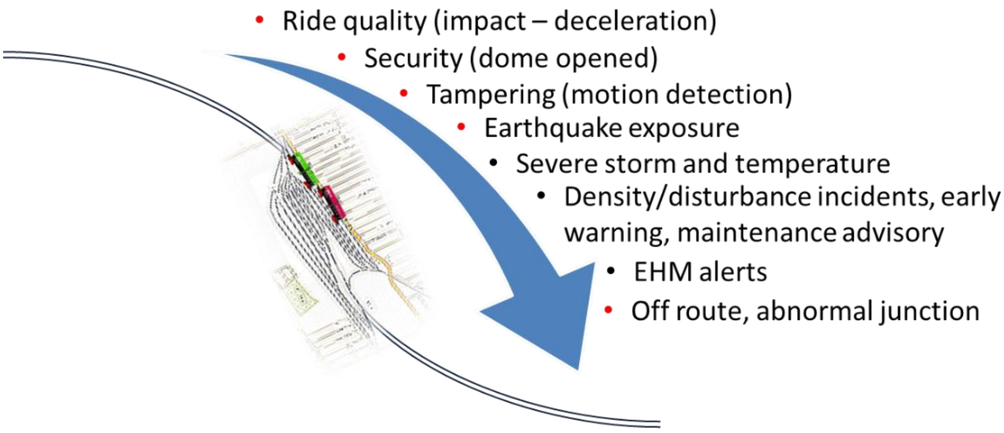


Figure 2.14 - Olin System Alerts

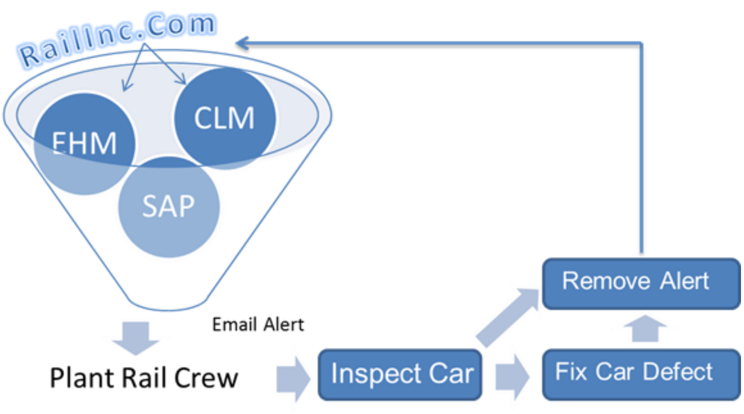


Figure 2.15 - Alerts Directed to Olin Rail Crew

- Do Not Load
- Bad Order
- Do Not Use
- RR DDCT
- RR EHM (Wild,etc)
- RR EW (ABT,etc)
- GPS Alerts
  - Impacts
  - Speed Drops
- Tracking Alerts
  - Weather
  - Quakes
  - Floods

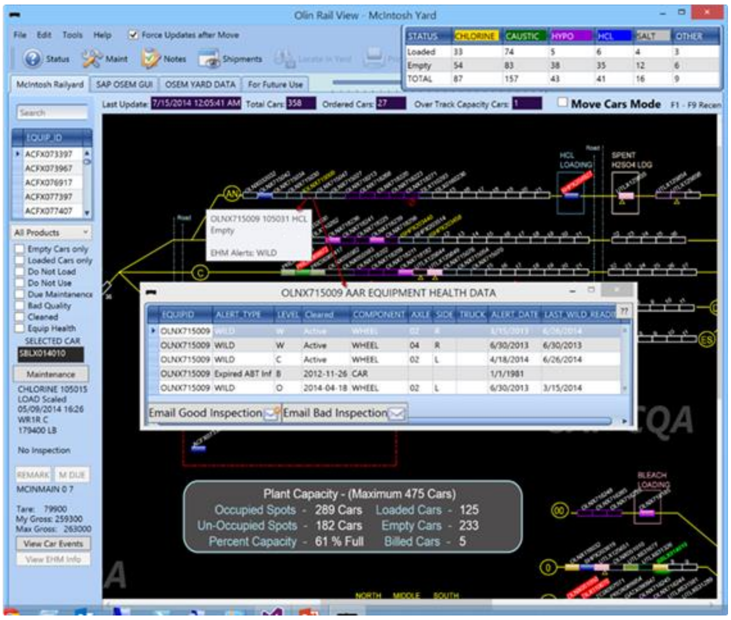


Figure 2.16 - Alert Visibility

Another element of the system focuses primarily on rail security. In addition to any immediate emails directed to Olin's security coordinator if an undesirable event is detected, the security coordinator receives a daily summary of each event, which includes images captured from the GPS unit that can be used to verify if the event had any impact on shipment integrity (Figure 2.17). Image capture from the GPS unit when in transit helps eliminate false alarms by providing visual context around the event.

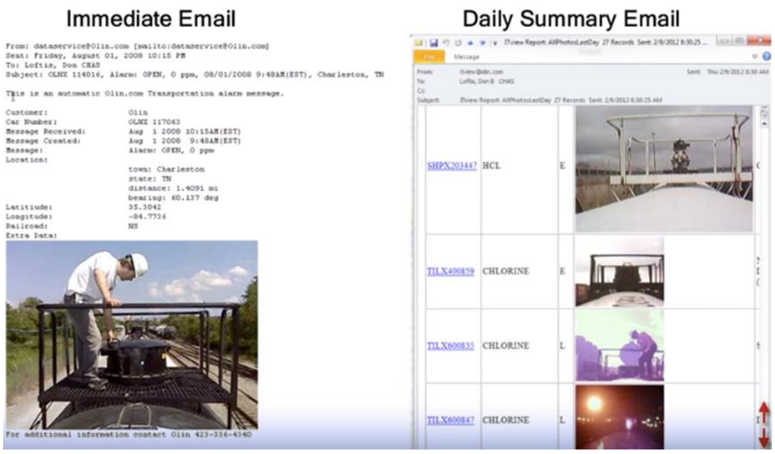


Figure 2.17 - Olin Daily Summary Report with GPS Image Capture

2.3.3 Deceleration Threshold Determination

As previously discussed, alerts are sent to plant operations when railcars entering Olin plants have experienced a deceleration event in excess of a target threshold. In an effort to determine where to set the deceleration alert threshold that would trigger visual and mechanical inspection of coupler components (Figure 2.18), Olin conducted a study to determine damage encountered as a function of deceleration speed. The study involved an analysis of 200 tank cars that Olin owns that were tracked and inspected over a 12-month period, using data generated by the GPS-enabled fleet when being moved by Class I and regional railroads, and while located in shipping and receiving yards. This amounted to a sample size of 2,660 car bills. All cars were loaded to within 3% of their maximum allowable weights, and decelerations were monitored during the loaded legs of the trip because the higher mass would result in higher forces and more damage. Olin operation inspections and repairs were combined with rail car repair billing data from Railinc (supplying in-transit repair information) to identify any coupler damage incurred by these tank cars during the study period.

Using the maximum coupling speed obtained during each car bill trip, the probability of a damaged component was determined by dividing the number of maximum coupling speeds at each level by the number of bad components found (Figure 2.19).

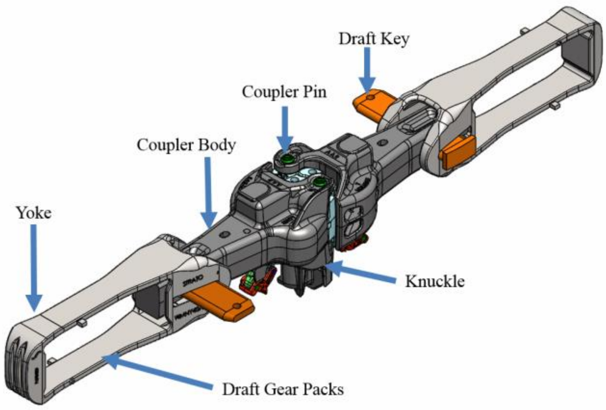


Figure 2.18 - Railcar Coupler Configuration

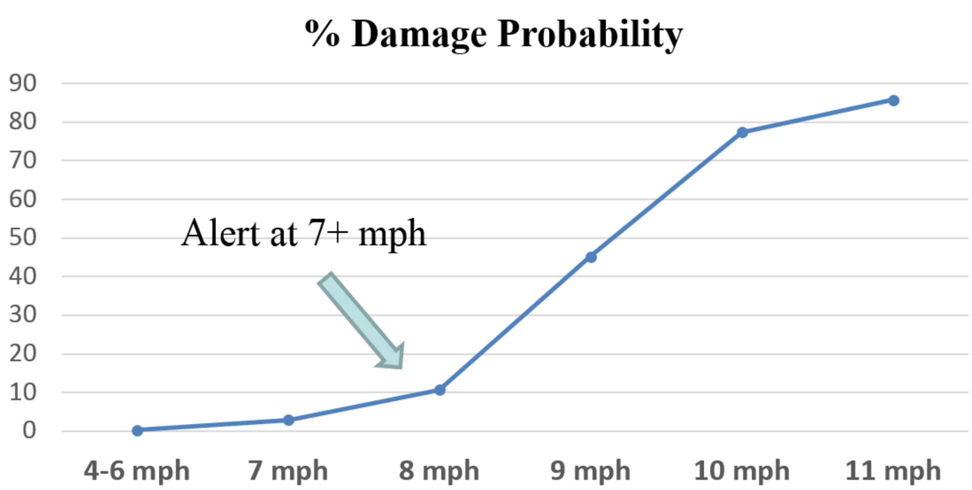


Figure 2.19 - Coupler Damage Probability Versus Maximum Deceleration Speed

Noting that damage classified is cumulative left to right, one can observe that at a collision velocity of greater than 8 mph, coupling damage becomes a much more frequent consequence. Hence, Olin set its alert threshold at 7+ mph, meaning that railcar alerts are sent to plant operations when railcars entering the plant have experienced a deceleration event in excess of the reporting threshold.

To adequately capture deceleration speeds, the location of the GPS unit on top of the railcar is an important consideration, as forces are concentrated, especially in an undamped system, and they may not propagate fully down to the GPS location. Since a car can be struck on either end, ideally having the GPS on the center of the car would be best to ensure impact is detected equally from both ends. In consultation with Lat-Lon, Olin's GPS vendor, a decision was made to position the unit off-center, enabling the device camera to obtain a wide angle of view such that the platform and ladder can be clearly seen. Placing the unit outside the platform area also reduces the potential for device damage and tampering.

As the GPS units contain an accelerometer that is capable of generating 10 Hz and 100 Hz filtered values, this provides an additional method for determining (and verifying) deceleration speed.[3] The accelerometer-based approach is capable of detecting short duration, high impact events that last less than 50 milliseconds. This shock pulse type event is measured by subtracting the 10Hz reading from the 100Hz reading, producing a G-force lateral impact. To accommodate this consideration, Olin's GPS devices are programmed to report any impact forces of larger than 2G that are accompanied by deceleration events in excess of 3 mph. An important consideration, however, is recognition of false alarms. For that reason, the GPS unit is prompted to take a picture whenever a deceleration event greater than 5 mph or an impact over 5G is recorded.

2.3.4 Monitoring Derailment Incidents

Derailments are another Olin trigger event requiring an alert notification. Figure 2.20 shows a derailment event on a train carrying an Olin shipment, which prompted an alert to be generated within three minutes of the event occurrence. Note that the derailment location is identified along with an image captured by the GPS unit. This information has been supplemented by data recorded on the change in velocity leading up to the incident. From the captured image, it can be seen that the trees are horizontal so the car is definitely on its side. In Figure 2.21, images are shown following re-positioning of the railcar on the track. The image shows that the dome lid is open, but also indicates that no product is leaking (opening the dome lid provides access to the valves, but does not expose the product unless the valves are compromised). Significant damage to the railcar skin is also visible.

