employees to use proper identification, and failure to use the words "over" and "out" when required.[8]

- In several instances FRA observed train dispatchers issue critical train movement authorities without obtaining proper identification and/or location of involved trains, a violation of the FRA radio regulations.

- In violation of radio standards, a few dispatchers were observed issuing mandatory train movement directives to employees operating the controls of moving trains (i.e., no attempt was made to identify the receiving employee).

- While the majority of train dispatchers utilized proper radio procedure, there were some who did not. Additionally, the radio procedures used by employees in the field, including supervisory personnel calling train dispatchers, were seldom in compliance with Federal radio standards. Most train dispatchers took no action to remedy the noncompliance by setting an example or openly requesting proper compliance.

Public Comments

FRA solicited both oral and written comments regarding railroad radio communications in its March 11, 1994, Notice of Special Inquiry. The Notice directed the attention of the public to seven core issues and invited comment on supplementary matters as well. At the March 29, 1994, hearing testimony was given by a rail labor panel, the Association of American Railroads, and the American Short Line Railroad Association (ASLRA). Written comments were accepted until April 11, 1994. FRA received eight written comments for inclusion in the official docket expressing general concerns, specific complaints, and addressing the seven issues outlined in the notice.

A transcript of the special inquiry has also been included in the official docket. Significant testimony by all three groups from the inquiry is summarized in this report. The rail labor panel was comprised of representatives from the Brotherhood of Locomotive Engineers (BLE), the United Transportation Union (UTU), the Train Dispatchers Department of the Brotherhood of Locomotive Engineers, and the Brotherhood of Railroad Signalmen (BRS). The panel collectively concluded that very little had changed regarding radio communications in the railroad industry since the last inquiry in 1987. The labor panel cited examples of accidents where radio communication breakdowns of some sort were contributing causes of the accident.

In general, the rail labor representatives said they believe that FRA should enact rules covering the use, maintenance and availability of voice radios. Citing a similar recommendation made to FRA in a 1987 safety inquiry on railroad communications, the

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[8]The safety necessity for use of these terms is disputed by some of the participants in the safety inquiry. Nevertheless, their use is currently required.

labor representatives said radio communications have not improved and in some situations have gotten worse.

The railroad companies affirmed the importance of voice radio communication to railroad operations. For instance, the AAR stated that "[t]he advantage of radio voice communications is that they permit running today's efficient and productive operation in a safe manner." Nevertheless, with respect to specific risks, the railroad companies generally denied that the availability of radio communications is of significant value with respect to maintaining reasonable margins of safety in train operations. The railroad companies stressed, instead, the importance of adherence to railroad operating rules.

Rail management and the short line railroads noted that they have spent millions of dollars upgrading communications systems. Rail management took the position that the railroads did not need Federal regulations in this area. The railroad companies said they are committed to quality radio communications as a matter of good business and do not need governmental intervention to continue improvements.

The BLE representative played a recording of a radio transmission to illustrate the poor quality of communication that exists in the industry today. The train dispatchers suggested improving radio communications by using a separate radio channel for dispatchers. The BRS reiterated their specific concern that effective radio communication is not enough to save the lives of signalmen. According to BRS, watchmen and flagmen along with good radio communication are necessary to protect workers along the right-of-way. The firm position of the rail labor panel was for FRA to require the use of radios in the rail industry.

The ASLRA and the AAR testified at the inquiry and submitted written comments. In so doing, the AAR and ASLRA essentially addressed the core issues listed in the notice. The ASLRA emphasized the need to tailor communication systems to fit the needs of a particular railroad. For example, short lines often find cellular phones, allowing the crew to contact customers as well as make emergency phone calls, more cost effective and more practical than elaborate radio systems.

The ASLRA supplemented the oral testimony by submitting written comments. In these comments, the ASLRA recognized the benefits of radio use on the railroad, but found no compelling justification for a blanket mandate requiring such use. The consensus among the short lines is that a two-way communication system such as a radio, is not essential for the safe operation of trains. Therefore, any requirement that railroads use radios as their communication system would stifle their ability to choose systems best suiting their individual needs and impede technological progress by preventing railroads from experimenting with other forms of communication.

Requiring replacement radios at intermediate terminals was also not favored by the ASLRA, because such a requirement would be burdensome and an inefficient expenditure of time and money. The ASLRA emphasized that radios assist in emergency situations, but do not ensure a timely emergency response. Regulating interference and disruption during radio communications would only impair the development of solutions, as interference is really a technology problem not one of compliance.

Lastly, the ASLRA addressed Advanced Train Control Systems, concluding that any mandate of a particular system, such as digital radios, would be unwise because it would further limit technological developments. The short lines' approach to operation is low but serviceable technology which contributes to low costs. Short lines should, therefore, not be forced to employ unnecessary and expensive technology. The ASLRA concluded that they are committed to safety and progress, but do not believe that increased regulation of railroad radio communications is necessary to achieve those goals.

The AAR's testimony at the inquiry essentially highlighted the issues listed in the notice. They urged that railroad safety is dependent on compliance with operating rules and Federal regulations, not radio use. In so doing, they acknowledged that radio use is an integral component of efficiency, but stressed that the absence of radios does not make the operation of trains unsafe, just as the use of radios does not ensure safe operation.
The AAR utilized the written comment forum to address the Federal Communications Commission's (FCC) proposed spectrum refarming (Docket No 92-235). Although this refarming is not the main emphasis of the safety inquiry, the tangential concerns are noteworthy. Essentially, the FCC proposes to convert channels from present band centers of 15 kHz to a narrow bandwidth of 5 kHz thereby reducing channel congestion. The AAR estimates such a conversion will cost railroads approximately $1.2 billion to purchase replacement equipment. Consequently, the AAR urged FRA to support its "offset overlay" plan, designed to achieve the same benefits at a reduced cost to the rail industry.

The written comments submitted by the AAR also answered questions that had been addressed to them by the FRA panel at the inquiry. The AAR was asked what type of investment railroads had made into their radio systems. Since FRA's inquiry into voice radio in 1987, the industry has invested over $100 million in improved radio communications. All Class 1 lead road locomotives are now equipped with radios, costing on average $3,950 for the entire package installed and with an average useful life of 10 to 12 years. Radio units for replacement in equipped locomotives cost $2,350. The average useful life for a locomotive radio is 10 to 15 years. Significantly, the AAR indicated that 90 percent of Class 1 railroad locomotives are now equipped with all-channel radios--a requirement for good communications in joint operations.

