

An Analysis of the Opportunities for Wireless Technologies in Passenger and Freight Rail Operations

Commissioned by the Federal Railroad Administration
Department of Transportation
1200 New Jersey Avenue S.E.
Washington, D.C. 20590

December, 2007

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ACKNOWLEDGMENT

This document provides the findings of a study commissioned by the Federal Railroad Administration under the terms of the Broad Agency Agreement. The study was awarded to and performed by Ronald Lindsey, and the value of the findings is directly related to the participation by the Class I freight railroads, Amtrak, suppliers, and shippers.

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* Given the broad range of individuals and organizations that may read this report, the Appendix provides descriptions of terms and phrases that may not be familiar to all. The terms and phrases that are included in the Appendix will be followed by a “¹” at their first appearance in the report.

Summary of Findings

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This study focused on the deployment of wireless technologies to advance railroad operations. As such, there are five key phrases that collectively capture the essence of this study.

1. Levels of Operability

Wireless technologies can provide an unprecedented level of timeliness of data as to the status of remote and mobile resources both within the boundaries of an individual railroad as well as across the industry. This micro and macro perspective, respectively, presents the challenge of operability (usability) in deploying wireless-based infrastructures that overlay, complement, or replace traditional operational-critical infrastructures, e.g., voice radio, traffic control¹, Automatic Equipment Identification (AEI)¹, Electronic Data Interchange (EDI)¹, and telephone. There are six levels of operability:

Railroad Intraoperability: the ability of a railroad to use its operating resources across its own network. This presents the classic challenge of how to manage “unequipped” units. In the case of locomotives, up to 20 percent of the fleet being used can belong to other railroads, thereby resulting in a tradeoff between reduced functionality and increased operating costs to equip foreign locomotives.

Interoperability: the challenge of the interchange of trains between railroads again presents the tradeoff between reduced functionality and increased operating costs relative to unequipped units entering the operating railroad’s network.

Industry Intraoperability: the value of having access to a railroad’s resources when on another railroad. This area has been little explored due to the lack of effective access to each railroad’s data by other railroads, as well as the lack of an industry-based tracking system.

Train Intraoperability: a developing level of operability as to the environment within and surrounding the train. This is an area that has recently received some attention due to some Association of American Railroads (AAR)-sponsored activities in addition to the pursuit of Electronic Control Pneumatic (ECP) brakes¹.

Cross Industry Operability: a developing level of operability as the attention on security and hazardous materials crosses boundaries between the railroads and their respective shippers/industries.

Global Intraoperability: taking cross-industry operability to the global level, with the focus on the shipment and domestic security.

2. Revolutionary Functionality

The use of the timely resource status data that wireless technologies can deliver in concert with planning and execution tools to process the data, can also provide a railroad's resource managers of track time (train dispatchers), yards, crews, locomotives, cars, and maintenance crews with a revolutionary set of business processes that predict conflicts in resource allocation. This predictability will permit *proactive* resource management, in lieu of the current *reactive* fashion, thereby optimizing utilization, reducing costs, and increasing customer service. Most interestingly, only a modicum of data is required of the wireless data network to pursue these major advancements, i.e., each locomotive's position and speed status every 5 to 15 minutes. And, with even less frequent data as to fuel level and health, a railroad can substantially advance its locomotive fueling and maintenance processes. Additionally, aligned with industry intraoperability, is the opportunity to extend each railroad's planning and monitoring horizon beyond its own borders, as to interchange operations, and optimize its train lineup and management of its shipments.

3. Evolutionary Deployment

The railroads have substantial IT and communication infrastructure upon which the railroads' business processes are based, and simply providing more timely data via wireless will not necessarily improve operations. For traditional IT architecture, such incorporation will require modification or replacement of current systems which could be viewed as being cost prohibitive. However, in several key areas, most notably crew, locomotive, and traffic management¹, complementary systems can be readily deployed to obtain substantial benefits without significant modification, yet alone replacement of the current systems. And with the requirement of only locomotive position and speed every 5 to 15 minutes, an effective wireless platform(s) can also be deployed relatively simply along with an industry-based tracking system through the use of owned and commercial wireless data services.

4. Hierarchical IT Architecture

Given the different levels of operability, there is the need for a corresponding hierarchical IT architecture. This is a hierarchy that begins with the locomotive communications and intelligence platform as a *mobile node* that serves as an extension of both the individual railroad's IT platform as well as that of an industry-based IT platform that services the requirements across the levels of operability for all players including railroads, shippers, equipment owners, and security services.

5. Enterprise Technologist

The pursuit of revolutionary functionality with evolutionary deployment is beyond the scope and expected skill set of a railroad's traditional technicians and IT architects that handle the design, deployment, and management of a railroad's traditional communication and IT infrastructures. Given the various levels of

operability, this lack of scope and skill set should be addressed within the railroads individually, where not already present, and with an industry perspective. The necessary skill set includes the ability to deliver business cases that are pragmatic, 80/20, and based upon an incremental value/incremental cost analyses that require a mixture of business, technology, and domain knowledge. Such a discipline points to the use of *Enterprise Technologists* within the railroads, both individually and collectively, to complement the skill sets of the technicians and IT architects. Such a discipline would focus on delivering value now, instead of latter, through evolutionary development that will complement the current industry efforts regarding interoperability.

Overview

Below, background information is provided that contributed to structuring the purpose and scope of this study, followed by the objective and process that were used to perform the study.

Background

It has been a decade since the railroads collectively performed a study of the opportunity for the use of wireless technologies. As effective as that study was at that point in providing structure in defining the critical role of wireless communications (both voice and data) for railroad operations, the environment has changed substantially in four critical dimensions to the point of minimizing the applicability of the study to the railroad industry of today.

- First, the types of wireless offerings, both private and commercial, have increased substantially, along with some obsolescence. Most important has been the increasing availability of commercial terrestrial wireless data and the use of wireless networks to extend the wired-IT infrastructure and management systems to remote and mobile resources in an IT-compatible fashion.
- Second, each railroad has advanced its individual agendas to include wireless technologies and applications. However, there are significant differences within their individual progress and approaches to date which has resulted in a concerted effort by the railroads, in the last 2 years, to address interoperability, albeit with a PTC orientation.
- Third, there have been several key regulations by Federal agencies that will have a profound effect on wireless advancement. Most important of these are the Federal Communication Commission's (FCC) VHF narrow-banding¹, also called refarming, and the Federal Railroad Administration's (FRA) March 2005 rulemaking, the PTC rule, that permits for the quantifying of risk in lieu of its subjective evaluation. Additionally, at the time of this report being written, Congress is considering the mandating of PTC.

- Lastly, the industry itself has changed dramatically including the impressive advancement of intermodal operations, infrastructure shortages, an increasing attention to security, and staggering fuel costs.

Objective

In consideration of the changes over the last decade, this study was structured and proposed to FRA with the following objective:

Provide a strategic perspective of the use of wireless technologies in high-speed passenger and freight operations, which is beyond the current use of wireless across the industry.

This study was not intended to make, nor does it provide, either a financial, rate-of-return analysis or a technical evaluation of advancing wireless technologies.

Process

The study was conducted via two sets of tasks. The first set consisted of interviews with business process managers in the Class I freight railroads, Amtrak, and several shippers. The discussions addressed the following points:

1. The opportunities and advantages to replace voice transmissions with wireless data;
2. The opportunities and advantages to improve the exchange of information between railroads regarding interchange;
3. The identification of data which would be required to improve current processes for managing or just monitoring remote and mobile resources;
4. The identification of planning or execution tools that are not usable, or are limited in functionality, due to the lack of resource status data;
5. The identification of advanced business processes, and their respective advantages, that could be incorporated with more timely resource status data; and
6. A sense of timeliness of the data that would be required for the advanced functionality identified above.

The second set of tasks consisted of a number of workshops held with suppliers and railroads to address particular topics as to the supply and application of wireless and associated technologies. Each workshop consisted of interactions between the participants on a variety of topics ranging from onboard communication and intelligence platforms to wayside requirements to advance asset

management opportunities. In addition to the workshops, individual discussions were held with selected suppliers and shippers.

This report proceeds from here with the study's findings to advance functionality, a structuring of operability, the means of deployment, and an introduction of a new skill set to advance railroad operations via wireless.

Functionality

Unlike airlines with their fixed, multi-month flight schedules that are supported with locked-in equipment types (if not specific aircraft), crews, maintenance, passenger reservations, gates, etc., railroad operations are more unscheduled than not as to traffic control and with little, if any, scheduled assignments for the supporting resources. There is a variety of reasons for why a railroad does not run to schedule, and some are quite valid. The primary legitimate reasons are those in which the railroad's customers make the decisions regarding the release of trains, e.g., ports and mines, and the railroad is required to fit them into the lineup¹ accordingly. However, the majority of disruptions are caused by conflicted traffic management due to the lack of adequate decision tools and the required timely resource status, including train position/speed and the status of yards, that effects the initiation of trains and their progress throughout a railroad's network. Additionally, this lack of lineup reliability within the railroads builds upon itself when it comes to the interchange of trains between railroads, and the resulting mutual disruptions for the receiving railroad.

The management of the primary resources that are required to run the trains suffer with traffic management due to the lack of lineup reliability. Simply stated, the effective management of train crews, locomotive assignments, track time, on-track maintenance crews, and yard operations begins with a common, single bit of information. It all begins with knowing where the locomotives are and, somewhat to a lesser extent, how fast they are moving (which is not known today). Similarly, with a modicum of additional data regarding the locomotive, its maintenance and fueling can be greatly advanced over today's processes. Below, each area is addressed as to their current environment and the opportunity for advanced functionality with the deployment of wireless technologies.

Traffic Management

The effectiveness of managing assets is only as good as the data that are available, as such their status; and only as good as the tools and processes that are available to message the data. Unfortunately, railroads continue to manage traffic with processes based upon a century-old technology aligned with decisionmaking tools that really are not, track circuits¹ or dispatching systems, a.k.a. Computer Assisted Dispatching (CAD)¹, respectively. The latter is only able to present, at best, to the dispatcher where the train was at some point in time via On Station (OS) reports¹, also called Centralized Train Control messages (CTC), but not where the train is

currently and whether or not it is even moving, or at what speed. Additionally, the dispatcher displays are simply that of a Supervisory Control and Data Acquisition (SCADA)¹ system that presents the status of the signaling infrastructure without consideration of distances between signals. The dispatcher is often left to his/her own skills and experience in finding workable solutions in complex situations instead of optimal ones, given the wide range of variables and lack of timely data.

In non-signaled territory¹ (dark territory) there is not even the availability of OS reports to place a train. And, non-signaled territory amounts to roughly half of the trackage in North America, although it handles only 20 percent of the traffic and 10 percent of the tonnage.