[3]Filtering is used to remove structural vibrations or ringing from the signal.

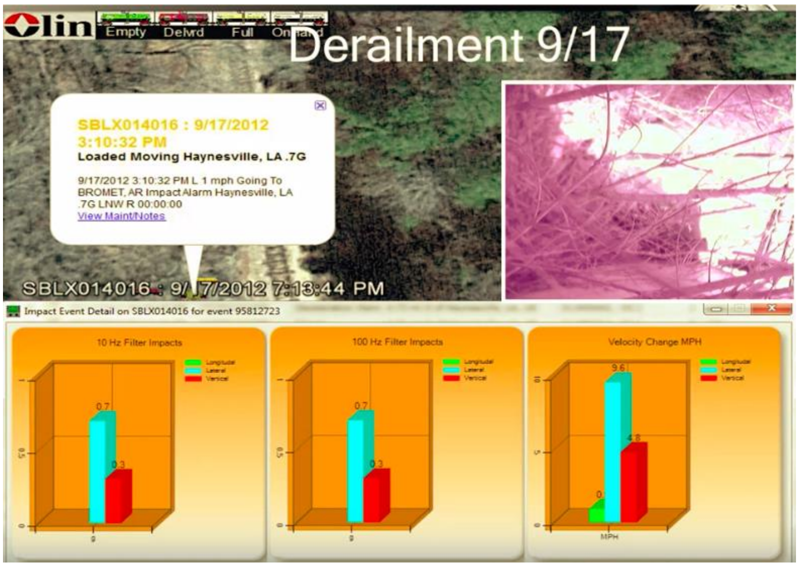
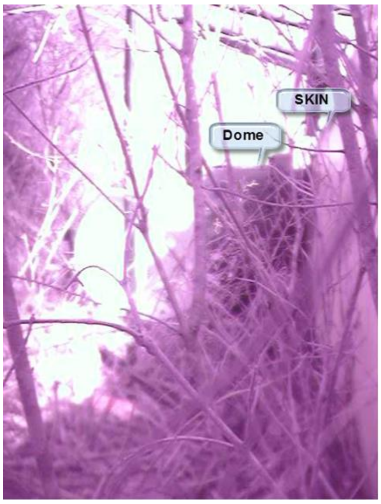


Figure 2.20 – Olin Derailment Event



Impact Picture

After Re-Track

Figure 2.21 - Dome Lid Open

2.3.5 Natural Hazard Event Tracking

Olin's Crisis Management System includes a real-time feed that provides up-to-date information on severe weather as well as seismic activity. Figure 2.22 displays information the company utilized after Hurricane Matthew had made landfall. By overlaying the hurricane footprint on Olin railcar assets (dots show railcar locations; colors represent different hazmat products), a determination could be made as to how to manage the safety of these assets. Seismic activity potentially impacting Olin's shipments are shown in Figure 2.23 for the La Habra earthquake that struck southern California. The location of railcars in vicinity of the earthquake were identified, from which a decision could be made as to whether any damage inspection was warranted.

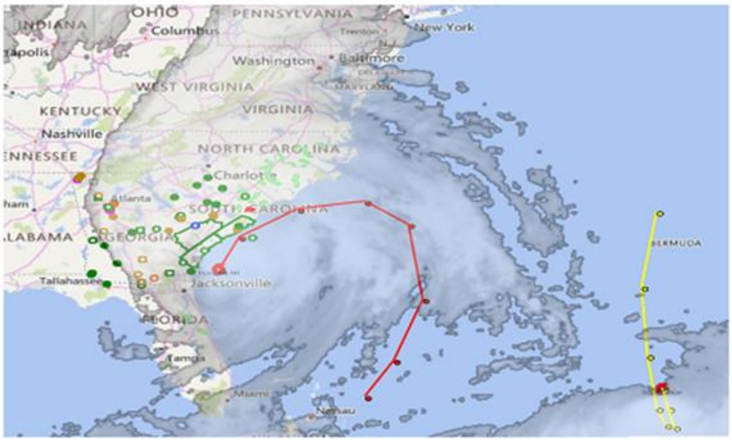


Figure 2.22 - Severe Weather Tracking: Hurricane Matthew

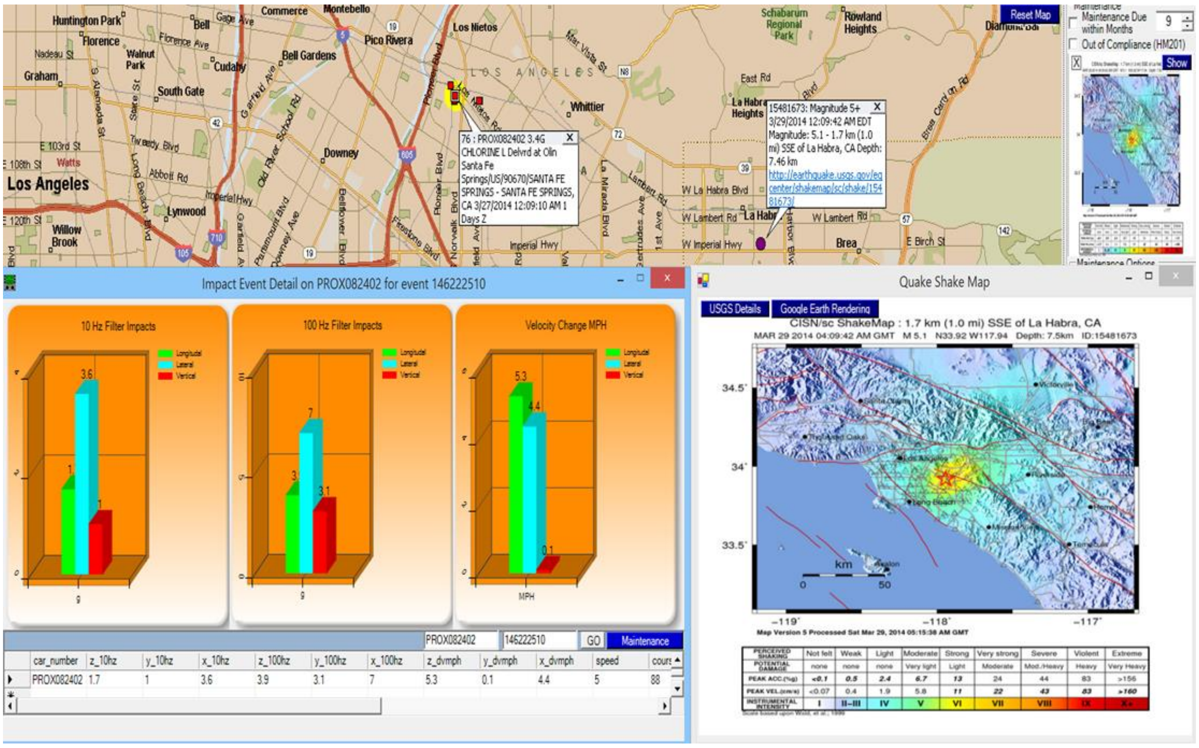


Figure 2.23 - La Habra Earthquake

2.3.6 Google Earth Flight Verification

An additional activity that Olin deploys is to utilize Google Earth flights to generate a movie that provides a bird's eye view of the trip made by a particular railcar (Figure 2.24). This includes demarcating the location of any alerts that were issued during the trip which, when combined with other relevant data, can create a more comprehensive profile of the event in question (Figure 2.25).

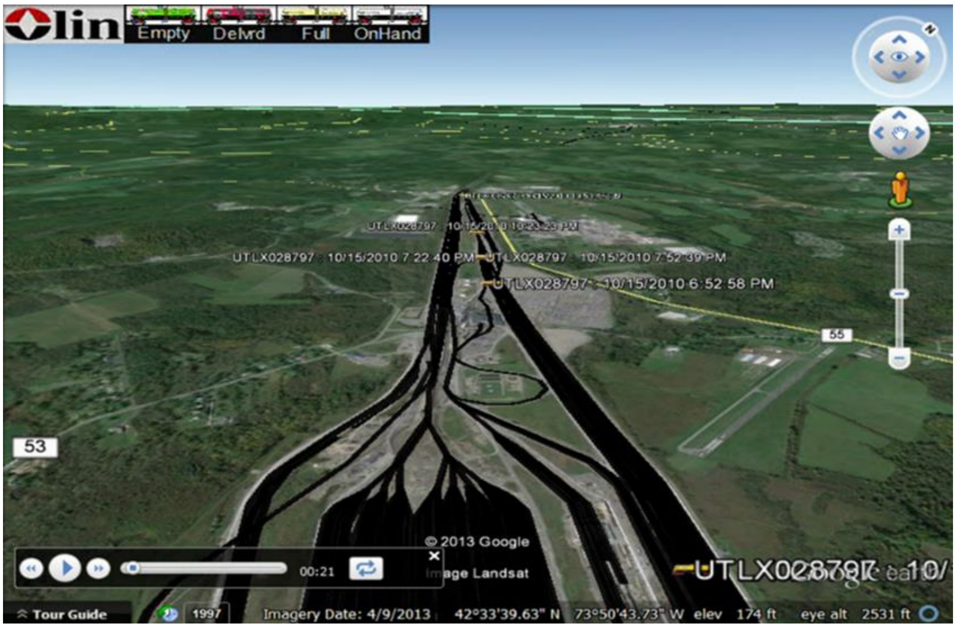


Figure 2.24 - Trip Imagery via Google Earth Flight

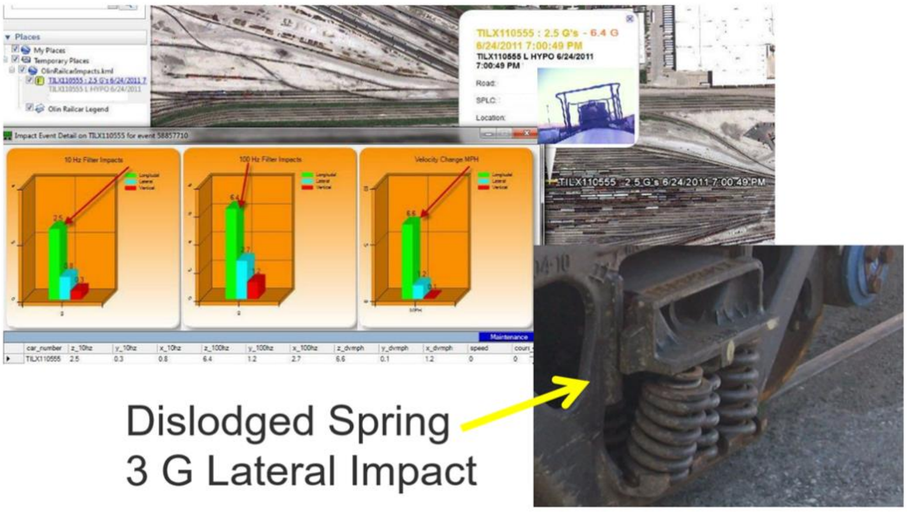


Figure 2.25 - Google Earth Flight Events and Images

2.3.7 System Impacts
Since implementing the Integrated Technology System for Rail Shipper Safety & Security, Olin has experienced a dramatic reduction in the risk of transporting hazardous materials as well as realizing cost savings. The discussion below provides examples of this achievement.

Condemnable Wheels

Figure 2.26 shows the impact on the weekly average of condemnable wheels during the past several years, coinciding with when the integrated rail safety and security system has been in place. Although there are aberrations in week-to-week performance, there is a clear general trend of a substantial reduction in the number of condemnable wheels related to Olin railcars. This significant improvement in fleet health has several important implications: 1) reduces the costs associated with installing new wheel sets, 2) helps to flatten the maintenance budget, 3) provides ability to better focus and streamline inspections, and 4) finds and repairs dangerous trucks before they can cause a serious incident.

