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INFORMATION ON DEVELOPMENTS IN VARIOUS RAILWAY FIELDS

Addendum 2

A VISION FOR THE FUTURE: INTELLIGENT RAILROAD SYSTEMS

Transmitted by the Government of the United States of America

A theme that cuts across virtually all parts of the Federal Railroad Administration's (FRA's) R&D program is the use of sensors, computers, and digital communications to collect, process, and disseminate information to improve the safety, security, and operational effectiveness of railroads. Intelligent Transportation Systems (ITS) for highways and mass transit are based on these technologies, as are the new air traffic control and maritime vessel tracking systems. Military services, major parcel delivery companies, pipeline operators, and police, fire, and ambulance services also use these technologies.

The FRA and the railroad industry are working on the development of **Intelligent Railroad Systems** that will incorporate the new sensor, computer, and digital communications technologies into train control, braking systems, grade crossings, and defect detection, and into planning and scheduling systems as well. The FRA believes that these technologies will prevent collisions and overspeed accidents, prevent hijackings and runaways, increase capacity and asset utilization, increase reliability, improve service to customers, improve energy efficiency and emissions, increase economic viability and profits, and enable railroads to measure and control costs and to "manage the unexpected." Intelligent Railroad Systems will enable railroads to respond with flexibility and agility to rapid changes in the transportation marketplace.

This paper describes a variety of technologies, programs, and systems that have been developed or are under development.

Digital data link communications networks provide the means for moving information to and from trains, maintenance-of-way equipment, switches and wayside detectors, control centres, yards, intermodal terminals, passenger stations, maintenance facilities, operating data systems, and customers. Data link communications will replace or supplement many of today's routine voice communications with non-voice digital messages and will effectively increase the capacity of available communications circuits and frequencies. Data link communications will utilize radio frequencies to communicate to and from mobile assets, and between locomotives in a train consist, and will use a variety of transmission media (owned either by railroads or commercial telecommunications carriers) to communicate between fixed facilities. These media include microwave radio, fiber optic cable, buried copper cable, cellular telephones, communications satellites, and even traditional pole lines. With data link communications, the information is digitally coded and messages are discretely addressed to individual or multiple recipients. The US Government, through the Federal Communications Commission, has assigned to the railroad industry 182 frequencies in the VHF band (160 MHz) and 6 pairs of frequencies in the UHF band (900 MHz). The UHF frequencies are being used for digital communications, and some railroads have converted some of their assigned VHF frequencies from analogue to digital communications. The conversion is expected to accelerate during the coming decade.

Nationwide Differential GPS (NDGPS) is an augmentation of the Global Positioning System (GPS) that provides 1- to 3-meter positioning accuracy[1] to receivers capable of receiving the differential correction signal. It is an expansion of the US Coast Guard's Maritime DGPS network and makes use of decommissioned US Air Force Ground Wave Emergency Network (GWEN) sites to calculate and broadcast the differential correction signals. NDGPS receivers will be placed on locomotives and maintenance-of-way vehicles where they will calculate location and speed, and that information will be transmitted back to the railroad control centre over the railroad's digital data link communications network. NDGPS is now operational with single-station coverage over about 80 per cent of the land mass of the continental US, and is expected to be fully operational with dual-station coverage in 2004 throughout the continental US and Alaska. To insure continuity, accuracy, reliability, and integrity, NDGPS is managed and monitored 24 hours a day, 7 days a week from the Coast Guard's Navigation Centre in Alexandria, Virginia. NDGPS provides a GPS integrity monitoring capability; it gives an alarm to users within 5 seconds of detecting a fault with the signal from any GPS satellite. NDGPS signals are available to any user who acquires the proper receiver, and there is no user fee.

Positive Train Control (PTC) systems are integrated command, control, communications, and information systems for controlling train movements with safety, security, precision, and efficiency. PTC systems will improve railroad safety by significantly reducing the probability of collisions between trains, casualties to roadway workers and damage to their equipment, and overspeed accidents. The National Transportation Safety Board has named PTC

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[1] According to the *1999 Federal Radionavigation Plan,* "The predictable accuracy of the NDGPS Service within all established coverage areas is better than 10 meters (2drms). NDGPS accuracy at each broadcast site is carefully controlled and is typically better that 1 meter." Even though those are the published figures, field data suggests even better performance. High-end receivers have been able to maintain a better-than-1 meter accuracy even at the edge of the coverage area.