The railroads have now been caught up in a Catch 22 with data and decisionmaking tools. That is, they have not had the availability of timely status data for their trains and therefore, have not been able to deploy mathematics-based decision tools, also called meet/pass planners¹, capable of dealing with a wide range of variables. Since most railroads do not have or explored the tools and processes that could use timely data, and have not yet invested in the wireless and related technologies that are now available to capture and deliver timely data.

Opportunity

Breaking into the circular logic above is at hand, and is being explored by several Class I railroads, but there are a number of constraints that need to be overcome including delivering the functionality (addressed below in **DEPLOYMENT**), making the business case (addressed below in **BUSINESS VALUE**), and modifying the business processes and mind-set of dispatching, as follows.

With the availability of a wireless data platform capable of reporting train position and speed with a frequency required to optimize the use of meet/pass planners, a railroad can make the transition from the current *reactive* (crisis based) traffic management processes to that of *proactive* processes. That is, with *in-time* data and the proper management tools, the dispatching process would change to one that projects traffic conflicts and provide recommendations to minimize the consequences, if not avoid the situations altogether. The consequences referred to are the costs of not meeting the business goals (objective functions) that management could vary by type and density of traffic via a set of various meet/pass planning tools.

The meet/pass planning tools that would be used for dispatchers to handle disruptions are directly akin to the mathematics-based tools that the railroads' transportation planning resources, known as Service Design, would use to establish and modify the schedule as required. Once the railroad is so scheduled, then the dispatcher is left with the challenge of using the meet/pass planning tools to get back to schedule in the most effective way when disruptions occur. This approach shifts a

majority of the challenge of effective train movements to the planning resources where it belongs. The effective management of the other primary resources shifts to the planning phase as well, with their respective execution managers using their tools in a proactive fashion instead of the current reactive (crisis) mode. Essentially, this is the airline's model of operations.

An example of a change in mind-set required to run a scheduled operation is that of perceived inefficiency. For example, traditional railroading calls for avoiding short trains to not "waste" crews or fuel or track time. Those clearly are inefficiencies. However, the price of avoiding those *unstructured* (unplanned) inefficiencies can be an increase in locomotives, crew deadheading, yard congestion, and dispatching conflicts to address disruptions. With a scheduled operation, *structured* inefficiencies are built into the schedule based upon past and projected requirements, e.g., short trains will occur, but they will still operate to maintain the schedule of locomotives and crews. The argument to do so is several fold. Arguably, structured inefficiencies will be more efficient than unstructured ones. Second, the reliability of service is optimized, leading to increased customer satisfaction and revenues. Simply stated, how successful would airlines be if they used the railroad's model of operation, e.g., fly the plane when it is full enough? The airlines instead build and modify their schedules with the expectation to "fill" the planes based upon past and projected requirements.

Yard Management

Yard management has seen a surge recently in yard planning and execution tools in the industry, but their usefulness is still constrained by the timeliness and accuracy of the train and equipment location data. There are two primary points here.

- First, there is the issue of managing the movement of switching crews based upon a train-build profile that is aligned with a reliable schedule of arriving consist and humping operations.
- Second, there is the lack of timely and actual receiving yard capacity and departures being provided to the main line dispatcher, thereby providing significant constraints to efficient, if not scheduled, train movements.

Opportunity

Unlike the main-line, the tracking of trains and cars in the yards is more challenging than the number of adjacent tracks and the interweaving of car movements in a seemingly unpredictable fashion. And, given the range of yards that exist in the industry, it is likely that there are a few categories of yard types with each one

suggesting a different blend of wheel counters, AEI, GPS-reporting, video scan, switch monitoring, and other undetermined technologies that could meet the timeliness and accuracy requirements. For example, for some yards it may be appropriate to use locomotive-borne *geo-fencing* for switching crews to monitor their movements. This is a technique of establishing virtual boundaries on the onboard intelligence platform that triggers an action, e.g., reporting position, when a boundary is crossed based upon GPS, passing a switch, or some other positioning approach.

With such improved visibility into the depths of a yard's working and status, managers can better monitor and direct their resources based upon the analysis of planning tools that can't be used effectively today. Similarly, with the timely status of in-bound and out-bound tracks, the train dispatcher's efficiency can also improve dramatically with the movement of trains on the main-line by incorporating actual yard capacity into the meet/pass planners as well as the handling of the lineup respectively.

Crew Management

Considering a railroad's primary resources, the management of train crews is arguably the most vulnerable to an unreliable lineup. This is due to the need to deadhead train crews to meet trains in compliance with convoluted labor agreements. This process often works with a 48-hour horizon of how the trains are moving across the railroad's network, or even more difficult, approaching from other railroads for interchange. In fact, it is not unlikely that crew management is often the first to challenge the reliability of the lineup in an effort to reduce unnecessary crew expenses and manning levels. One difference that was noted between the railroads interviewed was that one road that operated substantially more scheduled than another was able to deadhead and work crews back without rest. The more unscheduled railroad routinely deadheaded and rested crews before working thereby resulting in a significant increase in crew costs and manning levels as well as a decrease in the crew's quality of life.

Train crews are subject to hours-of-limit rules, and accurately knowing both their on- and off-duty time would ensure the maximum use of their availability while maintaining compliance with rules subjected to FRA inspection.

Opportunity

Whether or not the railroads could achieve the type of crew scheduling that is an extraordinary achievement by the airlines (airline crews bid each month for their schedule in a phenomenally flexible fashion), may be a worthy pursuit, but clearly impossible without a scheduled operation. However, what is achievable is the use of crew management execution tools that can balance a number of critical cost factors in an optimizing fashion, based on a reliable lineup including deadheading-then-

work versus deadhead-then-rest, outlawing, maintaining pool balances, avoiding terminal runaround, etc. Such tools are available, but they were not found to be in use in the industry. This may be due to a lack of awareness of such tools, or it may be due to the lack of lineup reliability and the inability to use the tools effectively. Additionally, with accurate train positioning information being available, local management can be provided with the information and tools to ensure that crew are on- and off-duty in compliance with their assignments and the rules.

Locomotive Management

Several railroads have incorporated the tracking of locomotives into their operations by means of commercial wireless services, primarily for locomotive diagnostics and selective position reports. However, the frequency of that reporting is not sufficient for the proactive asset management functionality discussed above. One reason for the low frequency may be the cost of providing such reporting via commercial services and the lack of identifiable benefits as per the previously mentioned tools/data Catch 22. Additionally, foreign locomotives running over a railroad's property will most likely not be providing any tracking information to the operating railroad, and their use can amount to 20 percent of the fleet at any given time.

Railroads do obtain locomotive position reports from the AEI infrastructure that reports consist movements across a railroad's network, but that discrete reporting process is not sufficient for proactive traffic management. Lastly, locomotives approaching interchange are not necessarily reported to the receiving railroad in a timely fashion for their proper handling, e.g., fuel levels, whether the locomotive is equipped for distributed power¹, position in consist, etc. This last point indicates that there is both an intra-railroad and inter-railroad challenge to tracking locomotives.

Opportunity

While commercial wireless permitted the initial implementation of advance locomotive tracking beyond that of discrete AEI reads, it seems now that those same services may have become a constraint for railroads in moving forward with industry-wide locomotive and other asset management systems. However, that is only true to the extent that a business case has not been built that would present the financials for taking action on the full spectrum of applications identified above, with either commercial and/or private wireless alternatives.

While making the business case would be the expected approach to moving forward, at least one Class I railroad's CEO has simply mandated the railroad's fleet to be equipped with location reporting capability; thereby breaking into the tools/data Catch 22 and providing the opportunity to begin building the management systems that can use that data as described above. Another Class I railroad is providing for a system-wide wireless data platform that can be used, even though it has yet to make the transition to an onboard reporting platform for its locomotives.

Locomotive Maintenance

Railroads are required to perform different levels of maintenance on locomotives on a 92-day, 1-, 3-, and 5-year basis. This prescriptive maintenance process is not based upon any diagnostics of the engine's health and suggests that engines may be spending valuable utilization time sitting on a shop track, which leads to an artificially high number of locomotives and excessive maintenance costs.

While some railroads have used wireless networks to monitor the health of their locomotives with the objective of avoiding in-service disruptions via predictive analysis, there is still the issue of foreign locomotives operating over their property and the inability to obtain their health data. The point is that if it must be operated, then the maintenance and operating consequences must be dealt with, regardless of ownership. Conversely, there is the issue of a railroad's locomotives running on foreign railroads and not being able to capture health data in those situations. Hence, in addition to the intra and inter-railroad requirement for tracking locomotives, there is also a need for intra-industry access to the locomotive's health.

Opportunity

With the availability of locomotive diagnostic data from across the industry, and the tools which can process that data for predictive analysis of the engine's health, the railroads could move to *performance-based* maintenance to extend, if not replace, current prescriptive processes with arguably increased reliability of locomotive operation while decreasing maintenance costs and increasing utilization. The capability to capture this data on an industry basis will be available in the Equipment Maintenance Information System (EMIS), an AAR-sponsored system that is due for full implementation in 2009. However, at this point, railroads involved in interchange are not required to report activity associated with locomotives as they are with rail cars. By integrating this data with the existing Event Depository Database that captures movements in the industry, there is the opportunity to, not only track the position and projected health of locomotives, but to implement planning tools for setting up the movement of individual locomotives to minimize maintenance costs while increasing utilization.

The availability of wireless data can facilitate the handling of in-service engine troubles (in-service via an established communication link between train crews and maintenance help desks that can monitor and adjust the engine's critical operating functions). Lastly, as with locomotive management across the system, the monitoring of locomotive movements through the shops can lead to reduced shop time, congestion and increased locomotive utilization. Wireless is one means to provide for this tracking.

Locomotive Fueling

Nearly 90 percent of the industry's locomotives are without electronic fuel gauges that could provide fuel levels if wireless data were available to report such dynamic information. In that the data are not available, several railroads have very conservative practices of fueling locomotives to avoid running out of fuel on the main line. Hence, a substantial amount of fuel and locomotive utilization is spent by locomotives sitting on fuel tracks awaiting fuel that in reality may not be required at that point.

In addition to their own fueling facilities, railroads also contract fuel delivery when deemed necessary. These direct-to-locomotive (DTL) services charge a premium price, and the opportunities for unnecessary fueling or fraud are significant.

All of the above contributes to the difficulty in determining the fuel burn rate for individual locomotives. This information is important for evaluating both locomotive and engineer performance, determining the distance that the engine can be operated and obtaining a fair evaluation of fuel levels at interchange when locomotives cross railroad borders.

Opportunity

The use of electronic fuel meters for onboard locomotives and fuel trucks with the transmission of the fueling activity by a locomotive in a timely fashion to the various planning and management systems, can likely deliver significant savings in fuel costs via proactive versus reactive fueling practices, while providing for fair interchange accounting, increased locomotive utilization, and increased traffic velocity. These data will also provide for determining the accurate burn rate of locomotives that further tightens the fueling process while providing guidance to train crews for efficient operation. Lastly, there is the opportunity for the railroads to minimize the cost of fuel, relative to varying state and province taxes by planning fueling activities based on accurate fuel tank status data.

