Railway Digital Base Maps, Location Referencing Systems and Interoperability of Positive Train Control Systems

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One component of a positive train control (PTC) system is the electronic representation of the railway route network. In its current form, the electronic route network consists of a digital base map, location referencing system and set of attribute data. At present, there is no single standard that encompasses all three of these systems in a global positioning system based PTC application. Because of this, several different PTC systems with different digital base maps and location referencing systems have been developed. The question of whether or not these systems can be made interoperable is addressed by creating four conceptual PTC systems and examining them in terms of interoperability. Through this process it is demonstrated that different PTC systems can be made interoperable if the digital base map, location referencing systems and attribute data meet minimum standards. Through an examination of the current PTC projects, the first step towards developing these standards is taken by identifying current methodologies in the development of digital base maps, location referencing systems and attribute data.

INTRODUCTION

One of the fundamental concepts of a positive train control (PTC) system is that "the control of all facets of train movement at a single point requires that all physical characteristics of the route network be represented in electronic form"(*1*). According to the PTC Positioning and Location Requirements Discussion Paper presented at the North American PTC Joint Program Location Systems, Braking and Data Requirements Workshop in June 1999, the electronic representation of the route network is composed of a digital base map, a location referencing system, and a set of attribute data.

The digital base map is a schematic diagram of the railway that shows its layout on the surface of the earth. Although the term "base map" implies that the schematic must be to scale and in a fixed global coordinate system, the level of detail and complexity of the map will vary with the structure and requirements of its corresponding PTC system. The location referencing system (LRS) is used to organize the data on the digital base map and consists of coordinates or code that locates points or segments in their correct position with respect to the base map. The set of attribute data includes all features of interest along the railway right of way that are required for the PTC system to calculate braking distances and make enforcement decisions. The attribute data are structured in such a way that their location is expressed using the coordinates of the LRS. These three components of the electronic representation of the route network interact with the system used to determine train location. This train locating system (TLS) is the set of equipment onboard the locomotive that establishes its location on the surface of the earth. Once the location of the train is determined by the TLS, it is translated into the coordinates of the location referencing system. This allows the locomotive and the PTC system to determine the position of the train relative to enforcement targets and other features of the railway infrastructure.

At present, there is no standard digital base map, location referencing system, or set of attribute data for use by all positive train control systems. Some standards for various aspects of PTC technology and various systems such as the Advanced Train Control System (ATCS) and European Train Control System (ETCS) have been established (*2,3*). However, components of the PTC systems currently under development, such as the global positioning system (GPS), are not included in these standards. As a result, several PTC systems have been developed independently that operate on different base maps, use different location referencing systems and reference different sets of attribute data. This conflicts with the goal of interoperability, which is another objective of positive train control. A completely interoperable PTC system is designed "to permit components of independent design to operate together, to ensure that when any equipped locomotive runs on any equipped track, any control function of which both locomotives and track are capable should be performable" (*1*). If the capability of the PTC system must be downgraded from moving blocks to fixed blocks under certain circumstances, it is said to be partially interoperable. To establish complete interoperability, a minimum set of standard specifications for digital base maps, location referencing systems and referenced attribute data must be developed. The complexity of these standards will be determined by the level of interoperable performance desired by the industry. Some within the industry argue that, with the number of different PTC systems in development, complete interoperability is not achievable without the extra expense of equipping locomotives in interchange service with multiple systems (*4*). One might be tempted to accept this statement in the case where a certain railway implements a transponder based system while another implements a GPS based system.

This paper considers some requirements to make different PTC systems interoperable without adding extra equipment to locomotives in interchange service. In these cases, a digital base map, location referencing system and set of attribute data that conform to standards increase the potential for interoperability. It should be noted that this discussion only examines interoperability from the perspective of the train locating system, digital base map, and location referencing system. Other interoperability issues that must be resolved, such as standardized communication systems and protocols, are beyond the scope of this paper.

EXAMPLES OF BASE MAPS AND LOCATION REFERENCING SYSTEMS IN CONCEPTUAL PTC SYSTEMS

The challenge in developing a PTC standard for base maps and referencing systems is that different conceptual approaches to the PTC system utilize digital base maps and location referencing systems in different manners and require different sets of attribute data. The set of conceptual PTC systems presented here is not intended to be comprehensive regarding all possible variants of PTC, digital base maps and location referencing systems. Its purpose is to begin formalizing the issues associated with interoperability of different PTC systems and their effect on an industry standard.