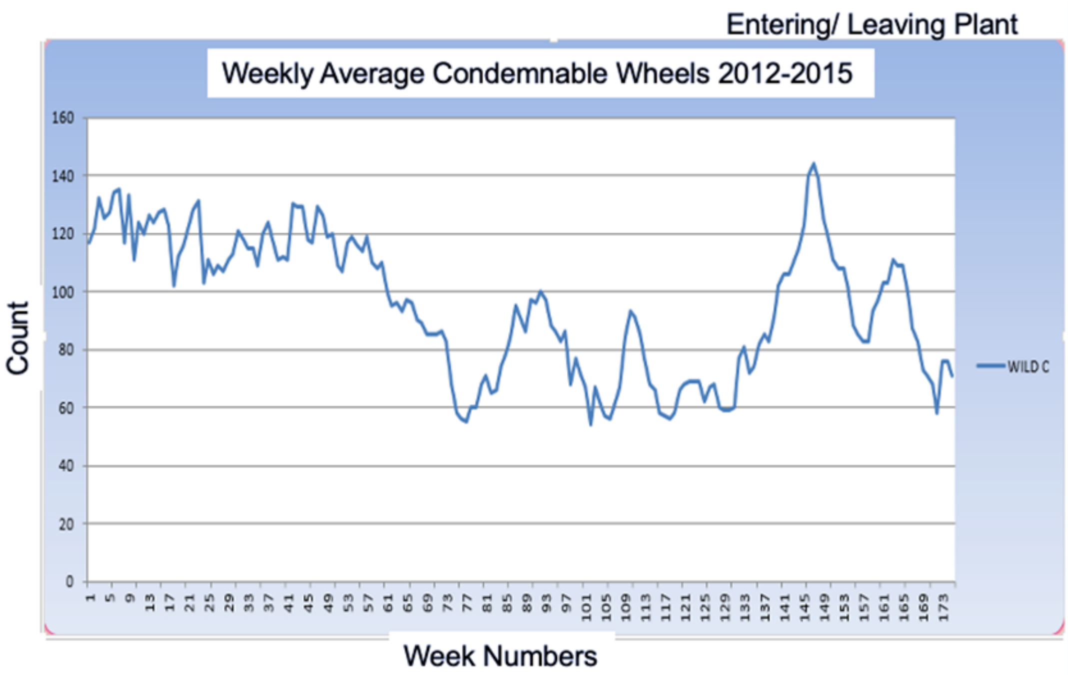


Figure 2.26 – Olin Weekly Average Condemnable Wheels: 2012-2018

Other Considerations

The ability to collect and archive such a vast array of railcar performance data, augmented by data analytics to investigate specific rail safety and security issues, has enabled Olin to utilize technology adoption in a proactive manner. For example, the company has the ability to compare safety records at various classification yards, and notify corresponding railroads where sub-standard handling of Olin railcars is being observed. A related consideration is the ability to evaluate flat yard versus hump yard safety performance, with an eye towards working with the rail carriers to route Olin shipments so as to reduce the risk of railcar damage based on analysis results.

2.4 Findings and Recommendations

The adoption of smart detection systems and corresponding communication technology affords an opportunity to further improve the safety and security of rail shipments of hazardous materials, with an eye on both incident prevention and consequence mitigation. The SHRIS system described herein leverages these technology advancements, with the hazmat shipper as the driver of this process. Providing the shipper with these capabilities is key to influencing the entire hazmat transportation supply chain, given their knowledge of the product, and their relationship with rail carriers and customers.

A distinct project objective is to transfer system knowledge for the purpose of enabling other hazmat shippers who use the rail mode to leverage its availability. The existence of a proven and affordable system can enable hazmat rail shippers of all sizes to leverage this capability, and not just a select few within the industry. Such widespread adoption benefits not only each individual shipper, but the industry as a whole.

3. FEASIBILITY TEST OF LOW-POWER WIDE-AREA NETWORK LONG RANGE GATEWAY MODEMS IN DEPLOYING AN INTEGRATED TECHNOLOGY SYSTEM FOR RAIL SHIPPER SAFETY & SECURITY

With GPS-based, cellular technology systems proving to be effective in managing the safety and security of high-hazard shipments via rail, a natural extension is to consider the efficacy of deploying a technology system with similar capabilities to be used in managing the safety and security of other hazardous materials that are not considered as dangerous. For these types of materials, arguably a technology-based solution that requires less time sensitivity and offers a potentially lower cost in its reporting can be utilized. In such cases, anomalies can be detected while the shipment is en-route, with the information stored until reaching a location that is more conducive to taking risk mitigation actions (e.g., shipper facility), at which time the information is retrieved and acted upon.

For this application, the study team evaluated a system that relies on the use of Low-Power Wide-Area Network (LoRa) gateway modems as a means of communication using a technology developed by Lat-Lon, LLC. LoRa requires less power for smaller transmission packets compared to a wireless wide area network, like cellular networks, which require more power and can handle larger data packets at a faster rate. This system has a network topology where sensors embedded with LoRa chips send messages to gateways. Gateways then pass along the messages with cellular, satellite, Ethernet, or wifi to a network server.

In the past, many hazmat shippers have avoided implementing GPS-based, cellular technology systems because of the monthly overhead costs of cellular or satellite provider fees. The LoRa configuration, if proven, could eliminate this concern by limiting the cost to the device purchase and avoiding monthly fees by allowing a trip history to be offloaded once a car returns to a gateway facility (see Figure 3.1).

Using data provided by a LoRa system pilot-tested by Olin Corporation on the company's rail tank cars, the study team analyzed the accuracy and reliability of this system based on data collected from these tank cars over an operating period of four months. Additionally, a GPS-based, cellular technology unit (hereafter referred to as the Shipper Hazmat Risk Information System - SHRIS) and a LoRa unit were installed on the same Olin tank car to afford a more direct performance comparison.

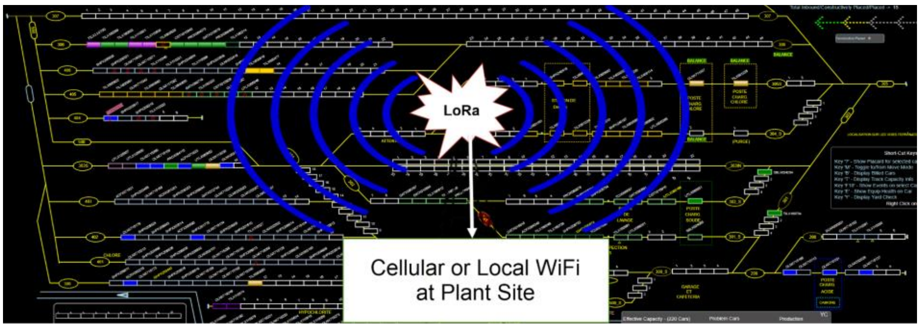


Figure 3.1 - LoRa Communication Transmission at Shipper Rail Yard

3.1 LoRa Network Technology

LoRa hardware evaluated by the study team consists of a solar tracking unit (STU) and the Lat-Lon gateway as displayed in Figure 3.2. The STU is designed to be operational at all times of the day and night. Since the STU unit does not contain a cellular modem, no cellular data fee is incurred, making it a potentially cost-effective data communication unit. When the LoRa STU is within range of a gateway (e.g., shipper rail yard), the STU wirelessly transmits the stored data to a server, from which users can analyze the information and take appropriate action. When the LoRa units are out of range, up to 5,000 messages can be stored. Each LoRa unit is designed to function for up to five days continuously without a re-charge. Figure 3.3 provides a schematic of system components and interactions (Lat-Lon, 2017).

Figure 3.2 - LoRa Hardware (left: STU, right: Lat-Lon gateway)

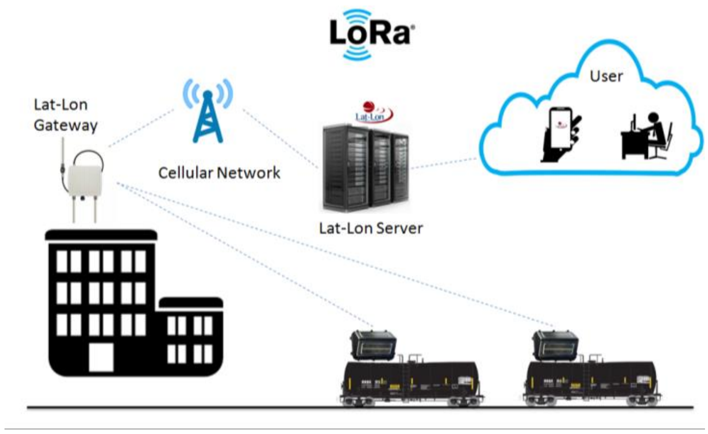


Figure 3.3 - LoRa Technology Overview

Each LoRa unit has a unique identification number, and is designed to record the following information:

- Date/time when unit begins recording a message or reading
- Date/time when unit completes a message or reading
- Date/time when unit transfers the message to a gateway unit

- Latitude/longitude location of the unit (railcar) when a message or reading is recorded[4]
- Railcar speed based on GPS satellite readings
- Number of GPS satellites used to recognize the railcar's location
- Time required for the GPS satellite to fix its position
- Environmental temperature reading for reported latitude and longitude location
- Sensor (accelerometer) reading providing impact force for 10Hz
- Sensor (accelerometer) reading providing impact force for 500Hz
- Sensor (hatch tilt) reading
- Change in velocity (deceleration) reading
- Number of messages in queue which are waiting to be communicated with a gateway when it is within range
- Various message types: 1) daily and daughter card health[5,6], 2) deceleration alarm, 3) impact alarm, 4) sensor triggered alarm[7], 5) move begin, 6) move end, 7) move time, 8) timed, 9) sensor begin, 10) sensor end, and 11) sensor time.

The LoRa units are designed to provide messages every ten minutes when moving, or every hour when stopped or when any changes are picked up by a sensor.

Move begin, end and timed message readings are related to car movement. These are reported by the solar unit. This unit is constantly monitoring the GPS location and a move begin message is triggered when a speed of 5 mph is observed. A timed message is issued nearly every hour, irrespective of whether the car is moving or staying still. These are similar to health messages. The frequency of reporting can be adjusted based on user preference.

Impact alarms are registered and calculated using two frequencies: 10Hz and 500Hz. The thresholds for reporting these alarms are set based on user preference and are programmable. The deceleration alarm is also programmable and can be set to a given speed drop within a specified time frame. Olin utilizes a speed drop threshold of 16 mph, such that when this threshold is met, the speed drop message is activated. This threshold comports with recognizing potential de-humping, de-slip, and de-coupling events.

3.2 Pilot Test Results

3.2.1 Multi-Unit Application

Fifty-four Olin rail tank cars were outfitted with the LoRa technology for an extended period of time. For the purpose of this evaluation, Olin provided the study team with data transmitted by the LoRa units covering the operating period from September 1 to December 19, 2018. All messages from these units were transmitted wirelessly to a gateway unit located at the Olin rail yard facility.

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[4] This information is also used when applying geofencing, such that if a rail car location is found to be outside of the geofenced area, an alarm is recorded.

[5] Some sensor units have two boards which process and send the required data via different communication channels (e.g., wireless, Bluetooth, usb). Hence, there are two health monitors for these units, one for the main board (daily health) and the second for the other board, also known as daughter card.

[6] Daily and daughter health are messages sent by the solar unit to indicate the health of the unit; this message is transmitted once daily.

[7] When a tilt of 45 degrees or more is observed, a dome open message is reported.