Positive Train Control

The greatest source of train accidents is that of train crew errors with violation of the speed, time, and/or distance parameters of the movement authorities¹. To prevent these errors, PTC systems are partially deployed, or under development, across the industry with three core objectives as defined by the RSAC-PTC¹ effort several years ago. That is, a PTC system is expected to:

1. prevent train-to-train collisions,
2. prevent over-speeding, and
3. prevent trains from endangering on-track workers.

Given the high safety level of railroad operations in general, the incremental safety benefits of implementing PTC on its own are not sufficient to cover the capital investment¹ for the infrastructure required, and therefore PTC has not been mandated by FRA. However, at the time of this report being written, Congress is considering the mandating of PTC across the industry.

Opportunity

The FRA's PTC rulemaking provides the opportunity for a railroad to implement PTC as a safety balance against changes in operations that may be perceived to, or do increase risk and have sufficient business benefits to cover the expenditure for PTC. The most notable operational changes include one-person crews, the reduction or avoidance of signaled territory operation (discussed below), and operating switches from the locomotive in dark territory (discussed below). Hence, PTC can be a facilitator in obtaining business benefits via other applications that may not otherwise be obtainable due to their individual increase in risk, whether real or perceived.

Traffic Control

As mentioned earlier, the majority of a railroad's traffic runs over signaled territory based on the century-old technology of track circuits¹. This results in a fixed block handling of trains, as with traffic lights in a city, which automatically provides the aspects (the equivalent of red, yellow, and green highway traffic signals) for trains to advance. The infrastructure provides the vitality¹ of operations and requires substantial maintenance to maintain and ensure its reliability.

In non-signaled territory, the vitality is provided via a rather simplistic software program, referred to as a *conflict checker*, which maintains the status of track occupancy and generates movement authorities if no conflicts occur when the dispatcher makes a movement authority request. The original form of this process is the *train sheet*, which is literally that - a piece of paper that provides the same process for movement integrity. Once generated, the movement authority is read by the dispatcher to the train crew over the voice radio, followed by a read-back by the crew. Any misunderstanding results in a repeat of the process. In addition to the effect of not having accurate knowledge of train position and speed, it is this voice transmission process that greatly limits the level of traffic that can be handled by the dispatcher in dark territory.

Opportunity

Both signaled and dark territory provide for the safe operation of railroads by preventing train dispatchers errors in directing the flow of traffic. Therefore, signaling is used to provide greater traffic throughput due to the lack of any positioning information, as well as the inefficiency of voice transmission of movement authorities in dark territory. But, the signaling operation has a high cost of initial capital investment and on-going maintenance. Hence, the use of wireless data to transmit the movement authority efficiently (digital authorities) and reporting

train position and speed could result in the reduction or avoidance of signaled territory, all other factors being made equal. In this case, those factors are the consideration for broken rail detection, that is inherent in track circuit technology, and the perceived, if not real, perspective that signaled territory is safer than dark territory. These two issues can be readily addressed by low-grade track circuits sufficient for broken rail detection and the deployment of PTC, respectively.

In addition to the transition or avoidance of signaled territory in favor of dark territory, is the deployment of Communication Based Signaling (CBS) which eliminates the need for wayside signaling infrastructure. CBS is currently being promoted by a number of suppliers in the industry to use wireless technologies to transmit aspects directly to the locomotive from a central “vital office” for display in the locomotive cab, also known as cab signaling. The vital components that generate the aspects currently along the wayside would be moved to the central office and train location would be provided by an undetermined technology in lieu of track circuits, providing a virtual fixed block operation. With CBS, there still would be the issue of providing broken rail protection, as with the transition from signaled to dark territory, but the incorporation of PTC would be relatively straight forward in that most of the authority parameters (aspects) would already be on board.

Lastly, there is the ultimate in traffic control referred to as *moving block*. This is a real-time, process control version of CBS that continuously generates authorities to provide a safety zone around a train, instead of fixed blocks, based on the train’s braking capability. However, the data requirements of moving block where it would be most needed exceed the capabilities of existing, cost-effective wireless technologies. However, in between moving block and CBS is the opportunity for *flexible block*, which is the discrete generation of moving authorities that would vary in length based upon traffic density. Both moving block and flexible block would require the development of a software-based vital office that would be a substantial effort beyond the CBS approach that centralizes the current, well-proven wayside components. Neither moving nor flexible block are known to be under development within the North American market.

Mobile Node

The railroads have been focusing primarily on the locomotives’ onboard intelligence and communication platform for safety purposes. That effort has not been expanded significantly yet to incorporate the business and operating perspectives of the locomotive. As reflected above with the individual discussions regarding locomotive management, maintenance, and fueling, several railroads have little, if any, coordinated activities between the respective departments within their railroad, yet alone across the industry. The unfortunate, but unnecessary, consequence of this separation is the lack of the integration in building the business case to bring the various locomotive-borne applications together for a common communication, positioning,

and intelligence platform. While the issue is complex, the benefits are very promising once pursued. However, as addressed below in **DEPLOYMENT**, wireless-based applications are challenged by transmission constraints as throughput, reliability, and coverage.

Opportunity

For other than locomotive-centric applications, the locomotive should be provided with an intelligence platform that minimizes the need to transmit information to and from the wayside and office systems. As such, this onboard platform serves as a *mobile node* on the railroad's IT platform that provides the basis to pursue a number of opportunities for advanced functionality in an integrated fashion. The possibilities include the obvious, e.g., PTC, work order, flexible block, digital authorities, EOT, customer-gate interaction, engineer performance, and interactions with on-track work gangs. However, what has yet to be considered with the availability of a mobile node is the integration of an intra-train communication platform, as identified in the original demand study, but for which there were no pragmatic technologies at that time. This capability would add on a variety of sensor and monitoring applications including shipment health and integrity, equipment health (e.g., bearings, etc.), track geometry measurements, distributed in-train force monitoring, selected braking criteria based upon consist, and other yet-to-be-imagined capabilities.

Remote Switch Control

In signaled territory, train dispatchers direct trains by the alignment of switches in the rail. The dispatcher effects these alignments by making requests of the vital wayside infrastructure, the same infrastructure that provides the aspects in the signaling equipment. In dark territory, that infrastructure does not exist and the train crews are required to manually operate the switches. This activity can require a great deal of time, as well increased risk to crew members, as they off-board the train, operate the switch, and walk the train distance to get back on board.

Opportunity

With wireless telemetry, the train crew can operate an equipped switch from the locomotive cab. Similar in concept to the dispatcher's activity in signaled territory, such an activity would be done in a fashion to not violate another train's authority. This capability is directly compatible with PTC deployed in dark territory that is currently monitoring the switch position to determine which track the train is on, as well as providing enforcement should the crew attempt to violate their authority with movement and speed through the switch.

Main Line Work Order

A number of railroads have developed wireless-based work order systems for their dedicated industrial switching train crews that are used to deliver cars to/from the shippers and the railroad's yards. However, on the main line there is a significant amount of activity that takes place with what would otherwise be through-trains to service shippers beyond the limits of industrial switchers. This activity can play havoc with the railroad's operation by causing disruptions to traffic management, as well as extensive delays to the affected train as the crew manages the process with imperfect information like car locations, trackage, etc. Finally, there is the possible effect that the rearranged consist may have on switching and train building activities at the destination yard.

Opportunity

In addition to the type of information that is made available to yard and industrial switching crews, main line train crews could be presented with a schematic of car locations along with switching order, with the final consist transmitted to the appropriate system(s) prior to the train arriving into a yard.

Wayside Maintenance

The wayside signaling and grade crossing infrastructure that provides for the integrity of railroad operations and the public's safety, respectively, is subjected to rigorous, continuous testing processes, regardless of the actual condition of the equipment. This process requires on-site presence. For coordinated combinations of tracks and switches (interlockings), multiple individuals are required for observation only in addition to the maintenance and testing effort.

Opportunity

As with the discussion above regarding locomotive maintenance, the availability of timely health and diagnostic data pertaining to wayside infrastructure can provide the basis for performance-based maintenance that extends, if not replaces, the prescriptive process. Additionally, on-site maintenance personnel can be provided with endless access to diagnostic material including history, diagrams, and real-time connection with help desks that can monitor, if not affect changes remotely. As to complex interlockings, wireless can be used to provide visual observation and data acquisition of associated locations instead of manual observation.

On-Track Maintenance

To train dispatchers, the work zones for on-track work forces are trains that do not move thereby, consuming valuable track time, and over which they have little or no control. From the workers' perspective, they are subject to the threat of train movements approaching their work zone and are not kept current, if even informed. While most work zones are protected by an authority process that requires communication between the train crews and the work gang's Employee-In-Charge (EIC), there are many mobile workers with and without fixed work zone limits that are deployed with only a "watchman lookout," who is watching for approaching trains. According to one major railroad, these lookouts are costing them "millions" for otherwise unproductive labor. Lastly, there is also the opposite perspective of on-track workers leaving their protected zone and placing themselves in danger with legitimate train movements.

Opportunity

There are several opportunities for wireless technologies. First, by providing on-track workers with some combination of train movement monitoring and proximity warning system, the lookout positions can be eliminated by maintaining a virtual protective barrier around the work areas, whether changing or static. Second, whether or not PTC systems that are installed currently do not directly integrate the EIC authority process, a digital authority process would be a significant improvement in safety, as well as productivity by eliminating the current voice communication process between train crews and the EIC. Lastly, one railroad has deployed a High Rail Compliance System that results in an alert to the train dispatcher when an on-track maintenance vehicle has violated the boundaries of its authority.

Intermodal Operations

Although not included in the original scope of the study, the intermodal industry is addressed below relative to the rail interface. It presents a phenomenal challenge to the tracking of both assets and shipments with the rail component being arguably the most reliable. There are three primary issues: 1) asset utilization, 2) shipment tracking, and 3) shipment integrity and health.

1. Asset Utilization

The challenge of asset utilization begins with the lack of available tracking data. For intermodal movements, this issue is directly due to the presence of the *beneficial owner* (i.e., the party who is in possession of the equipment/shipment at any given time, but is not the true owner). The true owner of the equipment, if not also the shipper, has little interest in tracking the equipment other than by knowing the "chain of custody," and the shipment tracking processes provide for that level of granularity. However, within any given beneficial owner operation, the tracking data doesn't normally exist because no one beneficial owner is willing to make the capital investment to provide for such reporting given the short period of possession.

2. Shipment Tracking

As difficult as it is to track the equipment, it is even more relative to containers within yards and along the main line. With varying granularity of shipment tracking in concert with the reported unwillingness of railroads to share consist data with other railroads, the shippers are left without cross-industry visibility of the advancement of their shipments.

3. Shipment Integrity & Health

Smart seals for containers have been developed and selectively deployed to provide indication of when tampering has occurred. Without a pragmatic communication link to get this data to the appropriate parties, a great deal of security is lost. Considering health, there is no ability to provide exception notification for the majority of rail traveling time.

