reduced. Further, advances in technology should make it possible to provide onboard printing of movement authorities, both for immediate use in operating the train and as a subsequent record of information received.

FRA believes that, over the next year, one or more railroads using data radio communications from train to central office will launch an experiment involving transmittal of track warrants by this means. FRA will assist any such an effort by working with the railroad's rules officers to ensure proper consideration of sound operating procedures.

CHAPTER V

Benefits and Costs of Positive Train Control

The immediate future of PTC implementation is, as suggested by the mandate for this study, tied closely to the progress of ATCS. As described in the previous chapter, ATCS is a system of technologies covering a broad range of railroad functions.

The benefits of ATCS to any railroad will depend upon which functional elements are chosen for implementation, how implementation is carried out, how the capabilities of ATCS are used, and the extent to which alternate means may have been elected to achieve the same benefits. Fuel and labor savings, safety, and improved equipment utilization are examples of tangible benefits--expenses are reduced or capital outlays are avoided. ATCS would also generate detailed information about railroad operations which could be used to improve service quality.

The safety features of ATCS address (1) collision prevention, (2) speed control, and (3) protection of roadway workers and their on-track equipment--the central objectives of PTC as described in this report. The AAR has begun to refer to technology designed to achieve these objectives as "positive train separation."[25]

During the development of this report, the major railroad companies have contended that, from the point of view of public policy development, there is no merit to consideration of nonsafety benefits of advanced communications technology that might be realized in connection with PTC investments. At the end of the chapter, FRA examines the value and limitations of that perspective.

Safety Benefits and Costs: AAR Positive Train Separation

Analysis of accident/incident data shows that virtually all collisions and overspeed accidents preventable by PTC result from human factors. This is not surprising, since by definition the area of inquiry is one for which the final margin of safety is presently provided by the human operator; and, after many decades of development, existing signal and train control

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[25]The full significance of this new name was not clear as this report was prepared. Certainly using "positive train separation" to refer to PTC attributes of new technology properly distinguishes train control from other systems. However, as indicated by the innovations included in the UP/BN pilot project, use of the term may also indicate that the major railroad companies view the ATCS specifications as only one of the available paths toward achievement of train control objectives.

hardware is extremely reliable. In reviewing options for what the industry now calls "positive train separation," the AAR and its committees have assumed that the technology deployed under that rubric would be fully competent to achieve all PTC objectives--or very nearly so.

Appendix 1 shows major train accidents which would have been preventable through the use of PTC. PTC systems could virtually eliminate these types of accidents, as well as events of lesser magnitude that occur with somewhat greater frequency.

In order to quantify the potential benefits from PTC, representatives from FRA, AAR and rail labor reviewed accident data from the period 1988 through the first eight months of 1993 (5.67 years). All reportable[26] collisions and overspeed derailments (there were 220 such accidents during the study period) were examined to determine the extent to which each would have been prevented by PTC. After several discussions as to the principles which should be applied to determine whether PTC would have prevented particular accidents, the FRA, AAR and rail labor reached basic agreement on a list of 116 accidents that all participants agreed would have been prevented with a PTC system.

The 116 accidents included 35 derailments, 21 head-on collisions, 39 rear-end collisions, 15 side collisions, and 6 other accidents that, after examination of the individual accident report, were judged to have been preventable by PTC. These accidents resulted in 420 injuries, 30 fatalities, and $70 million in reported railroad property damage.

The prevention of these types of accidents in the future is the potential safety benefit of PTC. Assigning a dollar value to these potential benefits involves both estimation and judgment, and different selections will produce a range of answers. Depending on the estimates used and judgment employed, the potential benefits range between about $27 million and $53 million annually.

The key factors in determining the high and low estimates are (1) the extent to which it is estimated that the elements of property damage required to be reported by the railroad companies underrepresent total adverse economic impacts, and (2) the monetary values assigned to the avoidance of casualties and fatalities. Railroad property damage required to be reported by the railroad companies does not include loss of lading, wreck clearance, environmental clean-up, and incidental costs (delay of operations resulting in extra train crew costs, etc.), therefore a reasonable adjustment factor is useful to avoid undervaluing accident avoidance. Assigning monetary value to fatality and injury avoidance is necessary as a tool in benefit/cost analysis in order to examine alternative uses of public or private funds fairly.