To simplify the discussion of the conceptual PTC systems, it is assumed that all of the transponders are of the same type. In reality, there are two different transponder types being considered for implementation with PTC. The first is a read-only device that only provides its unique identifying code. The second type of transponder is a readwrite device where the message can be changed though a backplane cable connection. This type of transponder is used in European PTC systems and is being considered for use in North America (*5,6*). For the purposes of this discussion, it is assumed that all transponders are of the read-only type.

In the discussion of the conceptual PTC systems, the following notation is used:

- Train A - Unique train identifier.
- T - Transponder identification code.
- $L_{X,Y}$ - The distance between the objects specified by variables *X* and *Y*. For example, $L_{A,T}$ denotes the distance between train A and transponder T.
- V_X - The speed of the train specified by variable *X*.
- S - Segment identification code.
- K - Track identification code in multiple track territory.

Note that in a practical application, each transponder, segment and track would have a unique value of T, S or K. In order to maintain generality, in the following discussion, transponders are arbitrarily assigned values of T starting with T1. A similar approach is applied to the segment and track identifiers.

The Conceptual Systems

A basic PTC system is illustrated in Figure 1. This conceptual system does not represent a PTC system currently under consideration and is presented here to serve as a heuristic to aid in the understanding of the more complex systems. In system one, train location is determined by transponders placed at control points and at a distance away from each control point equivalent to the worst case stopping distance for the trains operating on the route. The principal factors affecting this stopping distance are train speed, train weight, brake system and track grade (*7*). An onboard database interprets the location of the train and initiates braking to ensure that trains stop before control points. All trains are expected to begin braking at the same point even though some may be able to stop in a considerably shorter distance. System one locomotives are equipped with a basic axle tachometer for measuring speed. However, in this case it is assumed that the basic axle tachometer does not have the same capability or accuracy as the dual axle tachometers employed by more complex systems. System one does not require a detailed digital base map. A simple schematic showing the location of transponders relative to the track layout could be used to track and dispatch trains, just as is done with existing control systems. This particular system does not use a

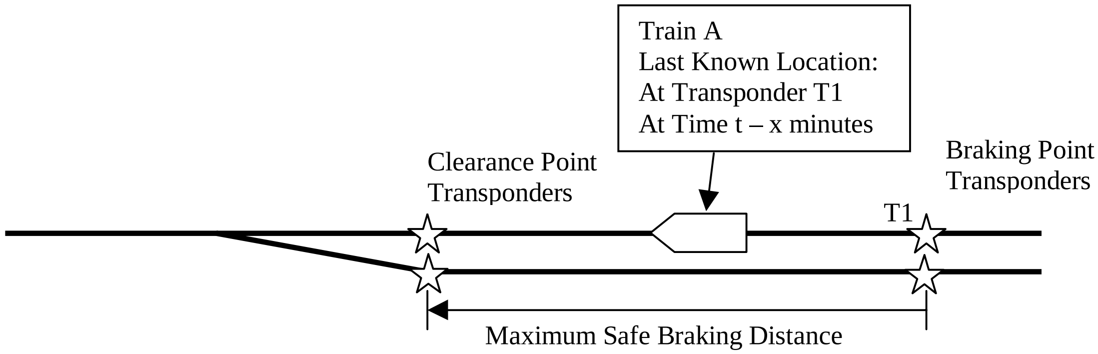

Figure 1: Conceptual Fixed Block Transponder-based PTC System

location referencing system as no attribute data are assigned between transponders. The only attribute data required by the system is the maximum safe braking distance but it is not communicated to the locomotive. Instead, it is intrinsic to the system through the location of the transponders.