Opportunity

As to the tracking of shipments, it appears that a depository is required for the industry that is independent of the individual railroads. This is a depository that would capture all movements relative to trains and consists, and permit subscribers to have access to the appropriate data. This concept is addressed below in **IT Architecture**.

The remaining two areas of utilization and integrity/health have the opportunity of being integrated. This is an integration that involves ownership, technologies, and operations. It is possible that chassis could be considered as a mobile node for intermodal just as the locomotive can be for the railroads. Consider the following.

Several years ago, the Federal government paid for the development of a chassis mounted unit that would report position on some scheduled basis (e.g., three times a day), recognizing that RF transmission power would be a major challenge in the pragmatic deployment of these devices. Subsequently, there was some degree of effort to tying in the reporting of electronic seals with chassis-mounted unit. By linking these devices with chassis-mounted reporting units, which were originally designed for chassis management, the basic platform is there for exception monitoring of shipment integrity, or health if those detection devices are incorporated within the unit. To date, the communication link for the chassis-mounted unit has been cellular-based, given the point that the handling of containers when on trucks would need to rely on services provided along highways. However, what about when those containers are on the rails? This is same multi-mode communication issue that confronts the railroads with their individual wireless agendas.

The problem remains as to who will make the investment in any positioning technology. There is one major type of exception to this consideration, and that is when equipment enters and leaves a beneficial owner's confined (controllable) area

(e.g., an intermodal yard). The use of temporary tracking devices that can be easily applied and removed can handle that level of tracking, for which there is tremendous value. However, as to the remainder of the supply chain, there needs to be some unifying force or entity. One answer may be the use of major chassis pools and agreements within the industry, if not a Service Bureau that takes on the capital investment and management of the data. Another possibility may be the consideration of domestic security and the availability of federal funds. Again, this issue is one more Catch 22 with systems and data availability, but with the beneficial owner twist.

Intermodal introduces two other levels of operability, i.e., Cross Industry and Global Intraoperability, relative to shipment tracking, integrity, and health.

Threat Management

After the terrorist attacks on September, 11, 2001 (9/11), the railroads went through an extensive risk analysis of their infrastructure and operations relative to terrorist-based threats to “*harden the targets.*” That analysis would have been bound by the capabilities of the technologies at that time to monitor and control remote and mobile resources.

With the lack of information available for this study regarding the objectives and results of the railroads’ effort, it is possible that there is significant value in expanding the scope to consider threats other than those of terrorists. The reason for this is one of financial evaluation and willingness to make investment in technology. That is, given that the railroads were without any significant opportunities for deploying wireless data at the time of the 9/11 analysis, there had to have been constraints on what would be considered in the identification of the *critical infrastructure*¹ and how to monitor and protect it.

In addition to the shipment integrity discussed above, relative to intermodal, there is also the issue of interagency communications, whether voice or data, that is most likely not there today.

Opportunity

Would the railroads’ post-9/11 analysis be different today if they would take a wireless data approach now? With the currently-realistic constraints of limited, cost-effective, wireless data removed, it is very likely that the type of systems, processes, and equipment deployed for terrorist and other threats could be significantly expanded, the lack of an acceptable, risk-based return of interest notwithstanding. For example, the monitoring of the integrity of remote facilities (e.g., alignment on bridges and expanded video), are well in reach at this point. As to critical rolling stock, one major chemical supplier has equipped its fleet of 700 Toxic Inhalation Hazard (TIH)¹ tank cars to locate and monitor their integrity on an as-needed basis. This information is coordinated within their industry, and the railroads subsequently are made of aware of possible problems as deemed appropriate.

Lastly, the opportunities for wireless would likely include voice and data requirements for inter-agency interaction of railroad, municipal, State, and Federal resources.

Passenger Services

While Amtrak has many of the same primary operation challenges as freight railroads, there are several key differences as to its requirements for wireless technologies and how those requirements can be met.

In regard to additional requirements, its customers are on board, or at stations, and its perspective of customer service with maintaining schedule and providing associated services is immediate. That includes providing communication and Internet access to its customers, status-of-train signage at stations, and handling onboard purchases, including services and tickets. This capability includes being able to take advantage of the changing availability of various services on board (e.g., berths, etc.), given the dynamics of the passenger manifest. From a security standpoint, Amtrak is looking to track the passenger manifest and to provide the communication requirements for a mobile police force.

With meeting its requirements, Amtrak is at a major disadvantage given that 95 percent of its operations are over another railroad's property, and therefore without private wireless voice or data coverage. Its view of interoperability encompasses the industry, and it relies on information from the railroads about the location of their trains and on commercial cellular services to service its basic crew and police communications other than traffic control.

Opportunity

Amtrak is reportedly looking at private wireless networking over the Northeast corridor that it controls for providing a number of the customer services described above. However, for the majority of its operating territory, it has little choice at this time but to rely on commercial services to meet the expanded functionality that it envisions for its passengers and security purposes given the inconsistency of private wireless data infrastructure across the Class I railroads. Amtrak would be able to benefit substantially from an industry tracking system as discussed below in **SCENARIO**.

Operability

The use of wireless technologies within railroads to advance operations carries with it the challenge of *operability* (i.e., the ability to use wireless technologies not only within an individual railroad's boundaries but also across the industry for the advantage of all roads when operating foreign equipment over their respective networks).

In the latter part of 2005, the railroads agreed to take on operability as it relates to the interchange of trains between railroads, known as *interoperability*, with a series of tasks referred to as the *Roadmap to Interoperability*. The underlying motivation was that of pursuing one-person crews and therefore the objective of seamlessly implementing PTC across the industry, noting the previously discussed point of PTC providing a safety balance for the possible increase in risk of one-person crews. However, with a stay in the negotiations between railroad management and labor to pursue one-person crews in November 2006, the priority of interoperability to facilitate industry-wide PTC has given way to each railroad's individual agenda of technologies and applications. Unfortunately, these singular railroad efforts can result in increasing the complexity of, and the resistance to, obtaining interoperability for several reasons including evolving infrastructure, as well as additional technical interfaces and business processes which will need to be incorporated at some point in the future.

The challenge of operability is significantly greater than that of interoperability. In the deployment of wireless-based applications, there are six levels of operability to be considered as identified in **FUNCTIONALITY: Railroad Intraoperability, Interoperability, Industry Intraoperability, Train Intraoperability, Cross Industry Operability, and Global Intraoperability.**

Railroad Intraoperability:

Railroad Intraoperability is a common challenge for a railroad when it implements a new function or deploys a new technology system wide. Until the entire affected infrastructure and/or fleet is configured properly, the application will be required to deal with the "unequipped" units in some fashion. As such, the railroad will be making a tradeoff during implementation that pits the capital investment for complete or rapid installation against the compromise in functionality and/or the operational cost of managing around the unequipped units, (e.g., swapping in/out devices on the lead locomotive of trains to provide for the required functionality instead of equipping all locomotives).

With the locomotives specifically, there is an additional complexity for a railroad's intraoperability as to the use of foreign locomotives, which can be up to 20 percent of the fleet at any given time. Additionally, when dealing with a railroad's use of VHF, its primary wireless voice network, the issue may involve tens of thousands of radio units, as well as the lack of available frequencies that can be assigned permanently or used as a buffer during transition given radio channel allocation across the industry.

Interoperability:

Interoperability refers to the challenges of the interchange of equipment across railroad boundaries. As such, the tradeoff is still the same as that of railroad intraoperability in the

consideration of capital investment, functional benefits, and operating costs, but its handling is raised to an industry level. This means that the AAR is involved to ensure industry-wide participation by establishing some mixture of interchange rules, specifications, and guidelines that the railroads have agreed to collectively.

Industry Intraoperability:

Industry Intraoperability involves having access to the status of resources regardless of which railroad they are operating. Whereas railroad interoperability and interoperability issues for each railroad involve owned and foreign assets on its property, industry intraoperability involves a railroad's assets on other railroads. This level of operability has been rarely discussed or pursued, and it presents a significant opportunity to railroads for improved operations as noted in **FUNCTIONALITY**, including traffic management, the locomotive application suite of management, maintenance, fueling, and threat management.

Train Intraoperability:

Train Intraoperability focuses on the mobile node perspective discussed in **FUNCTIONALITY**. With the developing expansion in scope of the locomotive's communication and intelligence platform to include intra-train and track monitoring, the challenge shifts to dealing with 1.3 million units of rolling stock, in addition to only the 22,000 locomotives involved in interoperability.

Cross Industry Operability:

Cross Industry Operability is a developing level of operability as the attention on security and hazardous materials crosses boundaries between the railroads and the respective shippers and industries. For those shippers that have attached sensors to their owned rolling stock (e.g., tank cars for hazardous material), they will know before the railroad that the hatch has been opened or tampered with and will notify their industry association first and finally the railroads.

Global Intraoperability:

Global Interoperability is taking cross-industry operability to the global level, again with focus on the shipment and domestic security.

Not all of the applications described in **FUNCTIONALITY** need to consider all levels of operability, as shown in the following table.

		OPERABILITY LEVEL					
		Railroad Intra	Inter	Industry Intra	Train Intra	Cross Industry	Global Intra
FUNCTIONALITY	Traffic Management	√	√	√			
	Yard Management	√		√			
	Crew Management	√		√			
	Locomotive Management	√	√	√			
	Locomotive Maintenance	√		√			
	Locomotive Fueling	√	√	√			
	Positive Train Control	√	√				
	Traffic Control	√	√				
	Mobile Node	√	√	√	√		
	Remote Switch	√	√				
	Main Line Work Order	√	√				
	Wayside Maintenance	√					
	On Track Maintenance	√					
	Intermodal Operations	√		√	√	√	√
	Threat Management	√	√	√	√	√	√
	Passenger Services	√		√	√		

The most significant thing about this table is that the value of operability far exceeds the singular pursuit of one-person crews, and introduces the consideration of how the railroads may want to move forward in addition to the current programs stemming from the Roadmap to Interoperability. Arguably, the best way to begin is to identify the business value associated with each of the areas listed.

Business Value

It is not the intent of this study to provide a financial analysis that would be sufficient to make an investment decision regarding the deployment of wireless and related technologies. However, the intent is to expose the areas of value by functionality and heighten the awareness of the opportunities that may indeed lead to appropriate financial analyses (business cases), both within

the individual railroads and from an industry perspective, given the various levels of operability. One of the driving factors for doing such analyses is the consideration of the FCC's Report & Order that deals with narrow-banding (discussed in **WIRELESS ENVIRONMENT**). This action will eventually result in the necessity to replace the current, mostly-analog, VHF infrastructure with a digital one. This means that the objective of the business case has changed from that of justifying an investment to that of optimizing the return on a required investment, assuming the railroads wish to retain usage of this most valuable spectrum. However, even without the narrow-banding requirement, it is believed that the value of the opportunities identified in this study would be shown to be more than necessary to make the transition to a digital VHF platform sooner rather than later based upon the following cursory evaluation.