as one of its "ten most-wanted" initiatives for national transportation safety. PTC systems are comprised of digital data link communications networks, continuous and accurate positioning systems such as NDGPS, on-board computers with digitized maps on locomotives and maintenance-of-way equipment, in-cab displays, throttle-brake interfaces on locomotives, wayside interface units at switches and wayside detectors, and control centre computers and displays. PTC systems may also interface with tactical and strategic traffic planners, work order reporting systems, and locomotive health reporting systems. PTC systems issue movement authorities to train and maintenance-of-way crews, track the location of the trains and maintenance-of-way vehicles, have the ability to automatically enforce movement authorities, and continually update operating data systems with information on the location of trains, locomotives, cars, and crews. The remote intervention capability of PTC will permit the control centre to stop a train should the locomotive crew be incapacitated. In addition to providing a greater level of safety and security, PTC systems also enable a railroad to run scheduled operations and provide improved running time, greater running time reliability, higher asset utilization, and greater track capacity. They will assist railroads in measuring and managing costs and in improving energy efficiency. Pilot versions of PTC were successfully tested a decade ago, but the systems were never deployed on a wide scale. Other demonstration projects are currently in planning and testing stages. Deployment of PTC on railroads is expected to begin in earnest later this decade.

Electronically-controlled pneumatic (ECP) brakes - Current train braking systems use air to both power the brakes and to initiate brake applications and releases. New ECP brakes use an electronic signal to initiate brake applications and releases, and thereby permit the simultaneous application of all brakes on a train, substantially shortening the braking distance and reducing in-train coupler forces and slack action. One system under test uses a wire line to convey the electronic signals, another uses spread spectrum radio frequencies to convey the signals. Either type of system also enables data to be collected from on-board equipment, track, and commodity sensors and moved to the locomotive where it will be observed by the crew and transmitted over the digital data link communications network to control centres, maintenance facilities, and customers, as appropriate. ECP brakes have been tested on unit coal trains and on double-stack intermodal container trains in the US, Canada, and Australia, and have been shown to improve train energy efficiency. More widespread deployment is expected in the coming decade.

Knowledge Display Interfaces - In-cab PTC displays will provide status information and command and control instructions to the locomotive crews. They will display train position and speed as calculated by the positioning system, the upcoming route profile, in-train forces, actual and recommended throttle and brake settings, speed control instructions and authorities as received over the data link from the control centres, on-board locomotive health information from all units in the consist, and data from on-board and wayside equipment, track, and commodity sensors. They will also display the train consist and special handling instructions for cars from work order reporting systems, data from the end-of-train device and ECP brakes, and any other information that will be sent over the data link. Control centre displays for dispatchers will show the precise location and speed of each train and maintenance-of-way vehicle, train consists, performance against schedule, and the plans generated by the tactical and strategic traffic planners. The challenge in developing the displays is to insure that only necessary

information, and no unnecessary information, is displayed. Displays currently being installed on locomotives and at control centres will have the capability to display the information that will be generated by the Intelligent Railroad Systems.

Crew registration and time-keeping systems will use identification techniques such as passwords, electronic card keys, or biometrics to insure that only authorized train crew members are permitted to control a locomotive. The control centre will issue a movement authority only when it has confirmation that the designated crew is on board and logged in. The times that crew members log on duty on the locomotive, depart their initial terminal, arrive at their final terminal, and log off duty will be automatically sent over the digital data link communications network to the control centre and to the operating data system. This will eliminate manual record-keeping and data entry chores and insure that accurate times are entered in the operating data system for payroll purposes.

Crew alertness monitoring systems promote on-duty alertness and vigilance of train crews through the use of non-invasive technology applications. Mental lapses and other human errors that result in unsafe safe job performance are often due to reduced alertness or vigilance. Real time monitoring and feedback of *individual alertness levels* will allow crew members to modify their behavior and reduce their risk of unsafe performance. Risk-appropriate countermeasures, such as napping, social interaction, and postural changes, will be suggested by the system, and in the case of high risk (e.g., the crewmember falls asleep), the system will both notify the control centre over the digital data link communications network and stop the train. Real time monitoring and feedback of *population alertness levels* will allow managers to dynamically adjust work schedules and help ensure the most well-rested individuals, or teams, are available for high-risk assignments. Models of fatigue and alertness in the system will accurately predict future risk of non-alertness in individuals and groups of individuals so that countermeasures can be applied to maintain optimal performance either before or throughout a work shift.