A second conceptual PTC system is illustrated in Figure 2. This system is still transponder based but is more elaborate as it allows for moving block operation. In this system, the train locating system (TLS) is composed of a transponder antenna and axle tachometers that determine the distance a train has traveled past a transponder. Since the error in distance measurement with axle tachometers is cumulative, if no wheel slip occurs, the uncertainty in the exact location of a train increases linearly with the distance from the last transponder. The digital base map for such a system could be composed of a schematic diagram that is to scale in the linear dimension along the track to allow for relative positioning between trains and other enforcement targets. The exact distance between tracks and the exact geographic position of the railway infrastructure are not required. The location referencing system takes the form of a linear referencing system as the distance along the track from a particular transponder to the location identifies individual points. In order to avoid having a single point referenced by two different distances from two different transponders, and eliminate the possibility of confusion between two points on either side of a transponder, distances should be measured in a consistent direction. When travelling in the positive direction, the transponder would serve as a zero point and measurements of distance would be added to reference the location of the train. When moving in the negative direction past a transponder, the onboard database would set the location as the total distance to the next transponder and measurements of distance would be subtracted from this value. The result, as shown in Figure 2 by distances $L_{B,T2}$, $L_{C,T3}$ and $L_{D,T4}$, is that the LRS measures the distance to each train in the same manner, regardless of its direction of travel. The attribute data required by such a system depends on the complexity of its braking algorithm and could include information regarding grade, speed restrictions and curvature.

The third conceptual PTC system, illustrated in Figure 3, utilizes GPS technology, supplemented by turnout gyroscopes and axle tachometers to determine train location instead of transponders. Advanced GPS systems that use differential or kinematic technology will probably be required to achieve the requisite confidence level in the GPS readings to allow the TLS to differentiate between parallel tracks and consecutive turnouts. The digital base map requirements for such a system are quite different than for the transponder based systems. Since GPS is used to determine train location, the digital base map must be highly accurate in two dimensions (as compared to one dimension for system two) and contain additional details. The exact geographic location of each feature of the