While each railroad will have its individual slate of benefits that it uses to consider the investment in technologies, the following six categories are being considered in this study:

- **Traffic Velocity:** minimizing travel time over the main line, which in turn has an effect on resource utilization, direct costs, and customer service;
- **Resource Utilization:** minimizing the unproductive use of resources, including crews, track time, locomotives, maintenance crews, and yard dwell;
- **Direct Costs:** minimizing the costs associated with operating the railroad, including maintenance, fuel, and crews;
- **Infrastructure:** minimizing the requirement for infrastructure including wayside and onboard;
- **Customer Service:** maximizing the level of customer service in pursuit of increased revenue; and
- **Security & Safety:** maximizing the cost-effective level of resource and shipment security, as well as the safety of operations.

The following table associates each of the above benefits with the opportunities identified in **FUNCTIONALITY**. Additionally, a subjective determination is made as to the total relative value of each.

		VALUE							Total		
		Source									
		Traffic Velocity	Resource Utilization	Direct Costs	Reduced Infrastructure	Customer Service	Security & Safety				
FUNCTIONALITY	Traffic Management	X	X	X		X					X
	Yard Management	X	X	X		X			X		
	Crew Management	X	X	X					X		
	Locomotive Management	X	X	X					X		
	Locomotive Maintenance		X	X					X		
	Locomotive Fueling		X	X							X
	Positive Train Control			Fac*	Fac*		X				X
	Traffic Control	X	X	X	X						X
	Mobile Node	X	X	X	X	X	X		X		
	Remote Switch Control	X	X				X		X		
	Main Line Work Order	X	X			X			X		
	Wayside Maintenance		X	X					X		
	On-Track Maintenance	X	X	X			X		X		
	Intermodal Operations		X	X		X	X		X		
	Threat Management					X	X		X		
	Passenger Services		X	X		X	X		X		

* PTC can facilitate the deployment of other business changes.

Value alone cannot be the determining factor in implementing wireless-based applications. This point was dramatically demonstrated several years ago with an attempt by a railroad to implement moving block, which was considered to be of tremendous value to the railroad. Even without considering the substantial effort to develop a vital office required by this ultimate traffic control methodology, it was clear that the wireless technology of choice at that time could not support the data transmission required over the part of the railroad where moving block could provide the greatest value. Unlike wired networks, the communication link is often the weakest design and implementation link in the successful deployment of advanced functionality. However, the deployment challenges are not just that of deploying wireless technologies, but also in providing the means that the data can be effectively used, as follows.

Deployment

In the abandoned moving block attempt mentioned above, a primary application killer was the inability to deploy a cost-effective wireless solution that could provide the required data throughput. Usually, however, in the railroad industry, it is a second dimension of wireless that is the most difficult to overcome (i.e., the challenge of coverage). The railroad's unique footprint of tens of thousands of miles of ribbon operations with intermittent hubs, has proven to be cost prohibitive for a number of projects that could not singularly justify the investment. Hence, commercial services have often been, and continue to be, utilized to provide the necessary coverage for individual, wireless-based solutions.

Coverage and throughput are not the only challenges to the deployment of wireless systems; there are three other areas. First, there is the challenge of dealing with the wireless environment, the parameters of which include installed infrastructure, regulatory issues, commercial versus private network opportunities, and advancing technologies. Secondly, even if the data can be delivered, it is likely that the current management systems are not able to use the data in a most-effective fashion. This is due to the fact that the to-be legacy systems are likely structured based on a very limited level of data timeliness and accuracy than that available via wireless (e.g., moving block), requiring a vital office development. Third, with the addition of the mobile node, a modified IT architecture is required that can effectively manage the positioning dynamics of resources, dynamics that are not to be found in the point-to-point communications of a wired, fixed node distributed or centralized IT platform.

Together, the five factors of coverage, throughput, wireless environment, management systems, and IT architecture suggest that the railroads may benefit from an approach to the development and deployment of wireless-based applications and the related infrastructure that complements the current efforts associated with the *Roadmap to Interoperability*. The railroads may benefit from an *evolutionary* approach to developing and deploying the wireless-based applications identified in **FUNCTIONALITY** that can be delivered relatively quickly and effectively while they continue with an industry effort that is clearly a number of years away from actual implementation, given technical, financial, and political considerations. A **SCENARIO** for such deployment will be addressed below following a discussion on the wireless parameters of coverage and throughput, the wireless environment, issues of management systems, and IT architecture.

Coverage & Throughput

Incorporated into the initial wireless study a decade ago, was a structuring of wireless' coverage and throughput dimensions, as associated with the applications identified then. To a great extent, that understanding remains applicable today, albeit with greater flexibility given the explosive advancement of wireless technologies.

Coverage: Unquestionably, a major issue for implementing wireless systems across freight railroads is that of terrestrial expanse. However, not all applications are required everywhere. There are clusters of applications that can be related to four different types of coverage, as follows:

- **Main-line:** the inter-city traffic that includes most of a railroad's terrestrial expanse;
- **Metropolitan:** the major metropolitan areas that include multiple railroad facilities;
- **Yard:** an individual terminal/facility; and
- **Group:** a number of users that require communications between themselves when they are together and are then disbursed (e.g., work gangs, trains, disaster teams, etc.).

Throughput: Throughput is not just an issue of baud rate as one would think of relative to wired communications. When exposed to the wireless world, one quickly learns that this untethered environment is challenged with a number of message integrity issues including dead spots (no signal), EMF interference, restricted bandwidth, user contention, limited signal propagation, and the occasional dead battery for the hand-held radios. Given this set of challenges, it is appropriate to define the throughput attribute in terms of the different types of transmissions, of which there are six.

Monitor: the transmission of remote data to a source of intelligence. The data flow is inbound only and consists of small data bursts that occur infrequently on either a routine or as-required basis;

Voice: a two-way transmission that occurs randomly and may be of relatively long duration;

Transaction: the interactive flow of data that is short in nature, but may occur quite frequently;

Data Transfer: the two-way flow of considerable volumes of data that will occur with some predictability as to location or time of day;

Loose Control: often referred to as SCADA in other industries, this two-way flow of data is associated with the remote control of equipment that is perhaps timely, but not safety critical as to the timeliness of the data (e.g., code lines¹); and

Tight Control: the two-way flow of control data that is operationally and safety critical and, therefore, the throughput attributes must maintain tight variances (e.g., moving block).

With four areas of coverage and six types of throughput, the wireless requirements of a railroad can be structured into 24 combinations as shown in the following matrix.

COVERAGE

		MAIN LINE	METROPOLITAN	YARD	GROUP
THROUGHPUT	MONITOR	1	2	3	6
	VOICE	5	6	7	8
	TRANSACTION	9	10	11	12
	DATA TRANSFER	13	14	15	16
	LOOSE CONTROL	17	18	19	20
	TIGHT CONTROL	21	22	23	24

When the applications addressed in the original study were viewed as to which blocks they fell into, there was a natural merging of the individuals blocks which led to a more practical strategic perspective. Specifically, as shown in the modified matrix below, six “wireless corridors” were identified with each being a combination of applications with similar wireless requirements. This perspective offers a pragmatic approach to tailor wireless infrastructures for shared usage by applications.

COVERAGE

THROUGHPUT		MAIN LINE	METROPOLITAN	YARD	GROUP
	MONITOR	MONITOR			
	VOICE	MOBILE NETWORK		YARD NETWORK	INTRA-GANG or INTRA-TRAIN
	TRANSACTION				
	DATA TRANSFER	SCADA			
	LOOSE CONTROL	PROCESS CONTROL			
TIGHT CONTROL					

Applying this same structure of wireless corridors to the opportunities identified in **FUNCTIONALITY**, as shown in the following table, provides the basis for building a deployment strategy for moving forward in an evolutionary fashion.

		WIRELESS CORRIDORS					
		Monitor	Mobile Network	Yard Network	SCADA	Intra-train Intra-gang	Process Control
FUNCTIONALITY	Traffic Management	X	X				
	Yard Management			X			X
	Crew Management	X	X				
	Locomotive Management	X		X			
	Locomotive Maintenance	X	X	X	X		
	Locomotive Fueling	X		X			
	Positive Train Control		X				
	Traffic Control		X		X		X
	Mobile Node		X	X		X	
	Remote Switch Control		X		X		
	Main Line Work Order		X				
	Wayside Maintenance		X		X	X	
	On-Track Maintenance		X		X	X	
	Intermodal Operations	X		X	X		
	Threat Management	X			X		
Passenger Services		X					

The two highlighted columns are the most notable. Between, the *Monitor* and *Mobile Network* corridors, all but one of the advanced functions can be serviced to some extent. However, the most interesting point is that the *Monitor* and the *Mobile Network* corridors represent the difference between evolutionary and revolutionary deployment, respectively. That is, they represent the difference in being able to deliver value immediately in a pragmatic fashion via a simplistic Monitor platform, while the industry continues to wrestle with the complexity of the long term perspective of a revolutionary Mobile Platform via the various AAR technical committees. As if the intrinsic challenges of developing a mobile platform were not substantially difficult on their own, the railroads are also being confronted with a FCC Report and Order to restructure their VHF infrastructure (discussed in **Wireless Environment**), which presents them with investment alternatives that have yet to be addressed with a business case analysis by individual railroads, yet alone at the industry level.

The Monitor corridor is a no-brainer, throw-away solution that will pay for itself immediately. It is an individual railroad approach that does not require standards, a data model to size, or even a complex business case to be made. In fact, it is an approach that one railroad CEO has taken to break into the aforementioned Catch 22 (i.e., having the data, to use the tools, to get the value to pay for the data). This is a simple “Just Do It,” and for an individual railroad, it makes a great deal of sense to get rolling on advanced functionality. But, from a multi-operability standpoint, there are some other challenges to be considered. Fortunately, those challenges are actually quite straightforward and readily achievable, as will be addressed in **SCENARIO** below.

Wireless Environment

The railroads have extensive private wireless infrastructures across their individual systems. The primary set of frequencies that have been in use since the middle of the last century for voice communications is in the 160 MHz portion of the VHF band. There are an estimated 250,000 units across the industry that operate on those frequencies. The railroads also use frequencies in the 450 and 900 MHz UHF bands for a limited amount of data for isolated applications, most notably EOT and wireless codeline, respectively. Recently the railroads purchased five channel pairs in the 220 MHz range for Remote Control Locomotive (RCL)¹ and other possible uses. Lastly, one railroad has purchased a company with licensed frequency at 44 MHz and is using that network for at least its PTC data requirements. Such an inventory provides the basis for moving forward.