Track forces terminals (TFTs) provide the means for moving information and instructions to and from roadway workers. A TFT consists of a laptop computer or personal digital assistant (PDA), data radio, and positioning system receiver. The TFT sends position reports from the field to the control centre over the digital data link communications network, and it displays authorities received from the control centre to the roadway workers. With a TFT, roadway workers will obtain authorities without talking to a dispatcher. The TFT will display the location of all trains in the vicinity, and the crew will determine when the track will be unoccupied and use the TFT to request track occupancy for that time. The control centre computer checks the proposed authority for safety, and if it is safe, the dispatcher grants the authority which then appears automatically on the dispatcher's display and on the TFT. At the completion of track work, the TFT will be used to place a slow order on the track by transmitting the information to the control centre computer. The TFT will also be used to transmit administrative data (e.g., gang time, machine usage and status, material usage and requirements, and production reporting information) to track maintenance facilities and the railroad operating data system.

Automatic Equipment Identification (AEI) tags have been installed on both sides of all freight cars and locomotives in the US and Canada since 1995. AEI readers, installed along the track at yards, terminals, and junctions, interrogate the tags over UHF radio frequency

(900 MHz), and the tags respond with the unique initials and numbers identifying each car. The readers assemble the information from all cars on a train and then transmit the entire train consist to the railroad's operating data system over the digital data link communications network or over dedicated telephone lines. Because PTC systems know at all times the precise location of every train, AEI, when combined with PTC, permits railroads to know at all times the precise location of every car and shipment. Some railroads have installed substantial numbers of readers and have integrated them with their operating data systems; others have not. Installation and integration of the full network of readers is expected in the first half of this decade. AEI readers will be integrated with wayside equipment sensors to provide positive identification of vehicles with defects.

Wayside equipment sensors are installed along the track to identify a number of defects that occur on rolling stock components and to transmit information about the defects so that trains will be stopped if necessary and maintenance crews can perform repairs as required. Among the defects that will be detected by the wayside sensors are overheated bearings and wheels, deteriorating bearings, malfunctioning brakes, built-up wheel treads, worn wheels, cracked wheels, flat wheels, derailed wheels, excessive truck hunting, dragging equipment, excessive lateral and vertical loads, skewed trucks, and excessively high and wide loads. AEI readers integrated with the sensors will provide positive identification of vehicles with defects.

Information from the sensors is now usually transmitted by voice-synthesized radio. Once data link communications networks are installed, the information will be transmitted from wayside interface units at the sensors to train crews, control centres, and maintenance facilities.

Wayside track sensors are installed to identify a number of defects that occur on and alongside the track as well as identify conditions and obstructions along the track and to transmit the information so that the train will be stopped or slowed if necessary and maintenance crews will perform repairs as required. Among the conditions and defects that will be detected by wayside sensors are switch position, broken rail, misaligned track, high water, rock and snow slides, excessive rail stress, misaligned bridges and trestles, blocked culverts, weather information (temperature, rate of change of temperature, wind velocity, precipitation, etc.), earthquakes, and general security and integrity information regarding track and structures. Information from these sensors is now usually transmitted by wayside signal indication. Once data link communications networks are installed, the information will be transmitted from wayside interface units at the sensors to train crews, control centres, and maintenance facilities.

Locomotive health monitoring systems consist of sensors mounted on engines, traction motors, electrical systems, air systems, exhaust systems, and fuel tanks on locomotives. Most new locomotives are equipped with most of these sensors. The data from all units in the consist will be displayed to locomotive crews, and are collected in on-board computers for retrieval when locomotives arrive at maintenance facilities. The data will be transmitted over the digital data link communications network to control centres, maintenance facilities, and motive power distribution centres to permit real-time monitoring of locomotive performance and efficiency. Each of those places could make an inquiry over the data link to a locomotive to receive a health status report.   The data will also be collected at maintenance facilities and analysed to permit maintenance to be done on an as-needed rather than scheduled basis. Traction motor performance in both traction and dynamic braking modes will be monitored. Locomotive health monitoring systems will improve locomotive energy efficiency and emissions. Limited testing of

real-time locomotive health monitoring has taken place over the last decade. Event recorders for after-the-fact investigations can record throttle and break information collected by the monitoring systems and combine it with the precise location and time information generated by the GPS/NDGPS receivers.