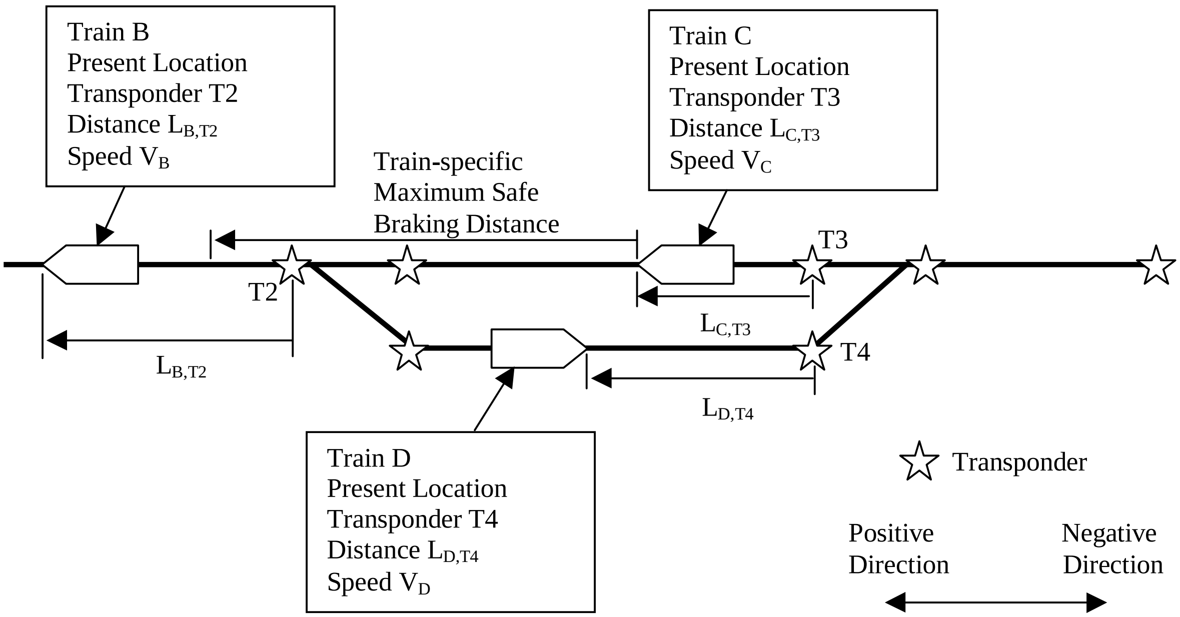

Figure 2: Conceptual Moving Block Transponder-based PTC System

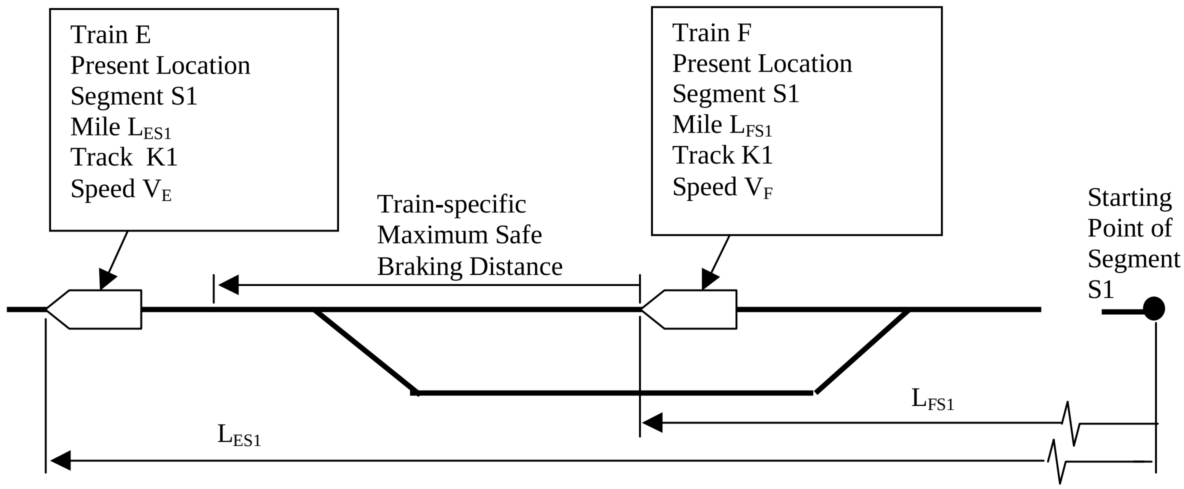

Figure 3: Conceptual Moving Block GPS-based PTC System

railway infrastructure that affects traffic control, including parallel tracks and turnouts, is required in this system. A variety of location referencing systems can be used. It is likely that a linear referencing system would be implemented that labels each point along the track with the distance to that point from some arbitrary starting point. The attribute data required by this system will vary with the complexity of the braking algorithm and enforcement targets. A basic algorithm might only require information on grade and curvature, whereas a more advanced algorithm might make use of additional attributes such as superelevation, rail lubrication and tunnels to model train resistance in more detail.

The final conceptual PTC system is a hybrid that combines GPS, turnout gyroscopes, axle tachometers and transponders. As with the third system, GPS is used as the main source of location data for the TLS. However, transponders are used at key junction locations where two consecutive facing point turnouts fall within the range of uncertainty in the TLS measurement. The transponders allow the TLS to determine which turnouts a train has traversed and which track a train is on in multi-track territory. This allows a different digital base map to be used with this system. Since GPS is not used for determination between tracks, the base map does not need to be as detailed or as accurate. However, a schematic is not sufficient, as a geographic location for each point is required to support the GPS portion of the TLS. The location referencing system could be the same as that used for the third system. Just like the second and third systems, the attribute data required depends on the exact braking algorithm used by the system.

The four systems presented above are summarized in Table 1.

POTENTIAL FOR INTEROPERABILITY

In the previous section, four different conceptual PTC systems were outlined. This section addresses the potential for interoperability between all four systems and determines the basic requirements to have locomotives from each system operate over all others. The potential for interoperability is determined through a series of "thought experiments" where a locomotive designed for use with one system is operated on another system. The results are grouped and presented by system.

System One: Fixed Block Transponder System

Since they are equipped with a transponder antenna, locomotives from systems two and four can operate over this system at the full level of PTC capability provided by system one. Locomotives from system three, which is

TABLE 1 Summary of Conceptual PTC Systems

System	Locomotive Onboard (TLS) Equipment	Digital Base Map	Location Referencing System	Attribute Data
1) Fixed Block Transponder	-transponder antenna	-not to scale schematic	-none	-none
2) Moving Block Transponder	-transponder antenna -axle tachometer	-schematic with distances along track represented to scale	-distance along track from a particular transponder	-vary with braking algorithm, enforcement targets
3) Moving Block GPS	-GPS receiver -axle tachometer -turnout gyro	-highly detailed geographic map with accuracy to allow for cross track resolution by TLS	-distance along track from arbitrary starting point -current milepost system	- vary with braking algorithm, enforcement targets
4) Moving Block Transponder-GPS Hybrid	-GPS receiver -axle tachometer -turnout gyro -transponder antenna	-less detailed geographic map	-distance along track from arbitrary starting point -current milepost system	- vary with braking algorithm, enforcement targets