In response to FRA's concern regarding the reliability of portable radios under adverse conditions, the AAR found that most hand-held portable radios are reliable except after being totally submerged in water. Finally, the AAR addressed the FRA panel's concern regarding radio effectiveness. Common problems such as bleed-over from neighboring dispatcher districts, dead spots, and channel congestion are not unique to the railroad industry. All users of major radio systems face similar problems. A variety of methods are used by railroads to alleviate this problem including frequency leap-frogging, dedicated dispatcher and road channels, Dual-Tone-Multiple-Frequency (DTMF), tone encoding, and adding new base stations. The AAR suggested a working meeting at which interested parties would work on streamlining existing rules and regulations.

Six other written comments were submitted. General comments were expressed by the American Public Transit Association (APTA) and two of its members, the Northeast Illinois Regional Commuter Railroad Corporation (METRA) and the Port Authority Trans-Hudson Corporation (PATH). APTA, representing all of the current U.S. Commuter Rail operators, concluded that safety regulations requiring the presence of radios and replacement of radios failing in route would have adverse consequences for commuter operations. APTA agreed with the views that the AAR expressed at the March 29, 1994, hearing. Essentially, both groups contend that railroad safety is dependent on compliance with the underlying operating rules adopted by each railroad and not the required presence of radios.

The United Transportation Union (UTU) National Legislative Department utilized the inquiry as an opportunity to air grievances from local organizations. These complaints specified incidents that occurred due to railroad radio communication failures including, insufficient broadcast range, radio transmissions from the yardmaster and control tower over the employee's hand-held radio, and the flooding of the air waves. In a separate submission, the UTU, Montana State Legislative Board, expressed concern about radios with insufficient power and suggested using cellular phones as an alternative. Finally, they suggested the use of two speakers located on both sides of the locomotive cab to ensure that all radio transmissions are heard.

The Brotherhood Railway Carmen Division Transportation Communications International Union (BRC) submitted written comments. BRC's general position was that all locomotives and cabooses must have radio equipment and that replacement equipment must be available at intermediate terminals. They stressed the necessity of radio equipment for emergency situations. BRC also felt that FRA should evaluate sources of interference affecting radio performance, enforce current standards and clarify the use of current technology. Lastly, BRC emphasized their opposition to any reduction in the use of voice radio communications on the Nation's railroads.

The final two comments were from the New York State Department of Transportation's Railroad Safety Staff (NYDOT) and Metro-North Commuter Railroad (MNCR). NYDOT acknowledged one significant disadvantage of requiring radios would be increased air clutter and overuse of the radio. NYDOT felt that regulatory monitoring should be established by FRA. MNCR emphasized the importance of radios on lead locomotives, but could not establish a justification for such a requirement.

The special safety inquiry served as an opportunity to poll the railroad community regarding radio use in the rail industry. This summary of testimony and written comments merely highlights significant information. As noted above, the transcript and the written comments are available for review in the public docket.

Analysis

When used in the context of a railroad operations, voice radio communications provide economic and safety enhancement opportunities when hardware is reliable and users comply with established standards. During the field investigation FRA safety inspectors encountered few locomotives with inoperative radios. Interviews with train and engine employees, train dispatchers, and other interested employees revealed that voice radio reliability has improved dramatically over the past few years. The problems that were identified involved occasional inoperative or weak radios on locomotives and frequency congestion around terminals (which is, to a large extent, a product of improper channel utilization rather than equipment shortfalls).

Adequate communications equipment. Effective communications among crew members, and to and from the dispatching center, is an important factor in safe train operations. Given the operating environment today with heavy reliance on voice radio and direct train control, and given the need to communicate emergency warnings and emergency requests, FRA believes it essential that adequate communications capability be provided on all trains. FRA also believes that a suitable level of safety redundancy should be built into the railroads' communications systems.

One important solution to the problems with voice radio no doubt resides in data communications associated with advanced train control technologies. This concept is already in use in some applications in the railroad industry. For example, through upgraded computer-assisted train dispatching systems and on-board locomotive receivers, some railroads have experimented with transmission of movement authorities electronically. This eliminates the potential for misunderstanding and miscommunication. FRA supports the move toward data communications as a means to reduce potential human "hearback-readback" errors which have contributed to several fatal collisions over the past several years. These issues are discussed further in the chapter that follows.

The need for voice radio, however, will apparently persist at least as long as railroad switching operations are conducted on long cuts of cars using two or three-person crews. Radio communications provide the only practical means of exchanging information and instructions in switching moves; and continuity of communication is important to safety.

Good procedures and radio discipline. Availability of communications hardware alone will not ensure sound communications. FRA accident data clearly reveal that, despite some shortcomings in radio systems, it is user noncompliance with radio standards that is most likely to create an unsafe situation, not inoperative radio equipment. For example, over a recent 4-year period, 83 train accident reports were submitted by railroads attributing the cause to radio/communication problems. These reports included 4 employee fatalities, 16 employee injuries, and $12 million in property damage. In each of these events, noncompliance with existing rules and standards (49 CFR Part 220) was evident.

Better radio rule compliance will occur only when railroads make it clear to their employees that compliance is expected and when dispatchers and operating officers set the example. The railroad companies have suggested that the formality of the present FRA radio rules makes enforcement of radio discipline more difficult. FRA agrees that the time has come to reexamine the rules to determine if they can be simplified to be less directive and more performance oriented.

Better utilization of capacity. The Federal Communications Commission has allotted channels in the VHF band which are dedicated to railroad radio communication. Part of the reason for this allotment of scarce radio frequency capacity to the railroads is the safety interest of the railroad companies and the public. The AAR plays a useful role in managing channel allocation to reduce interference.

Yet many railroad users continue to misuse available channels, particularly the dispatcher channels, resulting in congestion. Further, some railroads have not elected to employ contemporary technology that facilitates giving automatic priority to emergency communications. Finally, railroads have made only limited use of data communications capacity available in the UHF band in the 900 mhz frequencies. (For many purposes, digital data communication employing radio and hard wire paths is a far more secure and effective medium than voice radio.)

Railroads should enforce proper use of allotted channels to avoid to the extent possible interference with dispatcher-to-train communications and locomotive-to-ground-crew (conductor, brakeman) communications. Where radio traffic warrants and alternative means of emergency communications are not available, means should be provided to give automatic priority to emergency calls.

Summary. FRA recognizes the vast strides that the railroad companies have made in recent years to enhance their radio communications systems and the considerable contribution those efforts have made to safety. However, FRA is concerned that railroads participating in the safety inquiry have not expressly recognized the value radio communications can contribute to railroad safety. Although FRA understands the reluctance of rail management to shoulder further regulatory burdens, failure to credit the value of good communications to safety is an attitude that may inadvertently be expressed within the railroad organization, as well as in filings with the regulator.