Energy management systems (EMSs) are separate computer programs installed on locomotives to optimize fuel consumption and/or emissions. An EMS will receive information on track profile and conditions, speed limits, the train and locomotive consist, locomotive engine fuel performance characteristics, information from the locomotive health monitoring systems on engine and traction motor performance, train length and weight, and target times at specific locations as determined by the tactical traffic planner. It will then determine a recommended train speed that met service requirements, while minimizing fuel consumption and/or emissions and providing good train-handling characteristics. Conceptual work has been done on EMSs, but a prototype system has not yet been implemented.

Vehicle-borne track monitoring sensors will be installed on inspection cars, and perhaps eventually on locomotives, to identify a number of defects and conditions that occur on and alongside the track so that trains will be stopped or slowed if necessary and maintenance crews could perform repairs as required. Among the defects that will be detected by the on-board sensors are rail flaws, broken rail, misaligned track, and excessive rail stress. Weather information (temperature, rate of change of temperature, precipitation, etc.) will also be collected. Information from all these sensors will be displayed in the inspection car or locomotive cab and will be transmitted from the car or locomotive via the digital data link communications network to control centres and maintenance crews.

Car on-board component sensors will be installed on rolling stock to identify a number of defects and to provide information so that the train will be stopped if necessary and maintenance crews will perform repairs as required. Among the defects and conditions that will be detected by the on-board sensors are overheated bearings and wheels, impacts and vibrations from flat or derailed wheels or corrugated track, excessive truck hunting, excessive longitudinal forces, and braking system status. Information from the sensors will be transmitted over the ECP brake system's communications channel to the locomotive where it will be observed by the crew and transmitted over the digital data link communications network to control centres and maintenance facilities. Some development of these sensors has occurred, but deployment of the digital data link communications network and ECP brakes is a prerequisite for the installation of such sensors.

Car on-board commodity sensors are being installed on freight cars to monitor the status of the commodities being carried.   Among the parameters that will be measured by the on-board sensors are temperatures, pressures, load position, radiation, and vibrations. The security of shipments will also be monitored. Information from the sensors will be transmitted over the ECP brake system's communications channel to the locomotive where it will be observed by the train crew and transmitted over the digital data link communications network to control centres, maintenance facilities, and customers. If problems are detected, the train will be stopped and maintenance crews will perform repairs. Some customers are using proprietary sensor and satellite communications packages to obtain the data directly from the cars, bypassing railroad information channels.

Intelligent grade crossings - Intelligent Transportation Systems (ITS) for roadways come together with Intelligent Railroad Systems at Highway-Rail Intersections (HRIs). Information about train presence and arrival times, generated either by a PTC system or track circuits or off-track sensors, will be provided from railroad control centres to highway traffic control centres via the digital data link communications network and to motor vehicle operators via roadside traffic information signs or via dedicated short-range radios to in-vehicle displays or audio warning systems. Similarly, sensors at HRIs will send information to railroad control centres and trains over the digital data link communications network should an HRI be blocked by a stalled vehicle. Demonstrations of intelligent grade crossing devices have been conducted in eight states. Architecture elements to describe the HRIs have been added to the ITS National Architecture, and work on the development of standards for intelligent grade crossings has begun to insure that there will be national interoperability.

Intelligent weather systems consist of networks of local weather sensors and instrumentation - both wayside and on-board locomotives - combined with national, regional, and local forecast data to alert train control centres, train crews, and maintenance crews of actual or potential hazardous weather conditions. Intelligent weather systems will provide advance warning of weather-caused hazards such as flooding; track washouts; snow, mud, or rock slides; high winds; fog; high track-buckling risk; or other conditions which require adjustment to train operations or action by maintenance personnel. Weather data collected on the railroad will also be forwarded to weather forecasting centres to augment their other data sources. The installation of the digital data link communications network is a prerequisite for this activity.

Tactical traffic planners (TTPs) produce plans showing when trains should arrive at each point on a dispatcher's territory, where trains should meet and pass, and which trains should take sidings. As the plans are executed, a TTP takes the very detailed train movement information provided by the PTC system and compares it with desired train performance. If there are significant deviations from plan, the TTP will re-plan, adjusting meet and pass locations to recover undesired lateness. TTPs make use of sophisticated non-linear optimization techniques to devise an optimal dispatching plan. Once a TTP prepares a plan, the dispatcher need only accept it. Then the computer-assisted dispatching system of PTC produces all authorities needed to execute the plan and sends them over the digital data link communications network to trains and maintenance-of-way vehicles. Some prototype TTPs have been developed and tested.