GPS based, would not have any PTC functionality when operating on this system. This could be remedied by determining the exact geographic location of each transponder using GPS and storing them in a database. If this was done, the GPS capability of a system three locomotive could be used to determine when it was at a transponder location. This would give system three locomotives a high level of PTC functionality when operating on the fixed block transponder system. The performance of the system might be downgraded by the presence of system three locomotives if the GPS based location reports do not have the same level of confidence as the transponder based location reports. Downgrading the performance of PTC does not mean that the risk of an incident is increased. Risk can be kept constant by implementing special operating rules and increasing the time and space separation, or safety “bubble” of uncertainty, between trains (Richardson, unpublished).

Thus, the fixed block transponder location system can support PTC functions of all other locomotives if exact geographic positions of transponders are transmitted to locomotives that do not have a transponder antenna. In doing so, the digital base map, which in this case is a schematic, would be upgraded. The schematic must be fixed to geographic coordinates at transponder locations. However, the exact geographic position of the track between transponders does not need to be determined.

System Two: Moving Block Transponder System

Since they are not equipped with sophisticated axle tachometers, locomotives from system one will not have full PTC capability when operating on system two. The transponder antenna will allow the system one train to determine its location when it is near a transponder. Thus, the system one train will only become visible to other trains at certain points in time. Because the exact location of the train cannot be determined on a continuous basis, the moving block capability of the system must be disabled and the PTC system would revert to the fixed block capability of the existing control system in the vicinity of trains operating with system one locomotives.

Locomotives from system four, the hybrid transponder-GPS system, can operate on system two with the full level of PTC provided by system two.

Just as on system one, locomotives from system three would not have any PTC functionality when operating on system two. The same solution outlined in the previous section for system three locomotives operating on system one could be implemented to provide full PTC functionality.

System Three: Moving Block GPS System

Operating different locomotives on system three is the greatest challenge to interoperability. Since there are no transponders located along the track, locomotives from system one and system two cannot determine their location and become invisible to the PTC system. Thus, the PTC system must be downgraded when system one and two locomotives are operating in the area. A way of making trains visible to the PTC system would be manual input of train location. For system one locomotives, the position would be reported at regular intervals. Since system two locomotives are equipped with axle tachometers, the number of manual reports would be reduced to an initial position and updated positions when the train changed tracks. It is important to note that manual inputs are undesirable since PTC is intended to be safety critical and eliminate the potential for human error. Since the exact position of the train cannot be determined continuously or with a high degree of confidence, PTC could not enforce the speed or authority of the trains operating with system one or two equipment. Because manual inputs do not give system one and two trains PTC capability, the performance of the PTC system would be downgraded to that of the existing control system.

Trains operating with system four locomotives also experience degradation of PTC performance. The TLS on system four locomotives may not have enough resolution to determine which track the train is on. Recall that system four uses transponders for this purpose. If this were the case, track number would be entered manually at the starting point and determined though turnout gyroscope data and manual confirmation along the route. Since this type of operation increases the chances of error, the performance of the PTC system would be downgraded to provide an extra margin of safety. In this case, however, it is difficult to provide a margin of safety against reporting a position that is on the wrong track. One possible method would be to stop the train operating with system four equipment and reduce the speed of an oncoming train sufficiently to allow it to stop if it appears a collision is possible. This solution, however, is not practical in terms of either train performance or safety. A better solution is to set a minimum standard for the GPS receivers and TLS that is sufficient to provide cross-track resolution.

System Four: Moving Block Transponder-GPS Hybrid

Since this system uses components of the other three, one might be tempted to suppose that it should be fully interoperable. However, the opposite is true. Since transponders are only located at key junctions and locations where multiple tracks can be accessed by consecutive turnouts, locomotives from systems one and two cannot determine their precise position at other locations. In such areas, system four relies on turnout gyroscopes to determine which track a train is on if no transponders are present. Locomotives from system two could determine an approximate location by measuring the distance from the last transponder through the axle tachometer. This however, does not provide information regarding which track the train is on. Thus, the performance of the PTC system would be reduced to that of the existing train control system.