Determining the best use of voice radio technology as part of system safety requires functional analysis, consideration of alternative or supplementary measures, and delineation of the number of layers of safety redundancy that may be deemed acceptable for the function. Deployment of the digital data communications systems used in certain advanced train control technologies constitutes one important measure that may satisfy certain safety requirements. *Chapter IV* describes the emerging potential of such systems and the uneven progress of the railroad industry in realizing that potential.

CHAPTER IV

Positive Train Control and Digital Data Communications

Section 11 of the Rail Safety Enforcement and Review Act requires an assessment of how advanced technologies such as digital radio can be implemented to enhance the safety of railroad operations, the implications of advanced train control systems for railroad communications, and the need for Federal standards to ensure that such systems provide for positive train separation and are compatible nationwide. This chapter describes emerging technologies that can provide for positive train separation while achieving other safety objectives. With regard to potential for application across the breadth of the national rail system, the most promising of these technologies are founded on digital data communications platforms. As those platforms are put in place-- but before the systems are fully deployed-- railroads can begin to realize safety benefits, as data links replace the more error-prone voice radio systems for transmission of train movement authorities.

Terminology and Objectives

Positive train control. This report uses the term "positive train control" or "PTC" to refer to highly capable technologies for preventing train accidents and casualties. PTC is preferred for this purpose over positive train separation (PTS), "advanced train control systems," Advanced Train Control Systems (ATCS), or other possible formulations.

The term "positive train separation" is very useful to denote collision avoidance, but it is not sufficiently broad. Next-generation train control systems should be capable of keeping trains apart, but they should also be capable of preventing violation of permanent and temporary speed restrictions, including restrictions that protect roadway workers and their equipment. Further, the "PTS" acronym has now been adopted for a specific test bed application (described below).

Fully deployed ATCS, as conceived by the AAR and the Railway Association of Canada, includes all PTC elements, but ATCS also includes several nonsafety elements, such as work order reporting and locomotive health monitoring. Essentially all of the ATCS features thus far deployed by North American railroads have little safety relevance *as presently utilized*. Further, fully deployed ATCS offers advantages with respect to plant capacity that may not be realized using alternative technologies (advantages that are of great economic value where needed, but, again, not necessarily representing a major advance in safety).

Thus, PTC[9] refers to a set of safety objectives, rather than a specific technology. Specifically, positive train control should --

- Prevent train-to-train collisions (positive train separation);
- Enforce speed restrictions, including civil engineering restrictions and temporary slow orders; and
- Provide protection for roadway workers and their equipment operating under specific authorities.

PTC should accomplish these objectives by intervening only in the rare instance when the human operator (e.g., locomotive engineer) errs. The PTC system should be secure from tampering and should function as an integral part of cab electronics so that it cannot simply be "cut out" for reasons of expediency by an engineer.

Intelligent discussion of PTC must begin with the understanding that there is no current or planned technology that is capable of replacing the human operator.[10] Rather, PTC would be implemented to assist and protect the operator through enforcement of key, safety-critical limitations on train operation. The most advanced PTC technology would also provide the operator with all critical information required to operate the train without intervention.

<u>Interoperability</u>. In order to be affordable by North American railroads, PTC technology should be interoperable; on-board locomotive equipment will be equally responsive to the PTC system on each railroad. This is especially critical because locomotives often run through railroad boundaries and some of the most dense traffic is found in major terminal areas where multiple carriers operate over the same trackage. In practice, if systems are not interoperable, the regulator will be presented with many situations where it is not cost effective to require that certain trains (e.g., detour movements, freight movements for short

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[9]PTC is used here as a generic term and is not intended to refer to any proprietary technology.

[10]During the development of the industry's Advanced Train Control Systems program, consideration was given to the possibility of automatic control of road trains. However, as freight railroad operations are currently configured this is not practical. For instance, engineers are required to respond with warning and, where possible, mitigating measures, to a wide range of obstructions on the right of way (including pedestrians and vehicles at highway-rail crossings). Some heavy rail transit systems (e.g., BART, Washington Metro) are capable of fully automated operation. However, they operate trains of standard sizes over standard routes on protected rights-of-way. All such systems which operate at significant speeds continue to place an operator capable of assuming control of train operation on each train.

distances in joint operations, etc.) be equipped with on-board equipment responsive to PTC commands. When trains are not equipped, the value of PTC is lost.

Compatibility. From a commercial standpoint, compatibility of components from a wide variety of manufacturers should be ensured through "open architecture" specifications. This will help hold down the cost of components while permitting further technological advances within a flexible framework.

Digital data radio.[11] "Digital data," as applied to safety-relevant communications systems, refers to electronic data passed between computers over a wide variety of paths (short-range radio, microwave, fiber optics, conventional pole lines or cables, commercial telephone, etc.). Digital data communication has the potential to enhance safety by virtually eliminating miscommunication (though not necessarily misapprehension) of safety-critical information. Digital data radio promises to communicate safety-relevant information and commands across rail systems. It is also a key element in emerging PTC systems.

As the discussion below will demonstrate, the means to accomplish both positive train control and more secure communication of safety-relevant information may be integral parts of the same system. Compatibility of components and interoperability of systems from railroad to railroad then become prime planning objectives.

Background: Train Control Enforcement Systems

PTC is not a theoretical construct or distant vision. Where historical traffic patterns have warranted, railroads have been required to install relatively expensive train control systems incorporating warning and/or enforcement features, such as automatic cab signals, automatic train control (ATC) or automatic train stop (ATS).

There are 6,212 miles of automatic train stop and automatic train control installed on railroads in the U.S. An ATS system is arranged so that its operation will automatically result in the application of the brakes until the train has been brought to a stop if the engineer fails to acknowledge the more restrictive signal. There are two general types of ATS systems; namely, intermittent inductive ATS (which verifies compliance only at certain locations, such as approach and home signals) and continuous inductive ATS (which is interfaced with the track circuit).

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[11]Section 11 of the Rail Safety Enforcement and Review Act referred to "digital radio," and some commenters have taken this to mean digital transmission of voice, in place of today's analog systems. Certainly digital voice technology offers the promise to improve clarity and utilize frequencies more efficiently. However, there is no commercially accepted standard protocol for this function at the present time, and merely transmitting voice messages in a different way would not have a fundamental effect on safety of railroad operations. This report addresses radio transmission of digital *data* (in effect, from computer to computer) via radio.

An automatic train control system is arranged so that its operation will automatically result in the application of the brakes until the train is brought to a stop, or--under control of the engineer--until the train's speed is reduced to a predetermined rate or the condition that caused the restrictive signal ceases to exist. ATC is required to apply the brakes when the train exceeds the predetermined rate, until the speed is reduced to that rate.