Data Verification & Validation
A summary of LoRa trips and message types for each unit is provided in Appendix A (see Tables A.1 and A.2). Of the 54 LoRa units, it was discovered that only 38 units were functional.[8] Of the functional units, the most active unit (car UTLX631665) only reported on 72% of the days during the study time period. Moreover, none of the cars provided complete trip information. For example, as shown in Figure 3.4, the unit on car UTLX631266 recorded for 25 days between September 2 and December 4. The trip records from a location in Charleston, TN and breaks due to missing data for 69 days, before reappearing with messaging in Louisville, KY. Moreover, sensor move begin, sensor move end and sensor timed readings should align closely with the move begin, move end and move timed messages, yet these readings do not comport and have a large deviation[9].

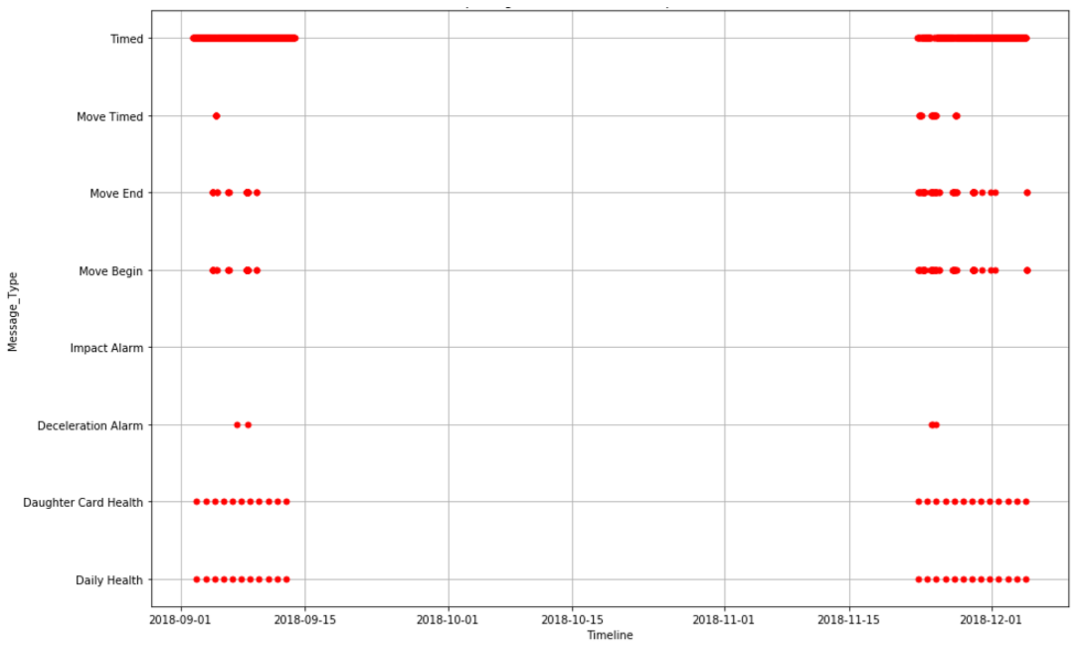


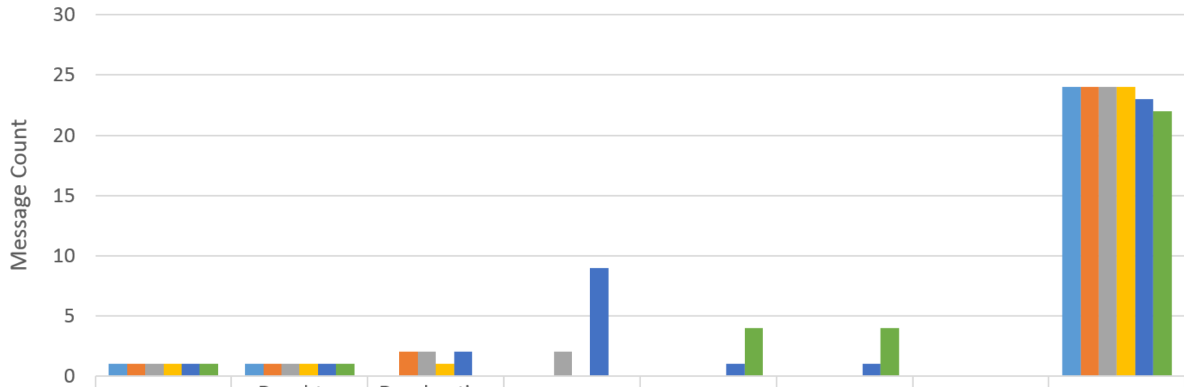
Figure 3.4 - Message Type Reported for Car UTLX631266

3.2.2 Direct Technology Comparison
Concurrent with the operation of the LoRa fleet, Olin installed both SHRIS and LoRa units on the same rail tank car for a limited period of time. This afforded the study team with an opportunity to make a direct comparison of the performance of the two technologies. Of particular interest was a one-week period in September, 2019, during which several different types of messaging were incurred. The messaging results for SHRIS and LoRa appear in Figures 3.5 and 3.6, respectively.

Several observations can be made based on an assessment of the results. First, every LoRa message recorded by the LoRa unit appears to be also captured by SHRIS, with the exception of an apparent movement on September 3. However, SHRIS contains several additional

[8] It is possible that 14 units were either not installed as indicated or removed prior to the study time period.
[9] Not all LORA units registered sensor triggered movements and timed reporting, hence the large deviation between move message types and sensor message types.

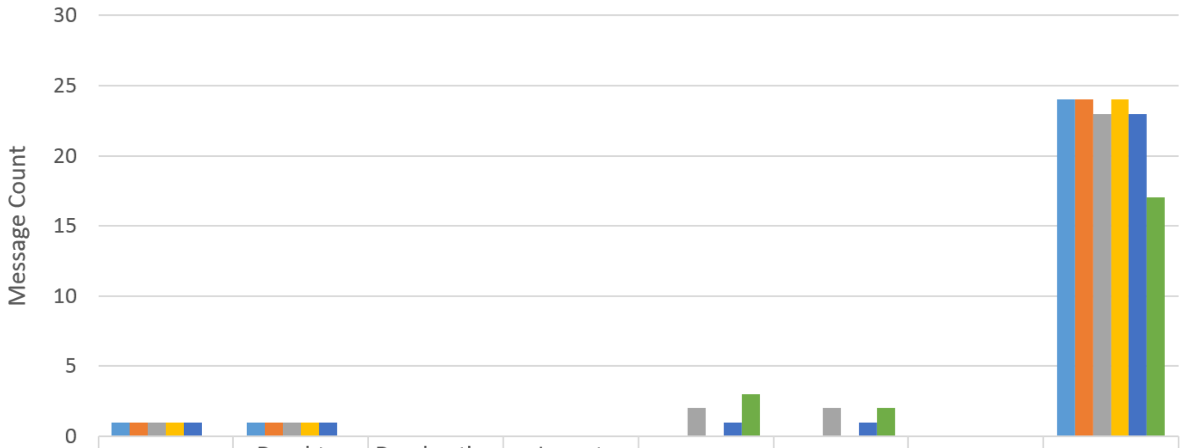
messages that are not included in the LoRa database. In the case of deceleration and impact alarms, SHRIS recorded several of such instances, whereas none were recorded by the LoRa unit[10]. Notable also is that the LoRa unit failed on one day to record either a daily health or daughter card health report, even though such messaging is expected every day, even if the rail car is sitting idle and going nowhere.



	Daily Health	Daughter Card Health	Deceleration Alarm	Impact Alarm	Move Begin	Move End	Move Timed	Timed
1-Sep	1	1						24
2-Sep	1	1	2					24
3-Sep	1	1	2	2				24
4-Sep	1	1	1					24
5-Sep	1	1	2	9	1	1		23
6-Sep	1	1			4	4		22

Figure 3.5 – SHRIS Messaging Results

[10] We acknowledge that it is possible that the sensors themselves may report false alarm positives; however, the consideration here is that these sensor messages were recorded as having occurred by SHRIS and were not picked up by the LoRa unit.



	Daily Health	Daughter Card Health	Deceleration Alarm	Impact Alarm	Move Begin	Move End	Move Timed	Timed
1-Sep	1	1						24
2-Sep	1	1						24
3-Sep	1	1			2	2		23
4-Sep	1	1						24
5-Sep	1	1			1	1		23
6-Sep					3	2		17

Figure 3.6 – LoRa Messaging Results

3.3 Findings and Recommendations

The objective of this effort was to examine the reliability of deploying a technology-based solution that utilizes Low-Power Wide-Area Network Long Range gateway modems as a means of communication, such that anomalies detected while a shipment is in transport could have this information stored until reaching a gateway location more conducive to taking risk mitigation actions. As many hazmat shippers have avoided implementing GPS-based, cellular technology systems because of the monthly overhead costs of cellular or satellite provider fees, this technology could offer an attractive solution, as it would require less time sensitivity and lower cost in its reporting for managing the safety and security of hazardous materials, particularly those that are not considered sufficiently dangerous to warrant an immediate mitigation response.

Two evaluation procedures were applied in assessing the LoRa technology, utilizing installations on several rail tank cars owned by Olin Corporation, one involving an analysis of data recorded by LoRa units installed on a fleet of fifty-four rail tank cars, and the other focused on the performance of a single rail tank car on which a GPS-based, cellular technology unit (as used in SHRIS) and a LoRa unit were both installed for the same time period. In both cases, the LoRa units failed to provide consistent and reliable messaging as intended by its functional design. There are several potential explanations for such poor performance, among them being: 1) drain on the solar batteries, 2) drops in coverage, and 3) other design and construction features of the units that render them inoperable in the environment (e.g., climate) in which they are expected to perform. As a result, we conclude that this particular LoRa-based technology solution cannot be recommended for active deployment.

If there is a silver lining, it comes with the knowledge that the cost for cellular service has dropped precipitously of late. Olin, for example, has experienced a roughly 50% reduction in the cost of its cellular service to support SHRIS operation over the past six years. Given this development, what was thought to be a cost-prohibitive solution for some hazmat shippers to deploy a SHRIS-like technology solution for managing the safety and security of their shipments, is now within economical reach. This being the case, a system based on LoRa technology may no longer be needed in the marketplace.

4. FEASIBILITY TEST OF IMPLEMENTING DIGITAL MECHANICAL LOCKS

A much-discussed topic among shippers has been the potential for installing digital mechanical locks that can be opened/closed via remote access. To date, this technology has not been applied to railcar shipments.

This task focused on investigating the potential for deploying this capability for rail tank car dome hatches, using a commercially available technology. The demonstration consisted of designing, installing and testing a digital dome hatch lock on a rail tank car owned by the Olin Corporation and located within the company's Charleston, TN facility. The following discussion describes the digital lock technology, installation process, and performance results.

4.1 Background

Typically, a rail tank car has product filled and retrieved via valves located in a protective housing. Access to these values is by a hatch located on the car's dome. The means to secure the dome is via the use of a metal pin, as shown in Figure 4.1. A pin is manually inserted to hold the lid closed. A small wire or cable seal is placed on the pin prior to transport to verify to the receiver that the product has not been tampered with. The wire or cable seal can be removed by cutting with standard pliers. Access to the product offloading valves can be easily gained by a voluntary or intentional action, posing both safety and security concerns.

Figure 4.1 - Traditional Dome Hatch Lock Configuration

For these reasons, rail shippers of hazardous materials have been interested in technological solutions that would enable the use of a digital mechanical lock as a safety and security enhancement.

The project team performed a search for available commercial technologies that offered the potential to be retrofit to serve this purpose. This resulted in the identification of the Power-In-Lock system, developed by QProducts & Services, a digital mechanical lock designed for use on trailers in the trucking industry.