The barrier to interoperability encountered by locomotives from system three is the detail of the base map. Although the locomotives can determine a precise location through GPS, when the location is matched to the digital base map, the map does not have sufficient accuracy for the train to determine its position relative to the track. This is not a problem in areas of less complicated trackwork as the turnout gyroscope can aid in tracking the train and determining which track it is on. However, in areas of complicated trackwork, the position of turnouts entered as nodes in the digital base map may not be accurate enough for the GPS to decide which turnout it actually went through. Thus, the tracking ability of the gyroscope is lost and the train cannot determine which track it is on. One solution is to provide sufficiently accurate coordinates of turnouts where two or more are encountered in succession. The rest of the map could still be constructed at a relatively low level of detail. This will not negate the need for the transponders, however, as the GPS units on the system four locomotives may not be able to determine the location of the train precisely enough to decide which turnout the train actually took.

Summary and Conclusions

A summary of the potential for interoperability is presented in matrix form in Table 2.

Examination of this table leads to several conclusions. The first is that the potential for interoperability is increased if all systems contain some basic geographic information. If the locations of transponders are specified with enough accuracy in a global coordinate system, locomotives that are not equipped with a transponder antenna but do have GPS based train locating systems can operate in transponder based territory.

The second conclusion is the fact that changes to the digital base map only allow for partial interoperability of systems two, three and four. In order for complete interoperability to be achieved between these moving block systems, redundant onboard equipment must be installed.

The third conclusion concerns the fact that in order to achieve full interoperability, systems must be able to both host other equipment and operate over territory controlled by other PTC systems. The ability to host other PTC equipment does not guarantee that the system will be able to operate elsewhere. As outlined above, if the

TABLE 2 Summary of Interoperability

		ONBOARD	System	
Host System	1) Fixed Block Transponder	2) Moving Block Transponder	3) Moving Block GPS	4) Moving Block Transponder-GPS Hybrid
1) Fixed Block Transponder	Full (fixed block) PTC	Full (fixed block) PTC capability	No PTC capability unless transponders are assigned geographic coordinates	Full (fixed block) PTC capability
2) Moving Block Transponder	Limited PTC capability (no moving blocks)	Full PTC	No PTC capability unless transponders are assigned geographic coordinates	Full PTC capability
3) Moving Block GPS	No PTC capability	No PTC capability	Full PTC	Degraded PTC capability due to limited cross track resolution and consecutive turnout detection by TLS
4) Moving Block Transponder-GPS Hybrid	No PTC capability	Extremely limited PTC capability	Degraded PTC capability due to limited accuracy of turnout locations on base map	Full PTC

transponders of system one are fixed with geographic coordinates, system one can host locomotives from the other three systems with full fixed block PTC capability. However, locomotives from system one have no PTC capability or very limited PTC capability when operating on other systems. The opposite is true for system four. Locomotives from system four, if equipped with a GPS system of a high level of accuracy, can operate on the other three systems with full PTC capability. However, system four cannot host locomotives from any of the other systems with a full level of PTC performance. An analogy that could be made is to the system of blood types where system one is the "universal receiver", system four is the "universal donor" and systems two and three are the other two types which can only receive and donate from selected systems.

From this discussion, the basis of a standard for the digital base map, location referencing system and attribute data can be established. In its basic form the digital base map can consist of a schematic where the locations of key points such as turnouts and transponder locations are fixed with geographic coordinates that can be matched with those obtained by the GPS receiver onboard a train. The basic digital map can be used without a location referencing system or attribute data to provide basic fixed block PTC capability to trains from all of the various systems outlined in this discussion.

STANDARD DEVELOPMENT

The standard digital base map outlined above may be sufficient to develop a basic fixed block PTC system. However, since the more elaborate PTC systems require additional information, additional standards must be developed that will ensure consistency between systems. If not standardized, different methods of collecting, storing, referencing and using information may become obstacles to interoperability at the highest possible PTC performance level. The first step in developing these standards is to examine existing systems and determine if there are common methodologies for developing digital base maps, similar approaches to location referencing systems or common sets of attribute data. The approaches identified in this paper may not necessarily be included in the standard but do give an indication of the direction this portion of the PTC system is heading.