Automatic cab signals provide warning when signal aspects change to more restrictive aspects. Cab signals also provide a continuous display of signal aspects, further reducing the possibility that wayside signals will be misperceived (or missed entirely).

Impetus for Change

It has long been recognized that features of PTC systems, such as those incorporated in ATC, ATS, and the developing technologies described below, can improve safety. Indeed, this was the reason that the Interstate Commerce Commission, during the peak years of the Nation's dependence on railroads for passenger service, required installation of ATC/ATS on portions of the national system.[12] However, the cost of installing and maintaining this equipment was high, and the Commission allowed exceptions even to the limited installations initially required. Some ATC/ATS systems were later discontinued, in some cases because of facility consolidations and in others because discontinuance was permitted by the Commission due to changing traffic (particularly, following the Second World War, as passenger traffic precipitously declined).

The physical damage and carnage associated with train collisions during the period just after the First World War can profitably be compared with the current situation with respect to benefits and costs of safety technology. In its first train control order, the Commission stated --

> The matter of cost is the basis upon which the carriers have raised objection to an order requiring the installation of automatic stop or train-control devices....Yet the compensation from a financial standpoint, which will result from ... securing added safety in train operations should not be overlooked. In the hearings before the Committee on Interstate and Foreign Commerce when Section 26 [the precursor to the Signal Inspection Act] was under consideration certain statistics gleaned from our accident reports were presented showing that from 1909 to 1917, both inclusive, there were 13,339 head-on and rear-end collisions resulting in damage to railroad property alone of over nineteen million dollars. These collisions resulted in death to 2,454 persons and injury to 37,724.[13]

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[12]See *Interstate Commerce Commission Activities 1887-1937* (Bureau of Statistics, ICC, 1937); *Reports and Orders of the Interstate Commerce Commission: In the Matter of Automatic Train Control Devices*, Docket No. 13413 (1931).

[13]Ibid. at 74.

As reflected in Chapter I and the Appendices, contemporary safety experience reflects tremendous advances since those times. For instance, during no year since 1975 have as many as 20 persons died in train-to-train collisions on the Nation's railroads.

In recent years, advances in safety have not reduced interest in affordable technology that could eliminate entirely those human factor accidents, such as collisions and accidents involving excessive speed, which tend to be most likely to cause fatal injury. As it has become increasingly evident that even higher levels of safety are possible, interest in closing the remaining gaps has risen. That interest has been spurred by each successive fatal accident for which train control technology might have made the critical difference.

The National Transportation Safety Board (NTSB) has made a series of recommendations to FRA concerning automatic train control and positive train separation.

In 1971, the NTSB recommended that FRA develop a comprehensive program for future requirements in signal systems which would require as a minimum:

a. That all mainline trains be equipped with continuous cab signals in conjunction with automatic block signals; and

b. That all passenger trains be equipped with continuous automatic speed control (train control).

In 1973 the NTSB recommended that FRA, in cooperation with the Association of American Railroads, develop a fail-safe device to stop a train in the event that the engineer becomes incapacitated by sickness or death, or falls asleep. Regulations should be promulgated to require installation, use, and maintenance of such a device. (Note: contemporary alerter technology comes close to meeting this objective, and FRA continues to seek fully fail-safe answers through research.)

In 1976, NTSB recommended that FRA promulgate regulations to require an adequate backup system for mainline freight trains that will insure that a train is controlled as required by the signal system in the event that the engineer fails to do so.

In 1987, NTSB recommended that FRA promulgate Federal standards to require the installation and operation of a train control system on mainline tracks which will provide for positive separation of trains.

In 1991, NTSB recommended that FRA, in conjunction with the Association of American Railroads and the Railway Progress Institute, expand the effort now being made to develop and install advanced train control systems for the purpose of positive train separation.

Finally, in 1993, in its report on the Ledger, Montana, accident of August 30, 1991, the NTSB made the following recommendation to FRA:

In conjunction with the Association of American Railroads and the Railway Progress Institute, establish a firm timetable that includes, at a minimum, dates for final development of required Advanced Train Control System hardware, dates for implementation of a fully developed Advanced Train Control System, and a commitment to a date for having the Advanced Train Control System ready for installation on the general railroad system.

As the drumbeat of NTSB and other public advocacy has swelled, the central issue has continued to be that of affordable technology. In 1991, FRA estimated a cost of $16 billion for 91,000 route miles merely to install automatic train control (ATC) systems, a figure that was many times greater than expected safety benefits over the systems' useful life.[14]

The railroad industry has responded to this dilemma, and to other business needs, by planning a communications-based train control system for the future.

North American ATCS

In the early 1980s, the Railway Association of Canada (RAC) began actively to explore the feasibility of a radio-based train control system that would eliminate human error in the operation of trains. During 1982, the RAC first convened meetings of senior railroad officials in Canada and the United States to explore this possibility. Subsequently, committees composed of the department heads of several railroads met and developed the concept of Advanced Train Control Systems. For the first time a method of operation was being preplanned for universal application. In 1983 a project chairman was designated. In early 1984, the Association of American Railroads assumed responsibility for project staffing and the AAR and RAC pledged funding.

On behalf of the RAC and AAR, a report of the Operating Requirements for ATCS was published in April 1984. The report forecasted the requirements for a series of comprehensive and advanced radio-based electronic systems essential for safety, productivity and efficiency in all aspects of on-track operations. The specifications contained in the requirements were purposely generic to accommodate a variety of hardware and software from different sources that would achieve industry-wide compatibility. The report recognized that some functions would require research and development of new systems.

As conceived in the specifications, ATCS is an enhanced train control system that utilizes microprocessors (computers) and digital data communications to connect elements of the railroad, locomotives, track forces, and wayside devices to the dispatcher's office. Additionally, it will link data to key managers of a railroad, through information management systems. The communications system that links all of the systems together is

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[14]*Advisability and Feasibility of Requiring Automatic Train Control Systems on Each Passenger and Hazardous Materials Rail Corridor* (Report to the Congress pursuant to the Rail Safety Improvement Act of 1988) (Federal Railroad Administration, 1991).

the key to ATCS. ATCS currently has six pairs of digital data communications channels available for exclusive use in North America. (For territory not equipped with data radio, cellular telephone communications are being studied.) The communications system can utilize components made by different companies, providing for modularity of the system and promoting competition among vendors.