Power-In Lock consists of a keyless, Bluetooth-enabled hardware device with a serial interface that can lock/unlock physical entry to a designated cargo location. The software platform supports a web application, backed by a secure control center (with AES128 encryption) that authorizes device users, with permission levels established according to user role and access to sensitive information. Users can send lock and unlock commands via Bluetooth from any Apple or Android smart device, with each action recorded in a database by user for verification and analytics. The system can be powered via a solar device mounted to the vehicle.

The Power-In-Lock has been successfully used in the transportation industry, specifically in the trucking industry, where deployment is subjected to similar environmental exposures. The project team thus recognized considerable potential for its use as a digital mechanical locking system for rail tank car dome hatches. Contact with QProducts & Services ensued, leading to a series of discussions between the vendor, Olin and Vanderbilt about the prospect for adapting this technology for tank car dome hatches.

4.2 System Design and Installation

Retrofitting the Power-In-Lock system design for rail tank car dome hatches required some modifications, particularly with regard to how the hardware would be mounted and the mechanical operation of opening and closing the hatch pin itself. After detailed analysis of the typical tank car configuration, the team agreed on the design specification shown in Figure 4.2.

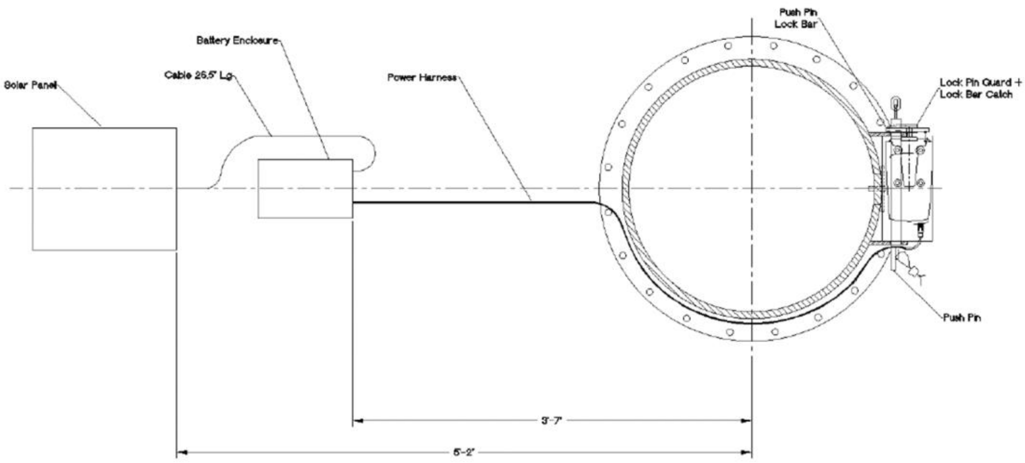


Figure 4.2 – Rail Dome Hatch Power-In-Lock System Design

In early July, 2020, QProducts and Services technicians traveled to Olin's Charleston facility to assist Olin engineers with product installation. As shown in Figure 4.3, the solar panel and battery box were mounted on the top of the rail tank car, with a cable leading to the Power-In-Lock device. The system is powered by a battery and recharged via solar power. Note that if tampering of the power wires to the lock occurs, the lock pin will retain its current state (locked or unlocked) when power is removed. However, although not included in the demonstration, tamper resistant hardware and cable covers can be added to protect the connection between the power supply and the unit mounted to the hatch dome.

Figure 4.3 - Solar Panel and Battery Box

The device itself was affixed as an external mount located directly under the dome hatch cover pin placement. Figure 4.4 shows the location of the lock mounting plate, to which the device is mounted and cabled to the solar panel (see Figure 4.5).

Figure 4.4 - Lock Mounting Plate

Figure 4.5 - Power-In-Lock Attached to Mounting Plate and Cabled to Solar Panel

The device is attached to the pin such that it can control the lock/unlock movement of the pin (see Figure 4.6). With the pin latch resting on the latch catch, the hole is aligned with the lock pin and magnet is aligned with lock's internal hatch closed sensor. After the lock pin is extended, internal sensors identify that the hatch is locked. Of particular note is that during the installation process, the following additional retrofits were performed: 1) replaced the hatch pin with a longer 18" version to accommodate the latch plate, and 2) re-oriented the chain so the first link welded to hatch pin is parallel with hatch pin.

Figure 4.6 - Dome Hatch Pin

The fully installed device is pictured in Figure 4.7.

Figure 4.7 - Fully Installed Device

4.3 Test Results

Following device installation, a series of lock/unlock tests were performed over a three-week period. Efforts were made to conduct tests at different times of day, as well as under varying temperature and atmospheric conditions. Some variation in environmental conditions were achieved though testing the device during a precipitation event was not possible.

Test results are displayed in Table 4.1. Overall, 33 individual lock/unlock tests were performed, with a 100% success rate.

Table 4.1 – Test Results

Timestamp	Event Type	Atmospheric Conditions	Air Temp (°F)	Precipitation
2020-07-27 06:22:03	Lock	Clear	72	No
2020-07-27 06:21:52	Unlock	Clear	72	No
2020-07-27 06:21:46	Lock	Clear	72	No
2020-07-27 06:21:39	Unlock	Clear	72	No
2020-07-27 06:21:33	Lock	Clear	72	No
2020-07-27 06:21:29	Unlock	Clear	72	No
2020-07-27 06:21:23	Lock	Clear	72	No
2020-07-27 06:21:16	Unlock	Clear	72	No
2020-07-27 06:21:07	Lock	Clear	72	No
2020-07-27 06:20:58	Unlock	Clear	72	No
2020-07-27 06:20:52	Lock	Clear	72	No
2020-07-23 08:00:08	Unlock	Clear	72	No
2020-07-23 08:00:02	Lock	Clear	72	No
2020-07-23 07:59:56	Unlock	Clear	72	No
2020-07-23 07:59:44	Lock	Clear	72	No
2020-07-23 07:59:37	Unlock	Clear	72	No
2020-07-23 07:59:31	Lock	Clear	72	No
2020-07-14 14:01:36	Unlock	Clear	77	No
2020-07-14 14:01:25	Lock	Clear	77	No
2020-07-14 13:59:41	Unlock	Clear	77	No
2020-07-14 13:59:29	Lock	Clear	77	No
2020-07-14 13:59:18	Unlock	Clear	77	No
2020-07-14 13:59:04	Lock	Clear	77	No
2020-07-14 07:35:43	Unlock	Clear	67	No
2020-07-14 07:35:34	Lock	Clear	67	No
2020-07-14 07:35:22	Unlock	Clear	67	No
2020-07-14 07:33:52	Unlock	Clear	67	No
2020-07-14 07:33:39	Lock	Clear	67	No
2020-07-14 07:33:29	Unlock	Clear	67	No
2020-07-14 07:33:16	Lock	Clear	67	No
2020-07-09 09:37:04	Unlock	Partly Cloudy	71	No
2020-07-09 09:36:57	Lock	Partly Cloudy	71	No
2020-07-09 09:36:40	Unlock	Partly Cloudy	71	No
2020-07-09 09:36:29	Lock	Partly Cloudy	71	No
2020-07-09 09:36:20	Unlock	Partly Cloudy	71	No
2020-07-09 09:31:55	Unlock	Partly Cloudy	71	No
2020-07-09 09:31:47	Lock	Partly Cloudy	71	No
2020-07-09 09:28:57	Unlock	Partly Cloudy	71	No
2020-07-09 09:28:44	Lock	Partly Cloudy	71	No
2020-07-09 08:01:34	Unlock	Partly Cloudy	72	No
2020-07-09 08:01:28	Lock	Partly Cloudy	72	No
2020-07-09 08:01:21	Unlock	Partly Cloudy	72	No
2020-07-09 07:00:03	Lock	Partly Cloudy	72	No
2020-07-09 06:59:56	Unlock	Partly Cloudy	72	No
2020-07-09 06:59:46	Lock	Partly Cloudy	72	No
2020-07-09 06:59:38	Unlock	Partly Cloudy	72	No
2020-07-09 06:59:32	Lock	Partly Cloudy	72	No
2020-07-08 15:15:04	Unlock	Partly Cloudy	82	No
2020-07-08 15:14:43	Lock	Partly Cloudy	82	No
2020-07-08 15:10:56	Unlock	Partly Cloudy	81	No
2020-07-08 15:10:48	Lock	Partly Cloudy	81	No
2020-07-08 15:10:41	Unlock	Partly Cloudy	81	No
2020-07-08 15:10:33	Lock	Partly Cloudy	81	No
2020-07-08 15:10:26	Unlock	Partly Cloudy	81	No
2020-07-08 15:10:10	Lock	Partly Cloudy	81	No
2020-07-08 14:54:53	Unlock	Partly Cloudy	81	No
2020-07-08 14:54:45	Lock	Partly Cloudy	81	No
2020-07-08 14:54:34	Unlock	Partly Cloudy	81	No
2020-07-08 14:54:06	Lock	Partly Cloudy	81	No
2020-07-08 14:53:26	Lock	Partly Cloudy	81	No
2020-07-08 14:53:11	Unlock	Partly Cloudy	81	No
2020-07-08 14:53:03	Lock	Partly Cloudy	81	No
2020-07-08 14:51:50	Unlock	Partly Cloudy	81	No
2020-07-08 14:51:32	Lock	Partly Cloudy	81	No
2020-07-08 14:51:16	Unlock	Partly Cloudy	81	No
2020-07-08 14:51:05	Lock	Partly Cloudy	81	No

4.4 Findings and Recommendations

The objective of this task was to demonstrate the feasibility of deploying a commercially-available digital mechanical lock system to secure the dome hatch on rail tank cars. This proof-of-concept demonstration consisted of identifying, installing and testing the performance of a digital dome hatch lock on a rail tank car owned by the Olin Corporation. The Power-In-Lock system, developed by QProducts and Services and used by the trucking industry as a digital mechanical lock to secure truck trailer cargo, was identified as a candidate technology for performing this demonstration. This system was re-configured to be compatible with a rail tank car dome hatch and subsequently installed on the dome hatch of an Olin rail tank car.

Following product installation, system performance was tested under a variety of weather conditions over a period of several weeks. The results showed that the digital lock successfully performed its stated function under these conditions. Consequently, we conclude that an opportunity exists to improve rail tank car safety and security with this innovation.

The potential exists to combine this smart-lock technology with on-board GPS technology. Both technologies possess Bluetooth capabilities. Although not tested in this pilot, combining these capabilities could provide the ability to geo-fence origin and destination locations, allowing the automatic unlocking at end point locations and locking during transport. Due to restrictions resulting from the Covid-19 pandemic, there was not adequate time to further investigate or demonstrate this potential application.

Extensive approval requirements have been established by the Association of American Railroads (AAR) to modify rail tank car equipment. Based on demonstration results, it is now possible for the AAR, in concert with the Pipeline and Hazardous Materials Safety Administration (PHMSA) and other industry stakeholders, to proceed with the next steps in obtaining preliminary approval to modify rail tank car equipment to allow the use of digital mechanical locks on rail tank car domes.

5. ASSESSING SYSTEM TRANSFERABILITY TO BARGE AND TRUCK MODES

This section assesses the feasibility and value of developing and implementing a SHRIS-like system that could enable hazmat barge and truck shippers to make functionally equivalent risk-informed decisions and communicate necessary information to appropriate hazmat transportation stakeholders. It includes recommendations as to whether/how such a system could be constructed and adopted, with the potential to offer a practical, affordable and achievable outcome.

5.1 Relevant Comparative Modal Characteristics

It is first important to recognize that the rail, barge and truck freight modes provide transport under very different operating conditions (see Table 5.1). Notable among these distinctions is the difference in the capacity of an individual hazmat shipment, where a rail tank car has roughly twice the capacity of a tank trailer, and both are dwarfed by the capacity of a single tank barge, which can be up to 100 times as large. Moreover, whereas each truck tractor typically hauls a single tank trailer, each train can be composed of multiple tank cars, and an individual towboat can carry a flotilla of tank barges transporting as much as 20 million gallons. Due to this difference in shipment size, arguably barge shipments pose the greatest threat to community safety and security in the event of a release during shipment.