Since the original wireless demand study a decade ago, there have been substantial changes in the availability of wireless technologies, both for private and commercial networks. Additionally, for sometime following the study, wireless and IT were seen as separate disciplines with neither exhibiting understanding, nor experience in the technical challenges of the other. That has now changed with the recognition that the wireless technologies offer the opportunity to extend the IT infrastructure beyond the end of the wire to more tightly incorporate the mobile

and remote resources into the management systems. However, unlike wired infrastructures, wireless technologies vary substantially in their ability to service the throughput, coverage, and reliability requirements of applications. And, since there is no one technology that provides the most cost effective infrastructure across the broad range of applications, it is necessary to consider a range of wireless technologies and services, both private and commercial.

Arguably, the most popular choice for wireless data for the last several years has been the usage of commercial services. As noted earlier, commercial services have been used to implement singular solutions to meet individual railroad department requirements that could not justify the installation of a private network. The good news is that railroads have been able to advance selected applications, albeit at a relatively high cost for the amount of data required when compared to a private network if it was available. However, other key applications have not been able to be advanced due to such costs. For example, as noted earlier, this same cost consideration has been a likely deterrent to moving toward a proactive traffic management functionality, given the value/data Catch 22. Therefore, a collective understanding of the opportunities for wireless is an underlying consideration of promoting private wireless infrastructure. But, there are several other considerations as well.

As noted earlier, the railroad's primary wireless infrastructure, VHF, is subject to the FCC's narrow-banding Report and Order. This order currently requires the railroads to split each of its 25 KHz channels in the 160 MHz portion of the VHF band in half to create twice the number of channels by the end of 2013. While on the surface this seems to be an excellent idea, the challenges are substantial including providing a channel plan that allocates frequencies efficiently and fairly along with providing a multi-year, interoperable migration plan. However, due to the way that the railroads have cleverly coordinated their channels in the past at the 25 KHz spacing, they will gain very little additional channel availability and usefulness with the 12.5 KHz spacing. Hence, without having developed a strategic perspective and associated business case of what a digital platform could provide, the railroads have invested in analog 12.5 KHz equipment to replace the 25KHz analog equipment to meet the time line of the FCC's order.

Recently, the FCC announced that they will be demanding an additional split in same spectrum resulting overall in a four for one split of channels to a spacing of 6.25 KHz. While this does indeed offer additional capabilities to the railroads, by supporting many of the opportunities noted in **FUNCTIONALITY**, it also means that the analog infrastructure, including the recent 12.5 KHz equipment, will need to be replaced with a digital infrastructure. This is estimated to be at least a \$500 million investment for the industry that would have to be spent by a date not yet determined for the transition. This point introduces a second consideration of advancing wireless in addition to understanding the opportunities. That is, if the order is made regarding the second split, then the railroads will have to make the investment to keep the most-valuable frequencies. This changes the business case from a return-on-investment analysis to one of maximizing the return on a required investment. As suggested by this study's findings, the sooner the transition is made, than the greater the return. This is directly opposite to the current perspective of delaying the investment for replacement purposes only.

There is one other consideration, however. In light of the total replacement of the VHF infrastructure to meet the possible 6.25 KHz spacing, an infrastructure ripe for data, there is the opportunity to do what the railroads did with their wired communication backbone requirements along the right-of-way, when fiber optics came into play several decades ago. That is, the opportunity is there to bring in a third party to make the investment in whole, or in participation with the railroads, to deliver the services to the railroads and others as a commercial enterprise.

As to the other wireless corridors that were identified earlier, there is one particularly interesting approach that is being pursued for the intra-train environment. This is the use of a wireless mesh network¹ throughout the train. A key design factor here is that of evolutionary deployment again. This technology does not require each car in the train to be equipped with the technology. Instead, the low-power, wireless-based, sensor nodes, (motes), can be installed on cars as deemed appropriate with their connectivity being coordinated via a gateway (a network controller that then can interchange data with off-board wireless networks).

Management Systems

The deployment of wireless data infrastructure doesn't mean that the current management systems and business processes will be able to use that data effectively. This is the next challenge to providing *evolutionary* versus *revolutionary* deployment that can deliver value immediately; value that might not have been achievable otherwise. Indeed, revolutionary changes in business processes may be perceived to be too difficult to implement or to have insufficient benefits to justify revolutionary changes in the IT and communication infrastructure. This is especially true for railroads in general, where the primary business processes have changed relatively little in decades. Arguably, the ideal opportunity in the railroad environment is that of revolutionary change with evolutionary deployment, which is very possible in a number of key areas. As identified in **FUNCTIONALITY**, there are those applications which are applicable to individual railroads and those that require access to resource status data from across the industry and have not been pursued due to do the lack of an industry-based infrastructure and databases.

Recognizing which management services to begin with is actually quite simple. If one is willing to make cursory evaluations of two criteria that need to play well together in a wireless environment which are value and data. As shown in the following matrix of these two parameters pitted against each other, there is an opportunity to define a deployment strategy that delivers high value, but with low data requirements. First with some level of wireless data infrastructure (e.g., commercial services) and then progress to, or complement with, a more robust wireless data platform (e.g. a private wireless network). This movement from light to darker shaded blocks (upper right to lower left) is directly aligned with the previous discussion regarding the Monitor versus Mobile Platform corridors.

		VALUE		
		Low	Medium	High
DATA	Low	Wayside Maintenance	Crew Management Locomotive Management Locomotive Maintenance Remote Switch	Traffic Management Locomotive Fueling
	Medium	On Track Maintenance Threat Management	Yard Management Mobile Node Main-line Work Order Intermodal Services Passenger Services	P T C Traffic Control Flexible Block
	High	Moving Block - Eastern Railroads *		Moving Block - Western Railroads

* Eastern railroads expect little value from moving block due to the high density of contentious traffic.

Specifically, railroads could benefit immediately by having the simplest of wireless data systems that could evolve in a financially responsible fashion. This is an approach that would include the shunning of installed technologies and implemented processes that were valuable at some point, but that are no longer required. However, discarding installed equipment is a difficult concept for many to embrace in the industry, even though the rapid changes in wireless and related technologies have, and will most likely continue, to provide valuable functionality. As such, those technologies may not be deployed due to the inability to discard the equipment of previous investments, even though the payback period has been well exceeded.

IT Architecture

Not inherent in the distributed fixed node or centralized IT platforms in use by railroads today, are the parameters of positioning and speed. The resources being managed by those platforms either do not move, or if they do, their management process progresses in a discrete fashion throughout the sequence of fixed nodes or in-frequent update reports. This is the case with current traffic management in the railroads based upon the SCADA, CAD-signaling platform with trains advancing on a block-by-block basis with no indication of speed (as in, did the train stop?). This lack of visibility as to interim train status has contributed substantially to the current reactive (crisis-based) traffic management approach addressed in **FUNCTIONALITY**. Therefore, moving forward with location-based systems require changes to the IT architectures in the railroads, both individually and from an industry perspective. There are four major considerations to make those changes.

1. Moving forward with wireless-based systems relative to proactive management of mobile resources can greatly benefit from the availability of a positioning platform, a *positioning engine*, that is tightly integrated with the IT architecture. This is a platform that merges the various sources of positioning data into a single data domain that services all applications requiring such data. Those data sources would include direct reports via wireless, AEI, voice messages, EDI, OS reports, lineup entries, and the handling of authorities in dark territory. At least one railroad is known to have developed such a Kalman filter-like¹ approach.
2. Given the levels of operability identified previously, the issue of positioning being incorporated into the IT architecture is not confined to each railroad addressing its own singular requirements. Positioning also has an industry perspective, as well as a cross industry and global perspective, depending upon the resource. For locomotives, obtaining positioning information today, whether on or off of the owning/leasing railroad's property, varies greatly by railroad with a number of different sources as noted above. Reportedly, a significant amount of this information is not being shared between railroads for competitive reasons when associated with train consist data.
3. Associated with each perspective of positioning is the necessity for a common referencing system, a Geographical Information System (GIS) that ensures that each positioning reference is interpreted by all in the same way. While each railroad has greatly expanded the sophistication of their individual GIS platform and associated data within the last 5 to 10 years for their own reasons, each effort has been done without an industry perspective. Additionally, there has been no sponsorship at the industry level to assure compatibility, or host an industry-level GIS platform, e.g., a Railroad Transportation GIS Model, as in other industries.
4. Recognizing the in-time and exception aspects of position reporting, instead of continuous real-time based upon the resource involved, a concept of geo-fencing is becoming increasingly important. As introduced earlier, this is the ability to have a location-based system take some action when a geographical boundary defined in the positioning platform is crossed. For example, a locomotive could report its fuel level when it crosses railroad boundaries. As with the GIS requirement, there are different levels of geo-fencing opportunities, e.g., mobile platform, individual railroad, and industry.

Together, the levels of operability and the selective availability of data, along with the multiple levels of GIS and geo-fencing, demonstrates the need for a hierarchy of positioning platforms that can be used on a selective basis by authorized users (subscribers) independent of the providers (publishers) of the data. This publish/subscribe (pubsub)¹ concept is a key IT design perspective in assuring data accuracy and consistency across the enterprise and industry. It can minimize the duplication of data collection and storage in lieu of the isolated, self-contained model of traditional application development.

Scenario

Having identified the deployment issues of wireless coverage and throughput, the wireless environment, management services, and IT architecture, a possible scenario is provided below on how railroads can advance a number of the opportunities identified in **FUNCTIONALITY** in a pragmatic and/or evolutionary fashion. It all begins with the deployment of a monitor platform on all locomotives for an individual railroad and finishes with an industry perspective.

I. Monitor Platform

While the industry proceeds to work through the development of a sophisticated mobile platform that will service the long term perspective of interoperability, there is a great deal of business value that is not being taken advantage of, as noted in this report. Additionally, once the futuristic platform is available, there will be a substantial amount of time involved in building the management systems that can use the data. What is not being considered by most of the railroads, and clearly not at the industry level, is an interim solution that can deliver advanced functionality sooner rather than later, a solution that disrupts the tool/data Catch 22 to get the railroads moving forward with advanced functionality, as described in this report.

By placing a simple GPS-based, position/speed reporting unit on a locomotive that can provide information every 5 to 15 minutes along the main line (for example, an inexpensive unit using commercial services), a railroad will have the opportunity to begin the development of the evolutionary management systems (described below) to deliver the range of benefits associated with proactive asset management. With just a modicum of additional capability of reporting key locomotive health and fuel data, along with geo-fencing, the business values associated with the full locomotive application suite are obtainable. This is a platform that need not be uniform across the industry as to the equipment, message sets, or even protocol. It will be uniform to the minimum reporting requirements as to exception and/or time intervals for various applications; thereby expanding beyond interoperability to address industry intraoperability. Reportedly, several roads have priced out commercial services for an increased frequency of reporting, and they have been disappointed by the cost of the offerings. However, if done as an industry, including the requirements for Amtrak against a number of suppliers in concert with a business case built on the business values identified in this study, it is believed that such an interim approach will have substantial net value. It is important to keep in mind that the requirements for such a platform are neither safety critical or of significant throughput to be subjected to the reliability issues that have discouraged some railroads from considering cellular systems to date.