The ATCS Operating Requirements envisioned the optimum system -- eliminating dependence on human compliance with signal indications, operating rules, and written instructions to achieve safe speeds and separation; obtaining increased traffic capacity and equipment utilization; and controlling operations for maximum savings in fuel and labor. Specifications were established for system-enforced movement authority, speeds, and positive separation. The system would ensure route integrity with the functional status of wayside equipment, including defect detectors and highway-rail grade crossing devices, communicated to each train and the control center. Specifications were established for --

- on-board displays that would identify track profile, route authority and conditions;
- work order reporting (car pick ups and set outs);
- locomotive health monitoring;
- interface with maintenance-of-way forces;
- predicted braking distances; and
- train operation management for crew identification and hours of service.

The specifications also included automatic stop protection that would preclude a train exceeding its limits of authority. Finally, the specifications required the system to be modular, with hardware and software capable of industry-wide operation of a locomotive moving from one type system to another automatically without hindrance, and compatible with all existing control systems, especially traffic control systems.

Subsequently, under the umbrella of the AAR, Aeronautical Radio, Inc. (now "ARINC") was selected as the consultant to provide technical and engineering services for the development of specific design specifications. Working committees composed of representatives from Canadian and United States railroads were formed to develop the specifications for ATCS. FRA also participated in the process.

The AAR's Communications and Signal Division, working with ARINC, developed the communications architecture for the system, using accepted procedures that assure transmission and receipt (handshake) of data, security and reliability. In addition, specifications for datalink operation of wayside apparatus (wayside interface units (WIUs)) were developed.[15] WIU specifications cover signals, switches (both hand-operated and power-operated), highway-rail grade crossing devices, defect detectors, and various detection methods for determining rail continuity.

The AAR's Mechanical Division developed specifications for a locomotive on-board computer (OBC). The OBC was designed constantly to monitor the locomotive's health (fuel, fuel consumption, water, oil, temperatures, main reservoir pressure, etc.); operation (speed, throttle position, brake position, brake pipe pressure, horn, bell, location, train profile, tonnage, etc.); train control (authority, route, block and interlocking conditions, highway-rail crossing device conditions, defect detector conditions, track integrity, etc.); management of operations (identification of crew, hours of service, work orders, projections, predictive conditions, conflict resolutions, etc.); and train handling requirements (limits of authority, speed restrictions, speed instructions, etc.).

The AAR's Operating Rules Committee, with input from representatives of FRA, drafted the rules for operations in ATCS territory. The work of this committee is yet to be finalized. Efforts to develop operating rules identified the disparities of the concept of ATCS that exist within the industry. It became evident that some carriers were seeking the optimum system in which all trains would be ATCS equipped; some carriers proposed equipping only passenger and manifest freight trains; and some carriers were opposed to the train control features. In some quarters, the objective was to eliminate all block signal systems in ATCS. In order to accommodate these differences, ATCS evolved into four categories -- Levels 10, 20, 30 and 40.

Level 10 would provide the equivalent of track warrant operations by visually displaying limits of authority and work orders.

Level 20 added to Level 10 locomotive health and predictive calculations for pacing, train meets and crew management.

Level 30 added to Level 20 communications with wayside interface units (WIUs) and PTC enforcement.

Level 40 was conceived as the optimum system interfaced with a centralized, computer-aided dispatching function. At this level, ATCS might replace the existing signal system (or provide the capability to operate trains in "dark territory" with the same or greater competency as if a traffic control systems were in place). Level 40 offers the potential that fixed blocks[16] might be eliminated in favor of flexible block length, resulting in significant

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[15]A WIU includes the hardware and software necessary to provide interface between new and existing wayside devices and ATCS.

[16]A "block" is simply a segment of track--in signal territory a segment of track between wayside signals. Since signal spacing must be set at a distance approximating the stopping distance of the heaviest and fastest train permitted to use the railroad, a fixed-block

increases in capacity in some cases (as more trains are permitted to use the same track, with reduced headways).

Since the specifications are modular, delineations among the levels of ATCS are not clearly defined; and many of the specifications written for ATCS are optional in the first three levels.

An ATCS locomotive display shows the mileage, speed limits, actual train speed and grade. ATCS differs from conventional train control systems in that all train movement authorities and operating instructions are displayed in the locomotive cab.

In the ATCS concept, transponders are located along the rail line to provide precise train location information. Between transponders, interpolation is by wheel rotation count (tachometer). The on-board computer integrates the location information from the transponder with the authorities provided from central control and determines enforcement parameters.

As the main body of the specifications was developed, ARINC coordinated all the working groups to assure the technical specifications were uniform, modular in construction with interoperable datalink communications. ARINC conducted several exercises to prove the flowcharted specifications in which representatives from the railroad companies, FRA and the supply industry acted out specific roles of the components, devices and computers being designed for ATCS. The role-playing exercises were tedious, intensive and precise. Design flaws were corrected and the handshake for data communications refined. From the flowcharts actual specifications were derived for electronic design of ATCS using concepts from the aerospace program, especially the National Aeronautics and Space Administration. According to an evaluation by Draper Laboratories, the failsafe factor of the electronic design is 10^{-17}, the equivalent of one hazardous failure in 64 years, which meets or exceeds the failsafe factor in current signal circuitry design.

In the ATCS development program, various railroads in both Canada and the United States conducted tests of ATCS components. Several railroads began a long-term restructuring of their communications systems to enable future radio transmissions required to implement ATCS. As a result, the industry has developed and proven many subsystems of the ATCS technology, particularly those elements integral to the communications platform. Many components are now available off the shelf for implementing ATCS.[17]

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arrangement tends to limit "throughput" of trains more than an arrangement that considers the speed and tonnage of the trains actually using the railroad.

[17]An extensive discussion of ATCS topics is contained in *Advanced Train Control Systems*, Transportation Research Record No. 1314 (Transportation Research Board, National Research Council 1991).

"Business" Applications of ATCS

ATCS is far more than a planning process. Nonsafety applications of ATCS have been undertaken by several railroads. In the United States, the Union Pacific Railroad has implemented ATCS work order reporting program system-wide. The work order reporting system enables the conductor to receive work requests (pick-ups and set-outs) and to report work completed in "real time", using data links between locomotives and UP's Transportation Control System. Work order reporting is designed to serve as an element of a integrated service management plan that will increase the quality of service to shippers, defined in terms of predictability and speed.

Burlington Northern Railroad (BN) has a pilot program for monitoring locomotive performance, by equipping 100 locomotives with ATCS-compliant health monitoring systems.

The Norfolk Southern Railroad is considering a pilot project for a work order reporting program using ATCS. CSX Transportation and The Atchison, Topeka and Santa Fe Railway are currently using ATCS communications technology for replacing pole line.
In Canada, the Canadian National Railroad (CN) and the Canadian Pacific are advancing their ATCS projects. CN has operated a prototype ATCS installation that includes "real world" and simulation testing, though this effort is not presently active.