PTC SYSTEMS AND INSTALLATIONS

Several different PTC systems have been developed for different applications on different railways, as outlined in the Compendium of Current Positive Train Control Projects (Association of American Railroads, unpublished).

Not only do these systems use different digital base maps, location referencing systems and attribute data; they also use different train locating systems. As outlined in the previous discussion, the type of train locating system (TLS) can be the determining factor in the type of digital base map and location referencing system used by a PTC system. The train locating systems for following PTC systems are summarized here:

- Union Pacific/Burlington Northern Santa Fe Positive Train Separation Pilot. This demonstration system was developed by GE Harris Railway Electronics. The TLS consists of differential GPS, wheel tachometers, odometers, turn rate gyros and accelerometers. Similar technology is being used on the Alaska Railroad PTC project also under development by GE Harris (*8*).
- Incremental Train Control System (ITCS). This project involves Michigan DOT, Amtrak and Harmon Industries. The TLS is composed of dual differential GPS, dual axle tachometers and switch position detectors (*9*).
- Enhanced Proximity Warning System (EPWS). This system is being developed for Burlington Northern Santa Fe by Pulse Electronics. The TLS is comprised of GPS, tachometers and gyroscopes.
- Communications Based Train Management (CBTM). This CSX program is designed as a safety overlay system for fixed-block, non-signaled territory and is being developed by WABCO. The TLS consists of GPS and tachometers and is aided by switch routing logic (*9*). Additional information regarding CBTM was obtained from the “Request for Bid, CBTM Railroad Track Survey” (Chandler, unpublished).
- Eastern Roads Positive Train Control Pilot. This joint Conrail, Norfolk Southern and CSX project is in the initial stages of prototype development. Although the details have yet to be established, transponders, GPS, tachometers and gyroscopes are all a part of the conceptual TLS (*9*).
- Illinois PTC Project. This joint Association of American Railroads (AAR), Federal Railroad Administration (FRA) and Illinois Department of Transportation (IDOT) project is in its early stages of development and is intended to serve as the vehicle for development of interoperability standards for many aspects of PTC.

To demonstrate how one of the existing PTC systems approaches digital base maps, location referencing systems and attribute data, the CBTM system is discussed in more detail in the following sections.

DIGITAL BASE MAP

The challenge in developing a digital base map is determining the actual or absolute location of the railway infrastructure. The CBTM system is discussed in terms of the data required to construct the digital base map, sources of this data, the structure of the map, and the accuracy and frequency of updates.

Data Required and Source of Data

To construct the base map, CBTM requires x and y position, elevation and information on curves including radii and beginning and end points. Position and elevation data are obtained from a new GPS survey of the territory. Existing track charts are used to identify the beginning and end points of curves.

Structure of Base Map Data and Accuracy

The CBTM base map is constructed with both earth-centered, earth-fixed XYZ coordinates (ECEF) and latitude/longitude/elevation (LLE) coordinates at an accuracy between one half and one meter. The map itself is composed of a series of nodes and links. Nodes are spaced at intervals of 10 meters and at the beginning and end points of curves. All main tracks, including sidings, are represented by separate links in the base map.

Temporal Dynamics

Temporal dynamics refers to how changes and variations in the digital base map over time are handled by the system. This is composed of three parts: the frequency of updates, the time lag between a change in the physical world and a change in the database, and the threshold at which a change warrants a database update. These three components of temporal dynamics can be explained using an analogy where the database is represented by a newspaper.

- Frequency refers to the amount of time that passes between updates of the digital base map. In the analogy, the newspaper is published every day. Thus, the frequency at which the news is updated is once per day.
- Time lag is the time between a change in track alignment in the field and the corresponding change in the digital base map. In the newspaper analogy, this is the time between an actual event and its corresponding article. Note that not all of the changes made the previous day are included in the digital base map. For example, changes made on Wednesday as the Thursday edition of the base map is being distributed do not show up in a base map until Friday. Thus, even though the map is updated at a frequency of 24 hours, the

time lag may be as long as 30 hours. In some instances, changes will be substantial and require a new survey of the right of way. It may be several days before the change can be incorporated into a new version of the digital base map.

- Threshold is the point at which a change to the infrastructure becomes substantial enough to require a change to the digital base map. In the analogy, not all news makes the newspaper.