Strategic traffic planners (STPs) - TTPs cannot function without knowing the schedule for each train. STPs measure train movements against a set of externally-defined schedules which include information on scheduled block swaps and connections, both internal and with other railroads. Integrating a flow of information about actual train performance from the TTP, the performance of connections, and detailed consist information for all trains from operating data systems, STPs make cost-minimizing decisions on whether, and how, train priorities and schedules might be adjusted on a real-time basis. STPs are the highest-level real-time control system in the PTC hierarchy. STPs will be able to display the performance of trains against schedule, the real-time location of every train by type (e.g., coal, intermodal, grain, intercity passenger), and the location of trains at future times based on current performance. The Federal Aviation Administration developed an STP (called "central flow control") to support the US air traffic control system; the same philosophy will apply to railroad STPs.

Yard management systems (YMSs) provide the essential link between the movement of trains and the movement of cars. The YMS will receive real-time information on the location and make up of each train on the system and will keep track of all cars in the yard. It will receive goals and objectives from the STP. This will allow the YMS to determine the best way to make up trains, that is, the order in which arriving cars should be classified, the order in which they should be pulled from the lead tracks, and the order in which outbound trains should be made up. The YMS will account for the time that trains will be arriving, the times they should be departing, and the time required for each yard operation to be performed. It will supply a forecast of yard departure times for each of the trains to the STP so that it will be able to perform better its job of creating time targets for smooth system functioning.

Work order reporting (WOR) systems send instructions over the digital data link communications network from the control centre to train crews regarding the setting out and picking up of loaded and empty cars en route. When crews acknowledge accomplishment of work orders, the system automatically updates the on-board train consist information and transmits information on car location and train consists back over the digital data link communications network to the railroad's operating data system and to customers. WOR information will displayed in locomotives on the same screens that will display PTC instructions and information. One major railroad has deployed a WOR system using a dedicated digital data link communications network.

Locomotive scheduling systems use data regarding train schedules, physical terrain, locomotive characteristics, locomotive health information, locomotive servicing and maintenance schedules, and expected train consists to assign locomotives to trains, making use of linear programming algorithms. Improved train consist information coming from a car scheduling and reservation system will result in better locomotive allocations. Keeping trains, and, therefore, locomotives on schedule is necessary to execute future locomotive assignments. Locomotive scheduling systems have been developed and are in use on most railroads. If the locomotive scheduling systems will be provided with real-time information on locomotive health, on current and future locations of trains, and on expected train consists, the utilization rate of locomotives will be significantly improved.

Car reservation and scheduling systems - Freight car reservation systems allow customers to reserve freight car capacity and routing in advance; freight car scheduling allows railroads to plan the movements of individual freight cars to match up with known customer demand. Scheduling of the movement of cars will reduce cross-hauling of empty cars and reduce delays to loads and empties at intermediate yards. This reduces fleet size requirements and improves asset utilization. Car reservation and scheduling systems, which are similar to airline seat reservation and scheduling systems, can only work when railroads operate on a schedule, and, in turn, car reservation and scheduling systems provide information to locomotive scheduling systems and are a prerequisite for yield management. One major railroad developed and used a car scheduling system for a number of years. However, the railroad's inability to keep its trains on schedule meant that cars often had to be reassigned to different trains in the course of their journeys.

Crew scheduling systems - When train operations are scheduled and stay on schedule, crew assignments can also be scheduled a number of days or weeks in advance. That will result in predictable work hours for most crew members, and will enable them to schedule regular

periods of sleep and recreation, reducing family and social tensions and emotional and physical stress. Crew scheduling systems will use information from the STP and from PTC along with information about crew members (seniorities, current locations, schedule preferences, most recent assignment worked) and Hours of Service Act and labor contract provisions to match up trains and crews most cost-effectively. Some European railroads currently use such long-term crew scheduling systems.

Yield management systems enable railroads to establish variable pricing policies which maximize profit by linking the price charged for a service to customer demand. Applicable to both freight and passenger railroad operations, yield management requires reservation and scheduling capabilities, and sophisticated information systems to keep track of changing capacity, complex service variables, and multiple prices. With yield management, railroads can identify opportunities for filling up existing capacity with lower-priced services for customers who are less service-sensitive. At the same time, it will show when and how much to increase prices for service-sensitive customers shipping or travelling at peak times. Amtrak and all major airlines now use yield management.