ARES

Simultaneous with development of ATCS, the BN developed a similar system designated Advanced Railroad Electronics System (ARES). The BN, with Rockwell International its prime contractor, implemented a test bed for ARES in northern Minnesota. The characteristics of ARES functions included those of ATCS with an additional feature that permitted emergency stopping of trains from the control center.

One significant difference between ATCS and ARES is the method utilized for train location. ATCS specifications employ transponders located at designated locations that will identify each train as it passes that location and transmit the data to the locomotive and central computer. ARES utilized the Global Positioning System (GPS) to monitor and calculate the location of each train periodically.[18]

Another difference concerned the communications platform. ARES utilized VHF frequencies (which are favored, among other things, for the greater distances that can be accommodated between radio base stations), while ATCS utilizes assigned frequencies in the 900 MHz range of the UHF spectrum (which may be less affected by interference from other radio frequency traffic in more congested areas).

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[18] In GPS, radio transmissions from communications satellites owned and operated by the U.S. Department of Defense are compared to determine location.

BN demonstrated ARES on a test bed in northern Minnesota (the "Iron Range") during the period 1988 through 1993. Although BN and Rockwell technical teams judged ARES ready for system-wide application, BN did not fund the project. Instead, in 1993, BN placed the fate of ARES in the hands of the AAR Board of Directors, which determined that ATCS technology should remain the industry standard for planning purposes. Although BN discontinued work on the train control aspects of ARES, BN elected to continue development of a digital data radio capability using VHF frequencies that is similar to the ARES communications platform.

Evaluation of ATCS

Under an interagency agreement, FRA asked the Institute for Telecommunications Sciences, Department of Commerce, to review the ATCS specifications to determine the readiness of the industry to achieve PTC objectives through ATCS and to outline the steps that would be required to bring the train control aspects of ATCS on line. ITS has extensive experience in the development and evaluation of telecommunications technologies.

Based on review of the ATCS specifications and consultations with the AAR, ARINC, and other sources, the ITS report to FRA (reproduced as Appendix 3) reached the following conclusions:

(1) The ATCS Specifications have been developed to ensure compatibility and interoperability. The specifications are written to ensure compatibility between system components produced by different manufacturers. They are written to ensure interoperability between railroads. Such compatibility and interoperability is needed to provide positive train separation throughout the North American rail system.

(2) The ATCS Specifications apply sound engineering techniques to ensure the proper delivery of data from source to destination. Data communications systems must rely on automated techniques to ensure that data arrive at the intended destinations, that errors are detected and corrected, that data have been protected, and data arrive within established time constraints. The data communication system must have the ability to detect and recover from faults. In the event of failure, the data communication system must allow a graceful and safe return of control to a secondary system, in this case voice communication between the dispatcher and locomotives or track maintenance vehicles. The ATCS accomplishes these tasks well.

(3) The ATCS has the components to provide positive train separation. Positive train separation refers to the capability to detect and prevent impending collisions between trains. Within the ATCS, the access of trains and track forces to any section of track is strictly controlled by authorities issued by a dispatcher. The speed and location of trains and track forces are continually monitored. If violation warnings are not heeded by the operator, speed restrictions of the limits of movement authorities are enforced through automatic brake application.

(4) The ATCS Control Flow Specifications need further testing and validation. The ATCS Control Flow Specifications provide functional descriptions of certain aspects of railroad operating logic, and define how hardware and software elements of the system should interact in order to execute railroad operations. For example, one of the ATCS control flows describes the process by which central dispatch would issue a movement authority to a locomotive, and defines the associated messages that would be exchanged between various system processors.

A major revision of the Control Flow Specifications was completed in 1993. The control flows have become increasingly complex as system development has progressed, and ARINC is working on further documentation to aid ATCS software developers.

Because of the complexity of the control flows and because correct control flows are essential to safety, ITS recommends independent modeling and validation of the ATCS control flows under a variety of operating scenarios to ensure that the system functions as intended.

(5) A coordinated field test of a full implementation of the ATCS is needed. Various railroads and railroad equipment manufacturers have implemented only portions of the ATCS Specifications, or have conducted only limited tests of ATCS applications and equipment. A coordinated effort is required to field test a full implementation of the ATCS on a section of track with typical environmental conditions. A more comprehensive field test or pilot demonstration would be required to show the ATCS can properly function in more severe environments such as the Chicago hub or the Northeast Corridor.

(6) A migration plan and a timetable for implementation of the ATCS are needed. A migration plan provides for an orderly transition from one system to another. The migration plan ensures that safety measures already in place are not removed before all trains that pass through the territory have fully-equipped ATCS locomotives. Older systems and the ATCS will probably have to be operated in parallel while the ATCS becomes fully operational.

The implementation timetable accounts for the acquisition of funding, the installation and testing of ATCS equipment, and training for users of the new system. The timetable should seek to accommodate all railroads to encourage widespread use of the ATCS.

ITS also recommended evaluation of the UP/BN PTS project (described below) as an important means of gaining some of the knowledge referred to in the fifth and sixth findings, above.

Northeast Corridor (NEC) North End

In connection with the improvements on the NEC between New Haven, Connecticut and Boston, Massachusetts, the National Railroad Passenger Corporation (Amtrak) is upgrading the signal system to a traffic control system and proposing the conversion of the present 4-aspect single frequency cab signal/ATC system to a 9-aspect dual-frequency system with an intermittent train stop system. These changes will provide for centralized dispatching, permit increased speeds between intermediate signals, provide enforcement of civil engineering speed restrictions,[19] provide means of protecting roadway workers, and implement positive train stop at key control points. The proposed system will allow maximum speeds of up to 150 mph and speeds of 80 mph through crossovers.

The proposed intermittent train stop system is a transponder-based system, passive in operation, being a fixed "overlay" system, designed to locate the actual braking points and capable of supervising curve speeds and other civil restrictions in increments of 5 mph.

The existing 4-aspect, 100 Hz, 3-code system will be expanded to a 9-aspect, dual frequency, 8-code system by adding 250 Hz to 100 Hz as a second power frequency carrier and by adding 270 code to the traditional 180, 120, and 75 codes. The 250 Hz and the 270 code rate will be added in a way that minimizes the impact upon the existing equipment using the NEC.

The FRA supports Amtrak's project, and has advised Amtrak that the proposed system should meet the following requirements:

1. The system must enforce both permanent and temporary civil speed restrictions.

2. All trains operating over the trackage of the proposed system must be equipped to respond to this system.

3. No conflicting aspects or indications shall be displayed in the locomotive cab.

4. The system must enforce the most restrictive speed at any location associated with either the civil restriction or cab signal aspect.