Another notable distinction is the amount of paperwork that is required by regulation to be present onboard a barge. Whereas no such requirement exists for the rail and truck modes, where documents may be carried by the assigned train conductor or truck driver, the opposite is true for the barge mode. In the case of barge, multiple parties are required to both provide and maintain this documentation onboard, and also to use and verify various elements during a voyage. One key consequence is that in the event of a barge accident, obtaining this vital information may be compromised (see Figure 5.1) if access to the vessel is prevented by the incident which may often be the case.

Table 5.1 - Comparative Modal Characteristics

Characteristic	Rail	Barge	Truck
Vehicle Employed	Tank Car	Tank Barge	Tank Trailer
Typical Capacity	25k Gallons	420k-1200k Gallons	12k Gallons
Vehicle Ownership	Shipper	Shipper or Carrier	Shipper or Carrier
Motive Power	Locomotive	Towboat	Truck Tractor
Loading/Discharging	Shipper/Receiver	Licensed Tankerman	Truck Driver
Inspection Responsibility	Shipper/Receiver	Tankerman/Towboat Crew/Shipper/Receiver/US Coast Guard/	Truck Driver
Paperwork Onboard	None	Extensive	None

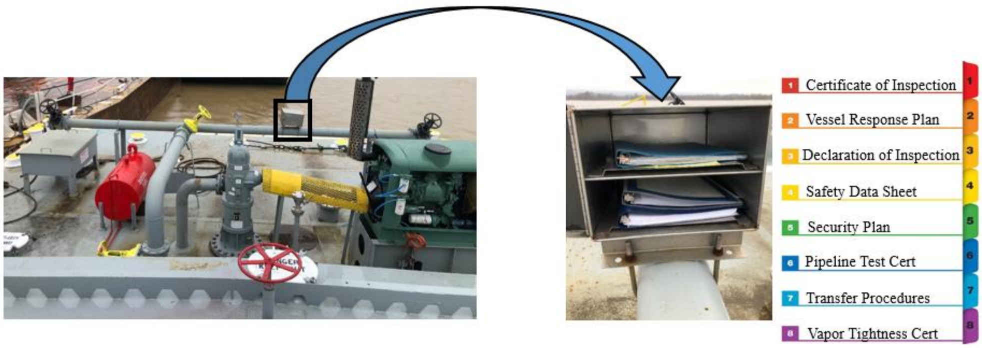


Figure 5.1 - Mailbox "Data Repository" on Barge

5.2 SHRIS System Elements

The SHRIS system is a combination of four interdependent functional components: 1) shipper/receiver facility system, 2) in-transit GPS data collection, and 3) in-transit natural hazard information, and 4) in-transit wayside vehicle location and detection/reporting. Each functional component is further comprised of specific feature elements, as shown in Figure 5.2.

- Shipper/Receiver Facility System
  - Automatic Equipment Identification (AEI) Reader
  - Cameras at Entrance/Exit from Terminal Facility
  - Scheduled Maintenance Identification
- In-Transit GPS Data Collection
  - Location Tracking
  - Tampering Sensors/Camera
  - Ride Quality Measurement
- In-Transit Natural Hazard Information
  - Extreme Weather Reporting
  - Earthquake Location and Intensity
- In-Transit Wayside Vehicle Location & Detection/Reporting
  - Vehicle Location Detection
  - Vehicle Condition Detection

Figure 5.2 - SHRIS System Components and Feature Elements

Based on an understanding of how these elements have been adopted and used in the rail environment, and on the inherent differences between the modes as reflected in Table 5.1, the feasibility of implementing a SHRIS-like system for barge and truck modes, respectively, was evaluated. Specifically, the assessment methodology examined each of the feature elements listed in Figure 5.2, utilizing two criteria: 1) the extent to which industry stakeholders would value the capability provided by the feature element, and 2) the feasibility and practicality of being able to provide the capability, given the modal operating environment and available technology.

5.3 Barge System Feasibility Assessment

Table 5.2 provides an assessment of the adoption value and feasibility, respectively, of the barge shipper/receiver facility system, with remarks included where appropriate. Note that while each of the feature elements has an adoption value considered as medium or high, the barge industry does not have automatic equipment identification (AEI) capability as is available to the railroad industry. With respect to cameras installed at the entrance/exit of a terminal facility, this feature element can often be accommodated at the typical shipper facility utilized in a barge system. Scheduled maintenance identification, considered to be of high adoption value, is a feature element that can also be accommodated in a barge system with modification.

Barge in-transit GPS data collection is considered to have high adoption value, particularly regarding GPS location tracking and tampering sensors/cameras (see Table 5.3). Moreover, these feature elements are judged to be feasible components to include in a barge system, with certain modifications. GPS ride quality measurement can also be accommodated in a barge system, although the measures of relevant ride quality characteristics are likely to be different.

Table 5.2 - Barge Shipper/Receiver Facility System

Feature Element	Adoption Value	Adoption Feasibility	Remarks
Automatic Equipment Identification (AEI) Reader	Medium	No	- No standard tagging - Towboat tracking feature widely adopted
Cameras at Entrance/ Exit from Terminal Facility	Medium	Yes	- Visual inspection by tankerman - Cameras already in use at many customer docking facility
Scheduled Maintenance Identification	High	With modification	- All tank barges have CG issued Certificates of Inspection (COI) that are carried onboard the barge - Expiration/Re-inspection is stipulated in the COI - Many tank barge owners also participate in international vetting protocol, SIRE - COI information could accompany carrier electronic Notice of Arrival

As shown in Table 5.4, extreme weather reporting is very important to the barge industry, as it can significantly impact navigation safety. Fortunately, this feature element can be readily accommodated within a barge system. Although earthquake location and intensity are also feasible to include in such a system, it is not considered to be a highly valued feature given how an earthquake event is likely to impact the maritime domain.

Table 5.3 - Barge In-Transit GPS Data Collection

Feature Element	Adoption Value	Adoption Feasibility	Remarks
GPS Location Tracking	High	With modification	- Towboats have AIS and ECDIS - Reporting done via towboat locations instead of separate device on barge - Barges in intermediate fleets represent a gap
GPS Tampering Sensors/ Camera	High	With modification	- Barges in intermediate fleet has gap in surveillance of barge - Crew inspects barge 4 times a day - Some towboats equipped with video surveillance of the flotilla to supplement inspection
GPS Ride Quality Measurement	Medium	Yes	- Impacts are readily detected via on-board inspection

Table 5.4 - Barge In-Transit Natural Hazard Information

Feature Element	Adoption Value	Adoption Feasibility	Remarks
Extreme Weather Reporting	High	Yes	- Can be sourced from NOAA - NAVTEX and ship to shore communication (part of ISM code)
Earthquake Location and Intensity	Low	Yes	- Can be sourced from USGS, unclear value in maritime domain

In-transit wayside vehicle location and detection reporting is highly valued by the barge industry (see Table 5.5), and we are optimistic about the ability to include these feature elements in a barge system. It appears that existing vehicle location detection technology can be directly applied to the barge system, whereas condition detection is deemed feasible, with modification, since there is presently no network-based sensor system present on the waterways as there is along rail rights-of-way.

Table 5.5 - Barge In-Transit Wayside Vehicle Location & Detection/Reporting

Feature Element	Adoption Value	Adoption Feasibility	Remarks
Vehicle Location Detection	High	Yes	- Relies on towboat tracking
Vehicle Condition Detection	High	With modification	- No network based system available along US Waterways

5.4 Truck System Feasibility

Tables 5.6-5.9 present a summary of truck system feasibility, using the same assessment approach as applied to barge system feasibility.

Similar to barges within the maritime industry, the trucking industry does not have AEI capability on trailers (see Table 5.6). While adoption feasibility is possible on both truck and barge modes, adoption of this feature element is more highly valued by the trucking industry. Conversely, while adoption of schedule maintenance identification appears feasible in both cases, this is a more highly valued feature by the barge industry.

Table 5.6 - Truck Shipper/Receiver Facility System

Feature Element	Adoption Value	Adoption Feasibility	Remarks
Automatic Equipment Identification (AEI) Reader	Medium	No	- No standard equipment tagging - Cab tracking feature may reduce the need for trailer tracking (automated license plate readers)
Cameras at Entry/Exit from Terminal	High	Yes	- Gated and restricted access facilities ready for camera deployment - Cameras already in use at many customer facilities
Schedule Maintenance Identification	Medium	Yes	- Condition health monitoring features available, where alerts for scheduled maintenance can be programmed

As shown in Table 5.7, the barge industry, similar to trucking, considers GPS location tracking to be of high adoption value, and appears to be feasible with some modification to what is available in SHRIS. The adoption feasibility of GPS tampering sensors/cameras and GPS ride quality measurement, respectively, are evaluated as having similar adoption feasibility for both truck and barge modes. However, the barge industry values the availability of GPS tampering sensors/cameras more highly than the truck industry, since the truck shipment is accompanied by an individual driver, whereas the truck industry places a higher value on GPS ride quality measurement.

Table 5.7 - Truck In-Transit GPS Data Collection

Feature Element	Adoption Value	Adoption Feasibility	Remarks
GPS Location Tracking	High	With modification	- Applicable directly on truck cab - Trailers can be equipped with GPS tracking - While underway, truck trailers are always in the custody of a single truck cab
GPS Tampering Sensor/ Camera	Medium	With modification	- Commonly used seal technology modified to signal tampering - Driver inspection regime reduces need for camera
GPS Ride Quality Measurement	High	Yes	- Deployment could be aboard trailer or cab - Provides measure of driver behavior

Regarding in-transit natural hazard information (see Table 5.8), similar assessment results were found for both the truck and barge modes. That is, extreme weather reporting is highly valued and can be adopted in a straight-forward manner. However, knowledge about earthquake location and intensity, while feasible, is assigned a much lower value than information associated with extreme weather given the presence of a truck driver during transit.

Table 5.8 - Truck In-Transit Natural Hazard Information

Feature Element	Adoption Value	Adoption Feasibility	Remarks
Extreme Weather Reporting	High	Yes	- Can be sourced from NOAA and utilized directly
Earthquake Location and Intensity	Low	Yes	- Can be sourced from USGS, unclear value in trucking domain

As shown in Table 5.9, similar to the barge hazmat industry, the truck hazmat industry places a high value on detection of vehicle location and vehicle condition. Also, for both modes, whereas the adoption of vehicle location detection can utilize SHRIS-like technology directly, adoption of vehicle condition detection will require some modification.

Table 5.9 - Truck In-Transit Wayside Vehicle Location & Detection/Reporting

Feature Element	Adoption Value	Adoption Feasibility	Remarks
Vehicle Location Detection	High	Yes	
Vehicle Condition Detection	High	With modification	- No network based system available along US highways - Condition monitoring available, but not wayside - Tire pressure monitoring available, but not wayside

5.5 Findings and Recommendations

Our assessment suggests that both the barge and truck modes can benefit with the implementation of a SHRIS-type system, and that the vast majority of highly-valued features can either be adopted directly using technologies embedded in the SHRIS system, or can be implemented by making modifications to SHRIS system elements. There are not dramatic differences in the development effort involving implementation of such a system in either mode, but rather certain feature elements are considered more essential by one mode and vice-versa.

While development of a SHRIS-type system to hazmat movements by either the truck or barge industry is likely to offer safety and security benefits, a greater need and opportunity appears to exist for developing and deploying such a system in the maritime domain. This rationale rests with the recognition that the significantly larger cargo volumes per shipment creates the potential for a more consequential impact in the event of a material release, and because of the communication technology gap found in the maritime industry created by the dependence on a paper-based system kept onboard each vessel. The SHRIS system did not include a feature to address such a paper-based system because no such system exists in the rail domain.