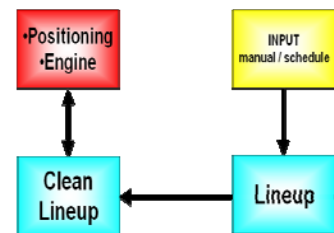
Some railroads already have the beginnings of reporting locomotive speed and position with either a private wireless network or the deployment of onboard communication/intelligence platforms, but no railroad was found to have put together the evolutionary perspective, that follows below, in delivering the business value, a perspective that begins with a *positioning engine*.

II. Railroad Positioning Engine

Again, the proactive management of a railroad's major mobile resources begins with knowing the position and speed of the locomotives, and there are a number of sources for positioning information. Currently, the railroads collect locomotive position, either directly or indirectly, by numerous means including commercial wireless services, AEI reports, OS reports (as to train movement), voice communications, lineup entries, and generation of authorities in dark territory. The accuracy and timeliness of these reports, as well as where and how they are maintained by their respective users, vary substantially. Most importantly, none of them are of sufficient timeliness, if even accurate, to be used for proactive traffic management and none provide speed information. However, they do have some value in servicing other applications, especially if a pubsub-based positioning engine is established that incorporates geo-fencing. With the development of such a platform that incorporates the appropriate data from the Monitor platform, a platform that is outboard of current systems, the next step becomes that of cleaning up the lineup.

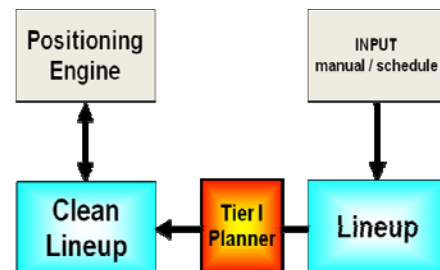
III. Cleanup the Lineup

A railroad's lineup that is an integral part of the CAD platform is typically fraught with errors and poorly managed due to the lack of timely data and the tools to manage the data. However, with the matching of the lineup against the positioning engine, the lineup can be cleaned up and made available to proactive resource management systems that are outboard of CAD.



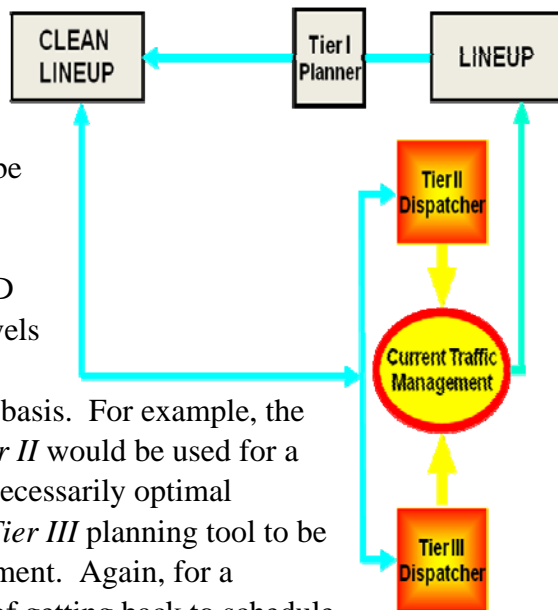
IV. Manage the Lineup

Cleaning up the lineup is not the same as managing the lineup. The former is that of continuously updating the true position of trains that have been initiated on the lineup. To manage the lineup, however, is the ability to bring planning tools into play that can project how the lineup will be changing over some period of the future. This means incorporating a *Tier I* planner that is used by operations management to align unscheduled and scheduled operations and account for physical network parameters, physical train performance, basic crew management rules, locomotive power requirements, and in-bound capacities of yards.



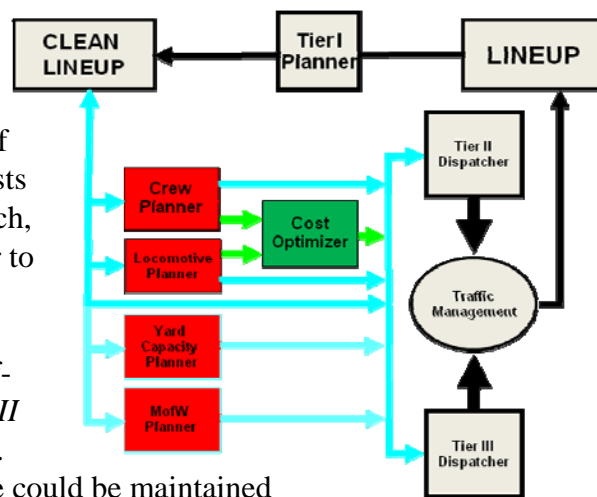
V. Proactive Traffic Management

With the availability of a clean, managed lineup that is as timely as the most recent position report, whether it be an AEI report or via the Monitor Platform, a proactive traffic management system can be provided to the dispatcher independent of, but complementing, the CAD platform. That is, this platform will provide various levels of planning tools that permit the dispatcher to perform advanced traffic management analysis on an as-needed basis. For example, the dispatcher could have two levels of planning tools. *Tier II* would be used for a true-crisis solution that strives for a workable, but not necessarily optimal solution in pressing situations. There would also be a *Tier III* planning tool to be used to meet the objectives of proactive traffic management. Again, for a scheduled railroad, the objective would simply be that of getting back to schedule. Once the dispatcher has determined the proper course of action, he or she would then use the CAD platform, as is done today, to set up the routing accordingly. At some point, there could also be an integration of the planning capability directly into the auto-routing¹ mechanism of CAD, if deemed appropriate.



VI. Proactive Resource Management

Expanding upon the above approach for traffic management, it is possible to advance the planning of other key resources, as well as incorporate their management within the dispatching function. Two of the resources, crews and locomotives, have direct costs associated with their deployment alternatives. As such, a cost optimizing function is added for the dispatcher to balance the costs with those associated with train movements (train delay and fuel consumption). Two other resources, yard availability and maintenance-of-way activity are constraints that are used by the *Tier II* and *Tier III* planners in deciding the routing of trains. As with Proactive Traffic Management, each of these could be maintained independent of, but complementary to, their respective current processes and management systems.



VII. Industry Locomotive Tracking System

If railroads were self-contained, then the structures presented above for this scenario would be sufficient to optimize their individual performance. However, there are challenges as to interoperability and industry intraoperability for both traffic management and the suite of locomotive applications, at least. Recognizing that the threshold unit of tracking is the locomotive, then there is a requirement for an Industry Locomotive Tracking System, as well as the positioning engines for individual railroads, to service these levels of operability. As noted previously, there is an excellent way to move forward with that possibility now, given the development of the EMIS system via Railinc's services. However, there will be a requirement in the railroad's interchange rules that require locomotive activity to not only be reported (which isn't required today), but also be required to provide a certain level of report frequency as to both position and speed.

What is interesting about this point is that locomotive positioning could be achieved in two different fashions. First, there would be a continuous link between the Industry Locomotive Tracking System and the individual railroad positioning engines. Additionally, to the benefit of everyone, the use of commercial services that a railroad may employ for locomotive tracking could also feed this data to the industry positioning engine, instead of to only the subscribing railroad. The Industry Locomotive Tracking System thereby becomes the clearing house for this information for the benefit of all. The Industry Locomotive Tracking System avoids the current issue of the privacy of consist data by means of the pubsub structure that restricts the accessibility of specific data to subscribers with the proper authority while blocking associated data that is not to be distributed to those same parties.

VIII. Industry Service Bus

Morphing the Industry Locomotive Tracking System into an Industry Service Bus is a small step that can service a number of applications including locomotive health, hazmat alerts, shipment integrity, and fuel management. Associated with this approach would be an appropriate level of GIS, as well as geo-fencing relative to the industry issues for which this tracking system would be used, e.g., fuel level at interchange points.

Skill Sets

To effectively deploy wireless-based applications requires three types of skill sets, three types of disciplines, of which only two can be expected to be found today in the railroads and at the industry level via the AAR and its various committees.

First, there is the requirement for the *Technicians* within each railroad that understand the capabilities of the wireless technologies that may be deployed. As such, each road has its technical staffs from which the respective AAR technical committees are staffed on a volunteer basis.

Second, recognizing that wireless can extend the IT architecture to the mobile and remote resources, as wired infrastructure does in a manufacturing facility, then wireless needs to be incorporated in a compatible fashion with the IT architecture. Fortunately, within the last several years, there has been a concerted effort to merge the two disciplines of wireless and IT together both within the individual railroads and the AAR technical committees, to expand the role of the *Enterprise Architect*¹ that aligns the IT architecture with the business requirements.

Third, with the infusion of wireless data into the railroad environment, the current enterprise architect discipline is unprepared and for justifiable reasons. That is, the current railroad IT architecture is typically structured to service primary business processes that have existed for decades based on technologies that stem back to the first and second quarters of the last century (track circuits and voice radio, respectively). Hence, these key business processes and the supporting management systems are geared toward a certain level of data timeliness and accuracy that are less than optimal. However, with the deployment of a wireless data infrastructure, in-time data as to the status of resources is introduced. This infusion presents the opportunity for a *revolutionary* change in the business processes across the individual railroad, as well as across the industry. These are changes that can incorporate planning and execution tools that embrace a wider range of variables, with a greater level of accuracy and detail, than that which is possible of being done today. Accordingly, these are changes that are likely to be beyond the experience and knowledge of Enterprise Architects that have operated primarily in a wired environment and/or who have been subject to the constraints of the railroad's traditional technologies. Hence, there is a requirement for a new discipline, an *Enterprise Technologist*.

The Enterprise Technologist is a discipline that is focused on a revolutionary re-engineering of business processes across the railroad that can include:

- distributed intelligence to the mobile resources as an extension of the IT architecture (a mobile node),
- the use of execution and planning tools based on Operations Research (OR),
- the establishment of new voice/data links between otherwise-disparate entities, and
- the integration of the management of remote and mobile resources.

However, revolutionary functionality is without value if it cannot be delivered in a fashion that is financially, organizationally, and technically responsible. This leads to the second role of the Enterprise Technologist, which is the challenge of evolutionary deployment. Such a deployment

is necessary given a railroad's extensive physical plant and IT architecture that is well established and not readily modified, or replaced. This is a discipline that structures the business case that includes:

- 80/20, incremental value/cost analysis,
- phased deployment based on payback analysis,
- multi-department infrastructure sharing, and
- the recognition that refarming has changed the business case model.

At first glance, it may seem that the Enterprise Technologist's tasks are not unlike that of the traditional Six Sigma process referred to as Define-Measure-Analyze-Improve-Control (DMAIC). However, DMAIC Six Sigma focuses on evolutionary, continuous improvement of existing processes. That is not the case for what is presented in this report, i.e., the revolutionary change in processes albeit via evolutionary deployment of management systems. In actuality, the Enterprise Technologist, is quite similar to an emerging discipline in Six Sigma referred to as Design for Six Sigma (DFSS). A key difference remains in any event, and that is the ability to deliver the business case aligned with the revolutionary changes in functionality, both at the individual railroad level and for the industry, given the various levels of operability.