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[19]"Enforcement of civil engineering speed restrictions" means limiting speeds at curves, stations and other points where the speed allowed by the signal system (based on track occupancy and rail integrity) exceeds the timetable speed restriction at the site. At FRA's request, the existing cab signal/ATC system has already been modified at several critical points on the NEC to provide this protection against overspeed operation, but the proposed system would provide an additional margin of safety at numerous additional locations.

5. The system must defeat any action by an engineer (e.g., as might occur should an engineer be on the verge of sleep and reflexively acknowledge a cab signal warning) that could allow a train to proceed past a key control point.

Amtrak submitted a block signal application seeking approval of the proposed modification of the automatic block signal system between New Haven, Connecticut and Cranston, Rhode Island. Approval was granted on October 28, 1992. This modification included the removal of the intermediate wayside signals in connection with the installation of a traffic control system and the expansion of the existing four aspect cab signals to include five additional aspects and speed control for high speed operation. However, this approval does not permit operation in excess of 110 miles per hour, and FRA expects to consider the matter of higher speeds in an appropriate public proceeding.

Currently all main tracks between New Haven, Connecticut and Boston, Massachusetts, 155 route miles and 338 track miles, have been signaled for reverse movement (bi-directional). This provides for flexibility for operating Amtrak, commuter, and freight services during construction, as well as increased traffic when high speed train operation is implemented.

The signal work is the first of two phases required to support 150 mph operation. The second phase will build on the first phase, by installing the additional equipment necessary for the operation and for upgrading the maximum speed to 150 mph. Three of the five new "high speed" interlockings have been placed in service, permitting 80 mph cross-over moves for the first time in the United States. Twenty diesel locomotives have been equipped with an interim 5 aspect cab signal featuring the additional speed command necessary to operate existing trains at 80 mph on these crossovers. This is an interim step until all locomotives and cab control cars can be equipped with the new 9-aspect cab signal and speed control system that Amtrak has developed.

Amtrak is developing the new system under the name "Advanced Civil Speed Enforcement System" (ACSES). It is designed to build on existing systems and to be compatible with application to electrified territory.

ACSES will use a carefully constructed blend of transponder scanning, radio, and microprocessor technology to meet specific needs of Amtrak's multiple-track, high-speed corridor. Prototype testing and final specification for procurement of the ACSES system will be completed in 1995.

ACSES will supplement the new continuous 9-aspect cab signal and speed control system by enforcing civil speeds at 5 mph increments up to 150 mph and by enforcing a *positive stop* at interlocking home signals where an overrun stop signal could compromise an adjacent high speed main track. It is being designed with an eye toward ultimately equipping the entire Northeast Corridor as well as the emerging high speed corridors throughout the country.

Both the 9-aspect cab signal and speed control system and the ACSES system will use proven, highly reliable technology to achieve Amtrak's and FRA's safety goals with the least possible impact on other railroad users of the Northeast Corridor. Both have been developed to accommodate the "incremental" or "building block" approach to upgrading the emerging high speed corridors in practical stages as funding is made available. The design ensures that each stage will contribute significantly to increased protection and to decreased trip times.

PTC Alternatives

Amtrak's ACSES--a signal-based ATC enforcement system--offers an effective PTC alternative to ATCS. The Florida East Coast Railway Co. (FEC), which operates a high-density railroad between Jacksonville and Miami, Florida, at freight speeds to 65 miles per hour, recently installed a modern ATC system that incorporates most PTC attributes (with the exception of direct data links to, or supplementary automatic protection for, roadway workers).

However, the Amtrak and FEC approaches, while cost effective in their particular operating environments, involve investments that are likely not sustainable over the national rail system. As such, they do not appear to be affordable alternatives to ATCS for much broader applications.

During roundtable discussions on PTC issues, and in discussions with suppliers, FRA developed information regarding alternative PTC concepts that might be no more costly, or less costly, than ATCS. Suppliers identified a variety of approaches, such as --

- Augmentation of existing signal systems with ATCS-compliant components that might communicate locally with an on-board computer;

- Use of range-finding technology with on-board computers to provide safety and facilitate flexible block lengths;

- Use of "spread spectrum" radio to track and manage trains on a very localized basis between signal system control points, potentially facilitating very short headways.

- Radio-based control that places all intelligence in the field, such that key route and traffic information is downloaded to the on-board computer for determination of movement authority, again providing for flexible blocks and short headways.

FRA is satisfied that a reasonably wide range of technologies could be employed with a high degree of effectiveness to achieve PTC. Selection of technology should rest with the railroad industry based upon all pertinent safety and non-safety requirements, cost, interoperability, and adaptability to changing requirements and technology.

AAR Strategic Planning

As FRA began the inquiry leading to this report, the AAR had in progress a strategic planning effort designed to determine the industry's course with respect to ATCS technologies, including positive train control. The timetable for that review had already been extended, and no resolution of any of the critical issues was expected prior to December 1994. At the request of the Federal Railroad Administrator, AAR accelerated its review of ATCS and provided briefings regarding preliminary findings to FRA at the final roundtable in late March 1994, with further refinement in early May 1994.

AAR believes that positive train control elements of ATCS must be supportable on their own merits if they are to be implemented. The AAR stated that the expected "business benefits" of ATCS are being achieved by "timely, more cost effective technologies." Example: implementation of work order reporting through use of "cellular-grid pad[20]" systems on Conrail, CSX Transportation, and the Southern Pacific Lines.

The AAR judged that developing technologies may in some cases be more cost effective than certain other ATCS features. For instance, the Class I railroads are developing a dynamic Automatic Equipment Identification (AEI) tag for use in offloading locomotive health data.

According to the AAR, other previously forecasted business benefits of ATCS exist, if at all, only in particular applications. Again, in many cases carriers are finding alternative means to achieve the same benefits. For instance, benefits associated with automatic train management and moving block could be realized only on those lines where capacity is at issue. Benefits associated with pole line elimination are being realized on some properties through use of reserved fiber optic capacity.

Speaking for the major freight railroads, the AAR continues to agree that "positive train separation" demands industry interoperability but notes that it has applications for transit, commuter and passenger rail operations, as well as freight. This raises the question of appropriate roles for the Federal Government, and State and local governments, as well as freight railroads and suppliers.

In summary, AAR stated that "positive train separation, if cost justified, will most probably be done on a carrier/corridor specific time table in phased increments."