The importance of outfitting the barge industry with this capability is underscored by the continuing importance of the maritime sector in hazmat transport, as demonstrated in the past decade with the growth of domestic crude production, which has led to a five-fold increase in waterborne crude shipments. Today, more barrels are shipped by barge than by rail.

Outlined below is the framework for an implantable system in the maritime domain, using both the innovative technologies demonstrated in SHRIS combined with a comprehensive electronic maritime hazmat communication system. We refer to this potential initiative as the Maritime Hazmat Risk Information System (Mar-HRIS).

5.5.1 Mar-HRIS System Description

Mar-HRIS is envisioned as adapting many SHRIS elements (tracking and monitoring, real-time surveillance, anomaly detection), while expanding the system scope to include QR-code access and the establishment of a Cloud-based data repository. The extended scope of the barge-deployed system is necessary to replace a complicated, cumbersome and error-prone paper-based system which is currently required by regulation and used across the industry.

A Cloud-based data repository (such as Amazon Web Services) can eliminate the need for multiple paper documents to be retained onboard each barge. It should be feasible for Mar-HRIS to use a customized QR-Code interface, affixed to each individual barge, such that all stakeholders – shippers, carriers, inspectors, regulators, customers, and first responders – can have instantaneous access to all relevant information via smartphones or tablets. This would represent the first such application of this technology in the maritime bulk hazmat domain.

Barges that are part of a flotilla are typically associated with the towboat rather than monitored individually. This creates a potential problem if the association between the towboat and barge is not made properly or if an individual barge is encountering an anomaly while underway. Moreover, there is often no direct tracking/monitoring of each individual barge when it is outside the custody of the towboat (i.e., at a facility terminal or fleeting site). As demonstrated as part of SHRIS, similar GPS devices can be affixed to each barge, with built-in sensor detection, video surveillance, geofencing and notification/alert capability, significantly improving the safety and security of the vessel and its contents.

Figure 5.3 provides a rendition of how a barge would be outfitted with the proposed technology communication system. The on-board sensors would be intended to go beyond the uses demonstrated in SHRIS; in addition to monitoring cargo temperature and pressure as well as acceleration/deceleration, sensors would be installed to address significant barge safety concerns regarding draft, tilt, list and trim. Moreover, this information could be interfaced with a barge owner's maintenance management system, providing key personnel with notification of issues requiring immediate or scheduled action. Based on the successful experience with implementation of SHRIS technology, we believe this work would find enthusiastic adoption.

The proposed initiative would be comprised of three project elements: 1) develop the Mar-HRIS system concept and corresponding design specification, 2) develop and install Mar-HRIS software and hardware in accordance with the design specification, and 3) implement the Mar-HRIS system on shipper's liquid barge transported by a barge operator and evaluate system performance. A brief description of each project element is provided below.

Figure 5.3 - Mar-HRIS Barge Configuration

<u>Element 1. System concept development and design specification</u>
The goal of this project element would be to produce a blueprint of how to deliver the communication system capabilities to the hazmat maritime industry (see Figure 5.4) in a practical and affordable manner.

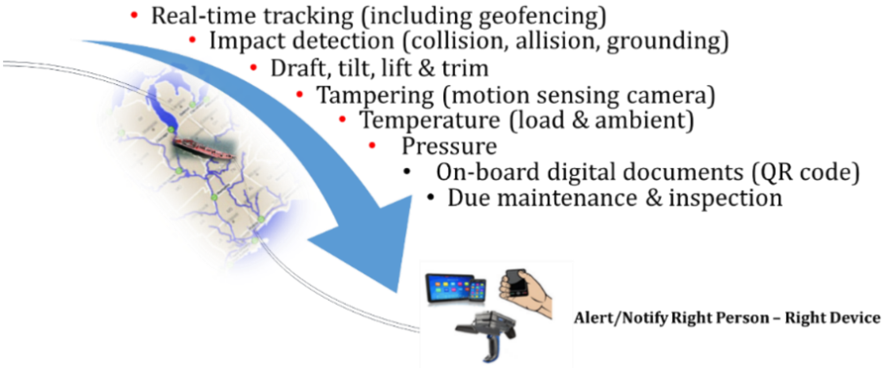


Figure 5.4 - Mar-HRIS Communication System Capabilities

With shipper, carrier and regulatory (i.e., Coast Guard) guidance, the system concept would be developed and transformed into a design specification from which Mar-HRIS can be constructed. This project element deliverable would consist of a series of schematics showing individual system components (hardware and software) and their interoperability, including a narrative that describes how each component would be configured and the various means by which information would be merged into an integrated database and transmitted to maritime hazmat stakeholders. The document would also provide guidance on setting deviation thresholds, triggering alerts/notifications, and communicating appropriate information in a form compatible with recipients' receiving devices.

<u>Element 2. Software/hardware development and installation</u>
The purpose of this project element would be to build the Mar-HRIS system according to the aforementioned design specification. Appropriate software and hardware would be obtained,

modified as appropriate, to create the desired system. Initially, the system would be tested on a “digital twin”, a laboratory simulation tool where the fabrication of various modules and their interconnections can be tested in terms of operational performance. This is an important step in the technology adaptation validation process.

Element 3. System implementation and performance evaluation
A barge operator, assigned to carrying a shipper’s hazardous material, would be outfitted with the Mar-HRIS system, with Cloud access provided to both parties through a multi-user portal where information would be stored, accessed and transmitted. The system would remain operational for a nine-month period, in order to evaluate performance under a number of operating environments (e.g., weather, location, navigating condition, frequent and rare events). As part of this project phase, a comprehensive evaluation of system performance would be conducted. This would include both quantitative and qualitative (e.g., operator feedback) considerations.

A promising next step would be for PHMSA to fund a project to develop and implement a Mar-HRIS. The availability of such a system has considerable potential for large-scale impact in advancing maritime hazmat transport risk management. The reason for making this assertion is four-fold: 1) research and development cost is low, 2) applications can be adopted quickly, 3) the likelihood of achieving measurable success is high, and 4) the technology solution is affordable, making its use attractive to a sizeable share of the industry. Affordability is an extremely important consideration because it enables maritime shippers and carriers of all sizes to leverage this capability, and not just a select few.

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APPENDIX A – LoRa TRIP AND MESSAGE TYPE SUMMARIES

Table A.1 - Trip Summary

	Car numbers	LORA id numbers		Start: 1-Sep	End: 19-Dec	Total 110 days		Trip Summary	
S.No	**equip**	**UNIT_ID**	**Recorded (Y/**	**Start Date**	**Stop Date**	**Days Report**	**Percentage Repo**	**Trips**	**Remarks**
1	UTLX631266	008000000000EE4B	Y	2-Sep	4-Dec	25	23	No round trips	1 return trip, trip info from mid Sep to Mid Nov missing
2	UTLX631269	008000000000EE44	Y	12-Nov	5-Dec	22	20	No round trips	1 return trip, readings given almost everyday
3	UTLX631270	008000000000EE40	Y	1-Sep	20-Nov	15	14	No round trips	Trip info missing from mid Sep to Mid Nov
4	UTLX631275	008000000000EE3F	Y	7-Nov	19-Dec	23	21	No round trips	1 return trip, trip info missing from 21-Nov to 10-Dec
5	UTLX631278	008000000000EE50	Y	14-Nov	26-Nov	13	12	No round trips	Trip info for Nov only
6	UTLX631280	008000000000EE06	Y	2-Dec	13-Dec	12	11	No round trips	1 return trip, trip info for Dec only, daily reading given
7	UTLX631283	008000000000E268	N						
8	UTLX631287	008000000000E27B	Y	6-Dec	17-Dec	12	11	No round trips	1 return trip, trip info for Dec only, daily reading given
9	UTLX631288	008000000000E265	Y	2-Sep	10-Dec	33	30	No round trips	2 return trips, No reading from mId Sept to end Oct and from mid Nov to beginning of Dec
10	UTLX631297	008000000000E276	Y	31-Oct	8-Nov	9	8	No round trips	Readings given everyday
11	UTLX631307	008000000000E286	Y	2-Dec	14-Dec	13	12	No round trips	1 return trip, trip info for Dec only
12	UTLX631310	008000000000E277	Y	6-Dec	19-Dec	14	13	No round trips	1 return trip, trip info for Dec only, readings given everyday
13	UTLX631311	008000000000E263	N						
14	UTLX631312	008000000000EE4E	Y	1-Sep	19-Dec	23	21	No round trips	1 return trip, trip info missing from 7-Sep to 11-Nov and 20-Nov to 10-Dec
15	UTLX631320	008000000000EE42	Y	31-Oct	12-Dec	20	18	No round trips	1 return trip, trip info missing from 8-Nov to 30-Nov
16	UTLX631325	008000000000E272	Y	9-Nov	26-Nov	18	16	No round trips	Trip info for Nov only
17	UTLX631334	008000000000EE4A	Y	4-Dec	13-Dec	10	9	No round trips	1 return trip, trip info for Dec only
18	UTLX631345	008000000000E26A	N						
19	UTLX631346	008000000000E270	Y	2-Sep	4-Dec	26	24	No round trips	2 return trips, trip info from mid Sep to mid Nov is missing
20	UTLX631347	008000000000EE4C	Y	1-Sep	25-Oct	31	28	No round trips	Trip info missing from 14-Sep to 7-Oct
21	UTLX631349	008000000000E260	N						
22	UTLX631350	008000000000EE45	N						
23	UTLX631367	008000000000E274	Y	1-Sep	25-Oct	30	27	No round trips	Trip info missing from 14-Sep to 7-Oct
24	UTLX631369	008000000000E283	Y	1-Sep	18-Dec	34	31	No round trips	1 return trip, No trip info from 14-Sep to 27-Nov
25	UTLX631370	008000000000EE40	Y	1-Sep	20-Nov	34	31	No round trips	Trip info missing from 8-Sep to 12-Nov
26	UTLX631375	008000000000EE52	Y	1-Sep	25-Oct	31	28	No round trips	Trip info missing from 14-Sep to 7-Oct
27	UTLX631380	008000000000E26B	Y	1-Dec	10-Dec	31	28	No round trips	1 return trip, trip info for Dec only
28	UTLX631581	008000000000EE4F	N						
29	UTLX631589	008000000000EE41	Y	5-Sep	19-Dec	10	9	No round trips	2 return trips, trip info missing from 14-Sep to 7-Nov and 20-Nov to 9-Dec
30	UTLX631593	008000000000EE07	Y	1-Sep	25-Oct	31	28	No round trips	Trip info missing 14-Sep to 8-Oct
31	UTLX631606	008000000000E25F	Y	5-Dec	19-Dec	30	27	No round trips	1 return trip, trip info for Dec only
32	UTLX631607	008000000000E266	Y	14-Nov	3-Dec	20	18	No round trips	Trip info given everyday
33	UTLX631608	008000000000E273	N						
34	UTLX631611	008000000000E269	Y	7-Nov	21-Nov	20	18	No round trips	Car has not moved, trip info for Nov only
35	UTLX631613	008000000000E27A	Y	10-Oct	26-Nov	26	24	No round trips	1 return trip, trip info missing from 24-Oct to 13-Nov
36	UTLX631614	008000000000E285	Y	2-Nov	8-Nov	27	25	No round trips	1 retun trip, trip info for Nov only
37	UTLX631623	008000000000E279	N						
38	UTLX631625	008000000000E282	Y	1-Sep	15-Nov	22	20	No round trips	Car has not moved, trip info missing from 14-Sep to 6-Nov
39	UTLX631634	008000000000E275	N						
40	UTLX631639	008000000000D349	Y	5-Dec	14-Dec	22	20	No round trips	1 return trip, trip info for Dec only
41	UTLX631642	008000000000E271	Y	10-Oct	29-Nov	10	9	No round trips	1 return trip, trip info missing from 24-Oct to 1-Nov
42	UTLX631644	008000000000EE2A	N						
43	UTLX631646	008000000000EE47	N						
44	UTLX631655	008000000000EE46	Y	1-Sep	5-Dec	38	35	No round trips	2 return trips, trip info missing from 14-Sep to 23-Oct and 10-Nov to 25-Nov
45	UTLX631656	008000000000E26F	Y	6-Sep	13-Nov	39	35	No round trips	1 return trip, trip info missing from 14-Sep to 9-Oct
46	UTLX631657	008000000000E280	Y	2-Sep	13-Dec	45	41	No round trips	1 return trip, trip info missing from 12-Sep to 5-Dec
47	UTLX631664	008000000000E264	N						
48	UTLX631665	008000000000EE49	Y	1-Sep	19-Dec	79	72	No round trips	1 return trip, trip info missing from 14-Sep to 7-Oct and 2-Nov to 8-Nov
49	UTLX631667	008000000000E284	N						
50	UTLX631676	008000000000E278	Y	21-Nov	3-Dec	13	12	No round trips	Car has not moved
51	UTLX631677	008000000000E266	Y	14-Nov	3-Dec	20	18	No round trips	Car has not moved
52	UTLX631679	008000000000E261	N						
53	UTLX631681	008000000000EE05	Y	6-Dec	14-Dec	9	8	No round trips	1 return trip, trip info for Dec only
54	UTLX631684	008000000000E267	Y	7-Nov	20-Nov	13	12	No round trips	Car has not moved