It can be seen that even if the digital base map is updated frequently, there will always be a lag between the time changes take place in the field and changes are made to the database. Since changes to the base map are made when changes are made to the track alignment, there will be a time when the actual track geometry will not match the database. How the train locating system will resolve this mismatch is a question that needs to be addressed.

LOCATION REFERENCING SYSTEM

Once the actual location of the railway infrastructure is determined, a method for locating railway features along a particular section of track must be established. These features may take the form of a point, which describes something at a single location along the railway infrastructure or a linear segment which describes an attribute that is consistent along a length of the railway infrastructure. The location referencing system is the set of coordinates or code that locates points or segments at their correct location with respect to the base map.

Referencing Point Locations

CBTM uses a linear referencing system similar to the system described for the third conceptual PTC system presented earlier in the paper. In this type of system, a point is located by specifying its segment identifier and distance from the starting point. The starting point of the CBTM segments is the direct train control (DTC) block boundary, which is physically represented by the DTC sign along the right of way. Since each segment is tied to a DTC block, the linear referencing segments are named after their corresponding DTC block.

The CBTM location referencing system measures the true distance along the track from the DTC block boundary to the point of interest in meters. Distance measurements start at zero at each block boundary and increase in the northward direction. The system is also compatible with the existing milepost system as the distance to actual trackside mileposts is recorded. This allows locations to be cross-referenced by true distance or trackside mileposts that correspond to landmarks observed by the crew.

Referencing Linear Segments

CBTM can reference a linear segment by specifying the start and end points or start point and length of a linear segment. Both methods can be used as the start point, end point and length of each linear segment are recorded.

ATTRIBUTE DATA REQUIRED FOR PTC

Once a system for locating features of the railway along the infrastructure is established, a database of attributes must be developed that has the proper location information. Three basic problems are encountered when this database is developed for PTC. The first is to determine what data types or attributes are required. The second is to determine the proper location information for each particular attribute. The final problem is to develop a way to integrate permanent data that are built into the infrastructure with variable data that are changing as the railway operates each day.

Locating and Positioning Attributes

Attributes for CBTM are located during the initial GPS survey conducted to construct the digital base map. At this time the distance to the point or segment along the track is determined in meters.

Required Point Attributes

The following point attributes are included in the initial CBTM survey and are used in PTC operations:

- Clearance point of each leg of a turnout
- Switch points.
- Derails
- Absolute and intermediate signals in Train Control System (TCS) territory and signals associated with a Self-Restoring Power Switch.
- Milepost signs
- DTC block signs
- Yard limit signs.

Required Linear Segment Attributes

The following attributes represented by linear segments are included in the initial CBTM survey and are used in PTC operations:

- Grade crossings including start point, end point, length, center line of roadway and edges of the roadway
- Grade at tenth of a mile intervals to an accuracy of 0.01 percent
- Civil speed restrictions
- Horizontal curvature including the start and end of curve, length of curve and center of curvature
- Bridges and trestles.

CONCLUSIONS

The digital base map and location referencing system used by a PTC system can influence its potential for interoperability. In order to be fully interoperable, a system must have the ability to host other equipment and have the ability to operate over territory controlled by other systems. The relationship between these two abilities is asymmetric, as a system that can host other systems may not be able to operate outside its own territory. The potential for interoperability between transponder based and GPS based systems is increased if the digital base map specifies the location of transponders and control points in a global coordinate system that is compatible with GPS measurements. This leads to the conclusion that basic fixed block PTC capability can be provided by a base map that consists of a schematic track diagram where the locations of turnouts and transponders are specified by geographic coordinates. No standardized location referencing system or attribute data are required for this type of operation. In order to achieve moving block PTC, additional standards for location referencing systems, standards for attribute data and additional detail in the digital base map are required. Complete interoperability of the moving block systems presented here can only be achieved by adopting a single system or installing redundant components.

By reviewing the digital base map and location referencing system of one of the PTC systems being developed, several issues are raised. The first is the concept of temporal dynamics and how train locating systems and other PTC systems will resolve potential mismatches between the physical world and the electronic route network. The second is the use of a linear referencing system that is compatible with both true measurements along the track and existing trackside mileposts. This feature has the added benefit of maintaining familiar milepost locations, enhances system flexibility and gives it a higher potential for interoperability.

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