The AAR committees studying ATCS also considered technical choices, risks associated with PTC, and cost and benefits (discussed in Chapter V, below); and they identified unresolved issues. The AAR noted that existing PTC systems such as Amtrak's ATC system are signal-

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[20]Commercial cellular telephone can be used either to send voice messages or data. A "grid pad" is a type of hand-help microcomputer that permits entry of data on a touch-sensitive screen. A "cellular grid pad" uses a commercial cellular radio telephone link to transmit the entered data.

based, very effective, and costly. Emerging communication-based PTC systems were projected to be less costly, equally safe, and capable of more applications (e.g., speed and capacity enhancements).

The AAR signaled new flexibility with respect to radio data paths, noting the availability of VHF, UHF, cellular, and spread spectrum options. Similarly, both transponders and GPS merited interest as location systems.

In reviewing the risks associated with PTC development and implementation, the AAR stated that software development and delivery risk was low to moderate, following verification of industry specifications. The AAR committees feared unstable requirements leading to cost overruns. Operating reliability was identified as a critical characteristic of any PTC system, both to serve the system's safety goals and to provide for operating efficiency.

As the major railroads continue to develop recommendations for the future direction of PTC, they will be attempting to identify a specific, flexible building-block approach that can be pursued by individual railroads according to available resources and operating requirements. The AAR suggested that the most likely migration path is as follows:

- Warning -- system warns of exceeding authority limits or speed limits and warns of approaching maintenance-of-way (MOW) work limits.

- Enforcement with existing signal systems -- positive train separation enforcement overlaid on existing systems with enforcement of authority, speed and MOW limits.

- Enforcement without existing signal systems -- adding wayside interface units and enhanced control software.

The preceding outline of a migration path is notably non-specific. It does, however, suggest a merging of existing signal system functions with PTC functions during the intermediate period before all advanced technology features associated with ATCS Level 40 are deployed.

This concept of "enforcement with signals" is relatively easy to imagine in the context of a traffic control system. Data regarding block occupancy and remote-control switch position, which is already received through nonvital paths and utilized to plan dispatching, would be provided by data communications link to the on-board computer, which would add train location information to determine enforcement parameters consistent with movement authorities communicated through the same data path. Very likely, these enforcement parameters (as opposed to the movement authority) would not be displayed to the engineer, since the quality of this data would be just slightly less than the quality of information provided by the vital signal circuits themselves. It would not be wise to invite the engineer to use this information to speculate regarding upcoming signal indications, etc.[21]

It is much less evident how the "enforcement with signals" option would work in automatic block territory (let alone dark territory). Presumably placement of WIUs would be necessary at key points, and the value of the enforcement system would be proportional to the comprehensiveness of WIU installation (e.g., at switches, wayside detectors, and signal houses).

As this report entered review, the AAR had once again reconstituted its committees addressing ATCS. In place of the "ATCS Steering Committee," a new "PTS Tactical Development Team" was appointed. The team will establish minimum requirements for PTS, define industry and individual railroad development responsibilities, develop a detailed migration path, define management structure for industry development ("if any"), address unresolved issues and report to the PTS Strategic Planning Committee. By November 1994, the Strategic Planning Committee is to report to the AAR Board of Directors with recommendations.

BN/UP Test Bed

The Union Pacific Railroad has put in place the most extensive ATCS communication infrastructure of any major railroad to support its work order reporting program. The Burlington Northern Railroad recently launched a major data radio network installation for pole line elimination, and BN's development of ARES provided the railroad with extensive knowledge of the challenges posed by communication-based PTC. Together, BN and UP are well situated to advance communication-based PTC.

On April 29, 1994, the two railroads announced a joint project to apply PTC to a large-scale test bed in the States of Oregon and Washington. The territory involved includes a north-south main line from the Canadian border at Blaine, Washington, through Seattle to Portland. (BN and UP share trackage between Tacoma and Portland.) Also included would be the carriers' parallel east-west main lines from Vancouver, Washington, to Pasco, Washington, on the BN and from Portland to Hinkle, Oregon, on the UP.[22] The territory comprises

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[21]The quality of an enforcement system of this type could never be greater than the quality of the signal and train control system whose data it utilized. For instance, in cab signal territory if a cut of cars rolled out of a siding onto the main in the next block ahead of an oncoming train, shunting the signal system, the train crew would immediately become aware of the obstruction and could begin to take preventive action. In traffic control territory without cab signals, this information would not be known until the train came within sight distance of the wayside signal.

[22]The railroads' initial announcement suggested that a BN branch line from Wishram, Washington, to Bend, Oregon, would also be included in the test bed. However, this line

over 700 miles of railroad. Most is governed by traffic control systems, with the remainder operated by track warrant control and automatic block signals. The two railroads have joint operations over 193 miles of this territory.

The railroads' electronic train monitoring and control system will be referred to as "PTS." The PTS system will be a central communication-based, enforcement technology integrated with existing signal systems (TCS, ABS). Although technical details were open as this report entered review, it appeared likely that both railroads would use GPS for location. However, UP planned to employ its UHF ATCS communications platform, while BN planned to use its VHF Rockwell data radio network. Thus, on-board units will be required to be equipped with dual-band transceivers.[23]

Over a decade after the North American railroads first sought to achieve a consistent approach to advanced train control, and more than 12 months after the BN allegedly terminated its competing ARES program, it is ironic that the first large-scale test bed for PTC will use GPS (ARES) train location technology. Further, it appears that UP and BN will address interoperability in the same basic way Amtrak has operated over disparate train control systems for some years (i.e., by equipping its locomotives with all systems and selecting the appropriate system upon entering a new equipped territory).[24]

Track Warrants by Digital Data

Even as PTC systems continue to be deployed, direct traffic control or "track warrant" operation will likely continue for some time over much of the national rail system, particularly on lines where density is low. To the extent digital data communication is available on these lines, railroads should develop software and establish procedures so that movement authorities are communicated by the CAD system directly to an on-board computer.

Issuing track warrants by data radio will result in significant advances in safety and significant reductions in voice radio congestion. Advances in safety will result from the secure means of transmission--errors that can arise as the dispatcher reads the authority aloud and the train crew attempts to hear and transcribe the authority will not arise. Since data communications are much more efficiently transmitted than voice, radio congestion will be

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was deleted based on minimal traffic levels.

[23]Interoperability could be achieved with contemporary electronics utilizing any number of radio frequencies; however, there are penalties in cost and complexity that must be overcome. The penalties increase where more than one communications software package is used, as will be the case with the BN and UP systems.

[24]This is a greatly simplified view, and optimistically the two railroads will develop technical approaches that make transitions relatively transparent from the point of view of safety objectives, while holding down costs.