Emergency notification systems installed at control centres provide for the automated notification of all involved organizations following railroad accidents, incidents, or threats. They provide for better coordination and control of the involved organizations: railroad response crews; police, fire, and emergency medical services, as well as other appropriate local, state, and national authorities. The systems are tied to geographical interfaces. When reports of accidents, incidents, or threats arrive over the digital data link communications network with precise and accurate geographical coordinates, the emergency notification system can identify the emergency responders for that locale, notify them, and provide them with correct location information. The systems monitor the timing of the call-outs and the arrival of emergency services at the scene so that performance can be analysed. The systems enable the faster resolution of problems and resumption of rail service.

Travellers advisory systems use real-time train location information generated by GPS receivers on locomotives and transmitted over digital data links to provide intercity passenger train and commuter train riders with expected arrival times of their trains. The information will be displayed on dynamic message boards at stations and on map displays posted on the internet. The information will be used by the passenger railroads, which are often tenants on freight railroads, to automatically collect data on the on-time performance of their trains. These systems are typically implemented as free-standing systems using cellular or satellite communications, but they will be integrated with other systems, using information from the PTC system and transmitting it over the railroad's digital data communications network.

System security is one of the overarching issues that effects deployment of many of the systems and initiatives just described. It must be designed into Intelligent Railroad Systems before they are deployed. Data regarding trains, cars, crews, and shipments must be kept confidential or private, and unwarranted extraction of information from the digital data link communications network must be prevented. Authentication of data will insure that the content is genuine, unaltered, and complete. Encryption is the security mechanism that converts plaintext into cyphertext that is unintelligible to those who do not have access to the appropriate key. Archiving of data from Intelligent Railroad Systems must also be done in a secure manner through the control of access privileges to prevent loss of data. Emergency notification systems

will enable control centres to identify and verify emergencies from the data inputs they receive, and to provide notification of emergencies to appropriate public sector authorities and railroad officials.

The Architecture of Intelligent Railroad Systems

In order to show how all of the previous systems and initiatives fit together, and to help identify the key interfaces for standardization, an architecture for Intelligent Railroad Systems is being developed. A first step in this direction is shown in the following figure, which is a top-level interconnect diagram that identifies the key elements of Intelligent Railroad Systems and the communications link interfaces between them. It is based on conventions developed by the Architecture Development Team for the National ITS Architecture. This type of diagram is known as a "sausage diagram" in which the "sausages" represent the various types of communications links that move information between vehicles, fixed installations along the transportation right-of-way, control and management centres, and customers.

INTELLIGENT RAILROAD SYSTEMS
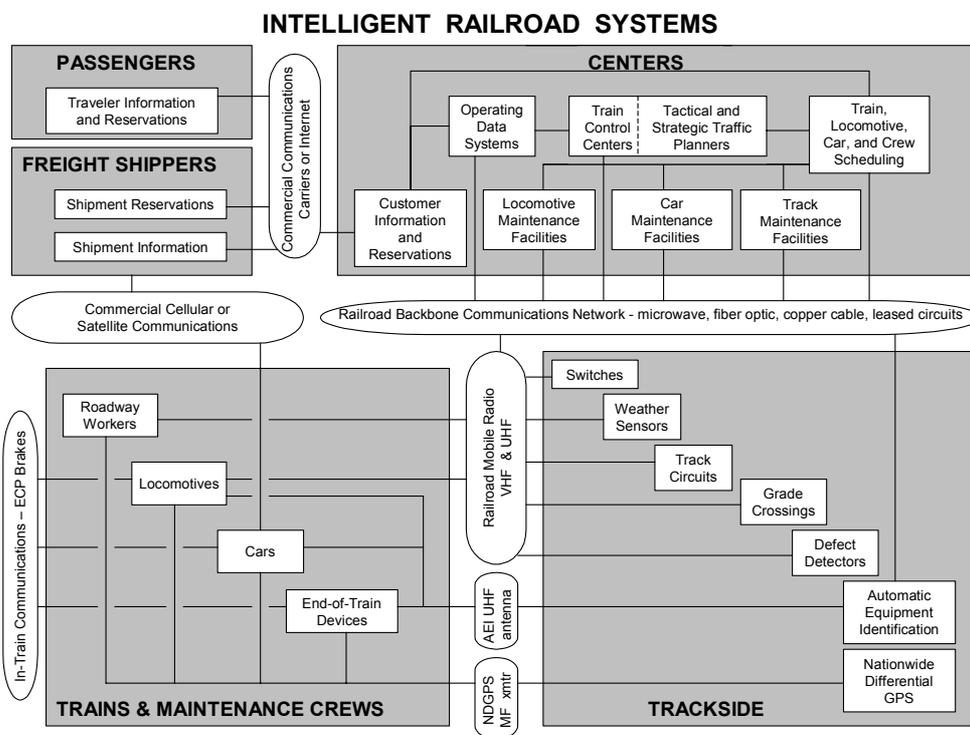
Summary and Conclusions