Table A.2 – Message Type Summary

	Car numbers	LORA id numbers	Message Types													
S.No	equip	UNIT_ID	Daily Hea	Daughter Card He	Deceleration Al	Impact Ala	Move Be	Move E	Move Tin	Sensor Move B	Sensor Move	Sensor Move Ti	Sensor Timed Re	Sensor Trigge	Timed	Total Messa
1	UTLX631266	008000000000EE4B	23	23	5		80	79	26						526	762
2	UTLX631269	008000000000EE44	21	21	5		67	66	39						496	715
3	UTLX631270	008000000000EE40	7	7	3	2	46	44	4	46	43	4	334	4	334	878
4	UTLX631275	008000000000EE3F	17	17	13	1	88	87	34						476	733
5	UTLX631278	008000000000EE50	11	11			37	36	3						291	389
6	UTLX631280	008000000000EE06	7	7	1	3	40	39	12	40	39	12	236	2	236	674
7	UTLX631283	008000000000E268														
8	UTLX631287	008000000000E27B	9	9	2	1	50	49	12	49	47	11	255	2	255	751
9	UTLX631288	008000000000E265	21	21	14	8	146	143	66	146	143	66	658		659	2091
10	UTLX631297	008000000000E276	6	6	1		22	21							195	251
11	UTLX631307	008000000000E286	9	9	1		38	37	12						258	364
12	UTLX631310	008000000000E277	6	6	4	2	48	48	13						303	430
13	UTLX631311	008000000000E263														
14	UTLX631312	008000000000EE4E	20	20	10	6	94	93	42						469	754
15	UTLX631320	008000000000EE42	17	17	7	4	85	84	53						401	668
16	UTLX631325	008000000000E272	17	17	11	2	37	36	3						403	526
17	UTLX631334	008000000000EE4A	6	6	2	1	48	47	12						209	331
18	UTLX631345	008000000000E26A														0
19	UTLX631346	008000000000E270	18	18	4		89	90	38						518	775
20	UTLX631347	008000000000EE4C	27	27	1		5	4							701	765
21	UTLX631349	008000000000E260														0
22	UTLX631350	008000000000EE45														
23	UTLX631367	008000000000E274	27	27	1		11	10		11	10		692		692	1481
24	UTLX631369	008000000000E283	31	31	13	3	60	59	22						753	972
25	UTLX631370	008000000000EE40	7	7	3	2	46	44	4	46	43	4	334	4	334	878
26	UTLX631375	008000000000EE52	27	27			9	8							699	770
27	UTLX631380	008000000000E26B	5	5	2	1	37	36	11						212	309
28	UTLX631581	008000000000EE4F														
29	UTLX631589	008000000000EE41	8	8	11	8	104	103		98	96		2382		2767	5585
30	UTLX631593	008000000000EE07	23	23	1		10	9		10	9		693		692	1470
31	UTLX631606	008000000000E25F	12	12		3	48	48	10						324	457
32	UTLX631607	008000000000E266	19	19			33	32	3						460	566
33	UTLX631608	008000000000E273														0
34	UTLX631611	008000000000E269	12	12	2	2	36	35	4						321	424
35	UTLX631613	008000000000E27A	16	16	9	3	70	68	39	70	68	39	573	4	573	1548
36	UTLX631614	008000000000E285	8	8	19	2	45	44	658						800	1584
37	UTLX631623	008000000000E279														
38	UTLX631625	008000000000E282	19	19	1		41	40	2						496	618
39	UTLX631634	008000000000E275														0
40	UTLX631639	008000000000D349	6	6	2	2	51	50	12						203	332
41	UTLX631642	008000000000E271	4	4	1	1	49	48							2163	2270
42	UTLX631644	008000000000EE2A														0
43	UTLX631646	008000000000EE47														
44	UTLX631655	008000000000EE46	33	33	4	1	111	110	24						803	1119
45	UTLX631656	008000000000E26F	38	38	7	1	108	107	30						956	1285
46	UTLX631657	008000000000E280	9	9	2	2	92	90	15	92	89	15	358	2	358	1133
47	UTLX631664	008000000000E264														0
48	UTLX631665	008000000000EE49	74	74	10	3	98	97	30						1790	2176
49	UTLX631667	008000000000E284														0
50	UTLX631676	008000000000E278	7	2	1		37	36	3						590	676
51	UTLX631677	008000000000E266	19	19			33	32	3						460	566
52	UTLX631679	008000000000E261														
53	UTLX631681	008000000000EE05	6	6	2	2	50	49	11	50	49	11	184		184	604
54	UTLX631684	008000000000E267	10	10	3	1	36	35	4	35	34	4	229		304	705
			662	657	178	67	2235	2193	1254	693	670	166	6928		23664	39367

APPENDIX B – EXISTING/EMERGING MARITIME AND TRUCK TECHNOLOGIES

The maritime and truck sectors over time have implemented existing and/or emerging technologies either to address regulatory requirements or to improve economic benefits. This appendix contains information on existing and emerging technologies within each of these industries, respectively.

Maritime Sector – Inland Waterway Barge Transportation

Presently, there are no sensors installed on individual barges for the purpose of monitoring or tracking. However, the tow boats are equipped with:

- Automatic Identification System (AIS) - The primary intent of AIS is to enable vessels to view marine traffic along with their unique vessel identification number (vessel IMO number). Each vessel is made visible to each other within a certain range, which is displayed on a chart and presented on a computer monitor.
- Vendors: Furuno (https://www.furuno.com/en/products/ais) and Kongsberg (https://www.kongsberg.com/maritime/products/bridge-systems-and-control-centres/navigation-system/ais-automatic-identification-sensor/)
- NAVigational TEleX (NAVTEX) - This device transmits coastal urgent marine safety information, including navigational and meteorological warnings and forecasts. The information can be displayed on a small digital screen installed on the device or printed from it. *Note - In November 2019, the US Coast Guard proposed terminating use of NAVTEX and shifting to satellite technology; however, this rule change is not finalized.
- Vendor: Furuno (https://www.furuno.com/en/products/navtex)
- https://www.federalregister.gov/documents/2019/09/11/2019-19675/proposed-termination-of-us-coast-guard-medium-frequency-mf-broadcast-of-navigational-telex-navtex
- Electronic Chart Display and Information System (ECDIS) – A computerized navigational system serving as an alternative to the traditional paper navigational chart. ECDIS integrates a variety of real-time information, including global positioning system (GPS). ECDIS can automatically aid in decisions by identifying vessel position with respect to charted objects, land and other unseen hazards.
- Vendor: Furuno (https://www.furuno.com/en/products/navtex) and Kongsberg (https://www.kongsberg.com/maritime/products/bridge-systems-and-control-centres/navigation-system/ecdis-electronic-chart-display-system/)

Truck Sector

A range of technologies are available and being used within the trucking sector today. This is being achieved by automating components within the truck system and/or using sensor-based technologies supported by wireless communication networks.

- Health Monitoring: Sensor equipped trucks can notify a maintenance crew when it is time for servicing brakes, tires, oil and other critical systems, prior to being sidelined by unexpected failures. Sensors can also help identify trailers that incur harder miles (where a lot of braking is involved), which would need to be serviced sooner than normal. In addition to overall health monitoring, historical compliance, safety and accountability (CSA) violations for a trailer can be linked to identify those trailers that have incurred a high level of CSA violations. There are also electronic inspection opportunities being

explored which could address Commercial Vehicle Safety Alliance (CVSA), Level III inspection such as Roadside Monitoring by Drivewyze.
Source: https://www.spireon.com/webinars/#1567102040737-4edb90a8-7c19
https://drivewyze.com/wp-content/uploads/An-Alternative-Compliance-Framework-for-Electronic-Inspections-to-Support-the-FMCSA-CSA-Operational-Model.pdf

- Safety & Security: Tracking and monitoring using GPS units ensures visibility for both the cab and the trailer. Some GPS units are equipped with theft detection, where instant alerts are sent when there is unauthorized door opening, unexpected loading or unloading activity, unplanned movements and stops, deviation from scheduled routes, and any detection of jamming devices. Additional light sensors can also indicate if trailer walls, roof or floor have been breached in an effort to steal cargo or for other illicit activity. By tracking forgotten assets (i.e., trailers not put into service or only used as storage or idle at customer site), replacement of a trailer can be based on actual utilization recorded rather than a fixed time frame.
- Source: https://www.spireon.com/webinars/#1567102040737-4edb90a8-7c19
https://www.ccjdigital.com/covenant-transport-to-install-omnitracs-ivg-across-fleet/
- Dash-Cams: Many trucking companies have started installing dual facing in-cab cameras. These cameras record in a loop until an incident occurs, such as a crash or hard braking. Ten seconds prior and post incident are recorded for alert or review by the company. In-cab alerts can also be sent if the driver is distracted, drowsy, drifting to another lane, or not maintaining safe driving distance. These video recordings are also useful in reducing liability during incident disputes.
Source: https://www.samsara.com/page/dual-dash-cams?utm_source=bing&utm_campaign=sitelink&utm_medium=search&utm_content=p&utm_term=dash%20cam&utm_ext_ad_id=kwd-72499258746555:loc-190&utm_ext_adset_id=1159984992357781&utm_ext_campaign_id=339750210&msclkid=a8126e2b4f8a1ba7365f305935ebbc8c
- Digital Tire Monitoring (DTM): DTM eliminates the need for manual tire pressure check in terminals. Here, tire pressure data is collected using Vodafone's IoT SIM technology. When a truck returns to terminal, data is displayed via a web portal to authorized parties.
Source: https://www.continental-truck.com/truck/tire-monitoring/conticonnect
- Electronic Logging Device (ELD): ELD took effect in late 2017 and requires all motor carriers to install an electronic device that will automatically track driver hours of service. A telematic device is connected to the engine control module (ECM) which can record speed, location, idling, fuel consumption, tire pressure, etc. A list of registered ELDs can be found under the following link - https://eld.fmcsa.dot.gov/List
Source: https://www.freightwaves.com/news/what-is-an-eld