Moving Forward

Based upon the findings of this study, there are a number of activities that would promote the advancement of rail operations, via the use of wireless technologies, which are not being pursued by the industry or most of the railroads. These are activities that would complement the current *Roadmap to Interoperability* and associated tasks currently underway. These are activities that would benefit by the availability of Federal support.

Traffic Management Tools & Processes

In general, most North American railroads have little to no experience with traffic management tools, and certainly not with those based on timely position and speed data, as discussed in this report. Developing and deploying such tools will be a blending of art and science, given the lack of experience and data that exist to identify the key variables and the primary objective functions that can be delivered through their use. And, there is both a planning (Service Design) and an execution (Operations-dispatching) aspect to these tools that should be considered. Hence, there is a need to perform the following analyses that would be applicable across all Class I railroads:

- the coordination of traffic management activities between Service Design and Operations;
- the identification of different tiers of dispatching tools as suggested in **SCENARIO**;

- the identification of dispatching processes and displays to support the use of traffic management tools; and
- the study of interchange requirements to efficiently support the use of traffic management tools.

Locomotive Position and Status

An Industry Locomotive Tracking System has substantial value for both the freight railroads and Amtrak. Railinc appears to be in a favorable position to deliver such a data service to the industry. However, the analysis still needs to be performed as to what data are needed when and where, not only as to locomotive position and speed, but also as to diagnostics and fuel. This would include the identification of geo-fencing criteria at three primary platform levels, mobile node, individual railroad office, and industry.

Performance-Based Locomotive Maintenance

As was done with PTC, there is an opportunity to have a RSAC or similar process associated with performance-based maintenance of locomotives based upon the availability of an Industry Locomotive Tracking System that included health and maintenance data.

Train Position Monitoring

In-line maintenance crews could benefit from the availability of train position monitoring available via an Industry Locomotive Tracking System. Such a capability could complement, or replace the current use of watchmen lookouts where currently required today.

Crew Management

Railroads and their train crews could benefit from the use of crew management tools. These are tools that can improve both the efficiency of crew usage, as well as the quality of life by minimizing non-productive crew usage (e.g., deadheading, held away, etc.). While there has been some pursuit of such tools, they require further refinement and the opportunity to be deployed.

Industry GIS Model

The industry could benefit from a concerted effort to identify an uniform, rail industry GIS model. This is a model that may need to be aligned with similar efforts in other industries (e.g., utilities, petro-chemical, etc.).

Performance-Based Wayside Maintenance

As was done with PTC, there is an opportunity to have a RSAC or similar process associated with performance-based maintenance of signaling infrastructure based on a yet to be determined level of monitoring and diagnostics reporting.

Mobile Node

The railroads' primary focus on the onboard intelligence and communication platform has been that of interoperability and safety given the interest in PTC and one-person crews. There has been some activity relative to expanding the functionality of the mobile node relative to intra-train operability. However, there remains the broader philosophical, functional, and strategic perspective of the mobile node as an extension of the IT platform.

Evolutionary Wireless Strategy

While the railroads' technicians and enterprise architects pursue the interoperable mobile platform and associated VHF refarming challenge, the opportunity exists to develop an evolutionary wireless strategy that can deliver substantial benefits in the interim. This approach involves the *enterprise technologist* discipline, as defined above, instead of just technicians and architects, to produce a business strategy aligned with an elementary wireless approach.

Operability

The challenge of operability is substantially greater than that of railroad intraoperability and interoperability, as is being currently addressed across the industry. The other levels as identified in this report need to be addressed as well as to the areas of functionality, data flows, and supporting infrastructure. Such a pursuit is as much functional as it is technical, with a touch of intra- and inter-industry politics.

Homeland Security

The response to 9/11 by the Class I railroads was immediate and responsible. A renewed effort may be appropriate, however, with an expanded understanding of what a wireless data infrastructure(s) can now provide, which was not available at the time of the initial effort.

Closing Comment

This study was not designed to be all-inclusive of the opportunities for wireless technologies in high speed passenger and freight rail. Instead, it was structured to seek out the incremental opportunities and the means to deliver those opportunities given the individual and collective railroad agendas as to functionality and wireless technologies. The bottom line for this study is exactly to identify the opportunity to deliver the business case that demonstrates the value of moving forward now, both at the individual railroad and industry level, with systems that deliver tremendous value while the industry continues to work on the long term visions. And, to do so takes a new discipline of the Enterprise Technologist that complements the efforts of the technicians and enterprise architects for the railroads, both individually and collectively.

APPENDIX: Description of Terms & Phrases

A E I	Automatic Equipment Identification: the passive RF tag and interrogator infrastructure that is used to identify cars and locomotives when they pass an interrogator. There are approximately 1.3 million rail cars and locomotives that have been tagged in North America.
AAR	Association of American Railroads: Industry association for the Class I railroads
Autorouting	a process built into some CAD systems that permits the dispatcher to set up routing for trains that will align the switches automatically as the train progresses based upon a relatively simple priority basis.
Book of Rules	the underlying rules for on-track operations - the passive vitality of railroad operations.
C A D	Computer Assisted Dispatching: the platform that permits the dispatcher to request routing for trains.
Code Line	the non-vital communication link between CAD and the wayside signaling infrastructure that permits the train dispatcher to make requests of the vital wayside infrastructure to route trains as well as provide indication of wayside signals - a SCADA platform .
Critical Infrastructure	“those physical and cyber-based systems essential to the minimum operations of the economy and government. They include, but are not limited to, telecommunications, energy, banking and finance, transportation, water systems and emergency services, both governmental and private.” (Source: Presidential Decision Directive NSC-63.)
E D I	Electronic Data Interchange: A set of standards for structuring information that is to be electronically exchanged between and within businesses, organizations, government entities and other groups.(Source: Wikipedia)
ECP Brakes	Electronically Control Pneumatic Brakes: the use of a wired connection running through the train that activates each car’s brakes simultaneously.
Enterprise Architect	a discipline that “build(s) a holistic view of the organization's strategy, processes, information, and information technology assets (so as to) take this knowledge and ensure that the business and IT are in alignment. The enterprise architect links the business mission, strategy, and processes of an organization to its IT strategy, and documents this using multiple architectural models or views that show how the current and future needs of an organization will be met in an efficient, sustainable, agile, and adaptable manner.” (Source: Wikipedia)
Kalman filter	an efficient recursive filter that estimates the state of a dynamic system from a series of incomplete and noisy measurements. It was developed by Rudolf Kalman. (Source: Wikipedia)
Lineup	the listing of trains that are expected to operate over a railroad’s territory within the railroad’s operation horizon.

Meet / Pass Planner	a set of mathematical algorithms that is used to optimize the objectives of traffic management selected by a railroad for its operation.
Movement Authority	the permission provided to a train crew to advance the train as to distance, speed, and/or time. In signaled territory, the movement authority is provided as an aspect (a configuration of lights) that indicates permission to proceed and speed restriction. In dark territory, the authority is transmitted by the train dispatcher to the train crew.
Non-Signaled Territory	a method of train operation in which the primary authority is generated by a manual process(train sheet) or a computerized conflict checker. The transmission of the authority to the train crew is done by the train dispatcher. There are two types of dark territory. One in which there are no signals (most common). The second type, known as Absolute Manual Block, incorporates signals in the territory, but the signals only provide a secondary level of authority within the primary authority, and their aspects are not provided to the dispatcher.
OS Reports	the (On Station) indications of a train entering a new control point in signaled territory.
Positive Train Control	a system that is used to prevent train crew errors. There are 3 core objectives of PTC: 1. prevent train to train accidents, 2. prevent trains from over-speeding, and 3. prevent trains from endangering work gangs. An overlay PTC system is one which does not affect the method of operation, meaning that it is not vital.
PTC capital investment	On its own, PTC is a locomotive-centric application, which by design requires only the transmission of information to the train, and not visa versa. Hence, designing a wireless network for PTC does not mean that the network would be capable of applications that are office-centric, e.g., traffic, locomotive, or fuel management.
Publish Subscribe	Publish/subscribe (or pub/sub) is an asynchronous messaging paradigm where senders (publishers) of messages are not programmed to send their messages to specific receivers (subscribers). Rather, published messages are characterized into classes, without knowledge of what (if any) subscribers there may be. Subscribers express interest in one or more classes, and only receive messages that are of interest, without knowledge of what (if any) publishers there are. This decoupling of publishers and subscribers can allow for greater scalability and a more dynamic network topology. (Source: Wikipedia)
R C L	Remote Control Locomotive: a wireless application that permits an individual on the ground to move a locomotive. This application is used for switching in yards. This should not be confused with pursuit of one-person crews which involves main line operations.
RSAC - PTC	Railroad Safety Advisory Committee - PTC: a joint effort by the FRA, railroads, and labor as voting participants to define a possible rulemaking relative to PTC as well as to evaluate the safety case for PTC. Suppliers also participated, but without voting rights. The PTC rulemaking was a direct result of this effort.

SCADA	Supervisory Control and Data Acquisition: “system that is placed on top of a real-time control system to control a process that is external to the SCADA system (i.e. a computer, by itself, is not a SCADA system even though it controls its own power consumption and cooling). This implies that the system is not critical to control the process in real time, as there is a separate or integrated real-time automated control system that can respond quickly enough to compensate for process changes within the time constants of the process. The process can be industrial, infrastructure or facility...” (Source: Wikipedia)
Toxic Inhalation Hazard	the transportation of chemicals that when inhaled can cause hazards to living organisms.
Traffic Management	the management of the traffic control process to meet a railroad’s objectives for the movement of trains. This is the true purpose of the train dispatcher.
Track Circuits	a DC circuit that runs through the rails. When a vehicle (locomotive) enters a segment of track circuit (block) and shunts the circuits between the rails, then the signaling infrastructure generates aspects based upon the block being occupied.
Traffic Control	the process that generates movement authorities that thereby is the vitality of rail operations. This is not what the dispatcher does directly, but is what s/he often initiates in the traffic management process.
Train Control	the handling of the train by the train crew. This phrase is often used mistakenly to refer to traffic control.
VHF Refarming	a.k.a. narrow-banding, a FCC Point & Order to split the frequencies in half in a portion of the VHF by 2013. An additional Point & Order was issued in March 2007 to note that the same channels would be split again at some point, but no date was provided.
Vitality	From a safety design perspective, vitality means that the device / system will fail safely, i.e., with no increase in risk. From a railroad operation standpoint, vitality refers to the functionality of the hardware and/or software that generates movement authorities that provides for the integrity of train movements.
Wireless Mesh	“a wireless cooperative communication infrastructure among a massive number of individual wireless transceivers (i.e. a wireless mesh) that has a network routing capability. Mesh networks are self-healing: the network can still operate even when a node breaks down or a connection goes bad. As a result, a very reliable network is formed. This concept is applicable to wireless networks, wired networks, and software interaction. “(Source: Wikipedia)