The implementation of Intelligent Railroad Systems is not without impediments. Several of the major ones are the magnitude of the costs, the availability of capital to the railroad industry, and the competition for capital within railroad companies. Railroads will need to understand that a well-executed investment in Intelligent Railroad Systems, by increasing asset utilization, will reduce the capital needed for locomotives, cars, and track. Financing available through the FRA's Railroad Rehabilitation and Improvement Financing (RRIF) program could be used by railroads to implement Intelligent Railroad Systems.

The implementation options for Intelligent Railroad Systems are varied; not all railroads will want to invest in all of the components. The use of an improper decision criterion, however, such as minimizing the cost of an individual subsystem (e.g. telecommunications), will, by raising other costs, lead to a sub-optimal deployment, or no deployment at all. The challenge with Intelligent Railroad Systems is for a railroad to optimize the relationship between total system benefits and total system costs, not just subsystem benefits and subsystem costs.

Interoperability issues affect some but not all of the Intelligent Railroad Systems. Locomotives equipped with radios using common frequencies and protocols, with common positioning systems, and with computers using common logic are necessary if Positive Train Control is to be implemented widely. Since the two types of ECP brake systems are not interoperable, the railroad industry must decide which will be the industry standard. Other systems, such as tactical and strategic traffic planners, locomotive health monitoring systems, and wayside equipment sensors, do not require railroad industry agreement.

Intelligent Railroad Systems may take a decade or more to implement, well beyond the tenure of many senior railroad executives. Some railroads today lack sufficient staff with knowledge of these new technologies. Additional staff with the proper skills will have to be trained or hired. Some railroads have expressed concern about liabilities they may incur if they acknowledge that these new technologies will make railroad operations safer or more efficient.

When new technologies are adopted and when methods of operation change, it is only natural that some individuals, and even institutions, will be fearful of and resistant to those changes. Some, however, will actively welcome those changes. There seems to be reluctance on the part of some railroads to write-off, or to view as sunk costs, investments in physical assets that would no longer be needed as part of Intelligent Railroad Systems.

Suppliers are reluctant to invest a great deal of their own money in the development of the Intelligent Railroad Systems without some assurance that railroads are going to commit funds to deploy them. The FRA recognizes this situation, and consequently is involved in sponsoring R&D and demonstrations for a number of the components of Intelligent Railroad Systems.

Some railroad marketing departments have expressed uncertainty about the response of their customers to service improvements. Those marketing departments doubt their customers' willingness to pay more for better service, or to shift more traffic from highways to railroads. Even though the railroads have little data to show their customers' elasticity of demand for significantly improved service, they have substantial data showing their customers' responses when railroad service deteriorated and recovered following some recent mergers.

The FRA acknowledges that all these issues and impediments can appear daunting to the organizations that are faced with the implementation of Intelligent Railroad Systems. The FRA also acknowledges that the deployments of ITS, new air traffic control systems, and maritime vessel tracking systems are not occurring without complications. Nevertheless, the FRA does believe that the new Intelligent Railroad Systems are the key to making railroad operations – freight, intercity passenger, and commuter – safer, reducing delays, reducing costs, raising effective capacity, increasing reliability, improving customer satisfaction, improving energy utilization, reducing emissions, and making railroads more economically viable.

Intelligent Railroad Systems will enable railroads to manage unexpected situations by providing real-time information about current operations and the current environment with little or no time lag. That will enable managers and dispatchers to have more knowledge of the status of the entire railroad and to detect and remedy early indications of trouble. Information will flow to the right people who have the ability to take corrective actions.

Intelligent Railroad Systems can be implemented as independent systems, in which case their benefits will be limited, or they can be implemented as integrated systems, in which case the benefits will be compounded. The railroad industry is urged to consider adopting an integrated approach when implementing these systems.

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