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[26] "Reportable" accidents are those which result in damage above the FRA reporting threshold. The current threshold is $6300. Collisions and overspeed derailments which resulted in less than $6300 in railroad property damage would not have been reported to FRA and are not included in this analysis.

Below are three estimates of the annual potential benefits of PTC based on the 116 preventable accidents referred to above. The lowest estimate, $26.6 million per year, was produced by the AAR and represents their best estimate of the likely annual benefits of PTC. The highest estimate, $52.9 million per year, was AAR's highest estimate, and represents very liberal assumptions as to both the extent of underreporting and the monetary value of casualties. The estimate in between was produced by FRA using the agreed-upon underlying data, but applying the values for avoided fatalities that FRA usually uses in its regulatory analysis of proposed safety regulations.

The calculations for each of the three estimates are shown in Table V-1:

Table V-1

ESTIMATED BENEFITS OF POSITIVE TRAIN CONTROL

ESTIMATE 1 (LOW) (AAR)		
Reported Property Damage (5.67 years)	$70.0m	
Additional Damage (56.25% of above)[27]	$39.4m	
FELA[28]	$40.8m	

	$150.2m	($26.6/yr)
ESTIMATE 2 (FRA)		
Reported Property Damage (5.67 years)	$70.0m	
Additional Damage (56.25% of above)	$39.4m	
Injuries (420 at $20,000 each)[29]	$ 8.4m	
Fatalities (30 at $2.6m each)[30]	$78.0m	

	$195.8m	($34.5m/yr)
ESTIMATE 3 (HIGH) (AAR)		
Reported Property Damage (5.67 years)	$70.0m	
Additional Damage (100% of above)	$70.0m	
Casualty Costs (Equal to ALL damages)	$140.0m	

	$280.0m	
Round up	$300.0m	($52.9m/yr)

Note: Comparable figures for the North American rail system including Canada are slightly higher (cf. Table V-2).

[27] The damages currently reported to FRA do not include loss of lading, wreck clearance, or environmental cleanup. AAR surveyed its members and reports that, on average, these other costs constitute an additional 56.25 percent of the reported damages.

[28] AAR's estimate of casualty costs stated in terms of Federal Employers Liability Act recoveries.

[29] $20,000 is the value used by FRA to represent the amount society would be willing to pay to avoid an average injury to a railroad employee.

[30] FRA uses $2.6m as the amount society is willing to pay to avoid a fatality to a railroad employee.

AAR Cost/Benefit Analysis

Responding to FRA's request that ATCS planning be expedited, an AAR committee considered the cost implications of major technical options for PTC. In April 1994, AAR prepared a cost/benefit analysis of requiring U.S. and Canadian Class I railroads to install PTC.[31] The AAR's analysis did not quantify nonsafety or "business" benefits to be derived from such systems. Instead, the AAR estimated the costs and safety benefits to be derived from a "safety only," government-required PTC system.

The AAR's analysis assumed a U.S.-Canadian system of 149,000 route miles (85,700 miles equipped with TSC/ABS and 63,300 miles dark territory). The AAR analyzed three system architectures: (1) signal control-based, (2) field control/communication-based, and (3) central control/communication-based.

PTC investment cost estimates for each of these architectures is shown in Table V-2. Signal control-based PTC was viewed as the most expensive approach, with an estimated investment cost of over $2 billion.[32] Field communication-based PTC was estimated to exceed $1.2 billion in cost.[33] The AAR estimated central communications-based PTC to be the least costly.

Signal control-based PTC systems are used in this country by Amtrak (e.g., as planned for the north end of the Northeast Corridor) and in European countries. Signal control systems are extremely effective in safety-related PTC. The AAR estimates signal control-based system investment costs for Class I railroads to be $2.1 billion, a figure well below previous estimates for automatic train control systems, but still well above other alternatives. No annual maintenance expenses were estimated for this option. Signal control-based systems are only capable of routing and protecting trains. There are presently few business benefits that would justify the freight railroad industry's investment in this type of PTC.

The two remaining PTC architectures are field control communication and central control communication. Communication-based systems are less costly than signal-based systems and potentially offer safety and PTC attributes that are equal to signal-based systems.

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[31] Railroad classifications are established by the Interstate Commerce Commission are based on indexed operating revenue levels. Effective January 1, 1992, a Class I railroad has operating revenues equal to or exceeding $250 million; a Class II railroad has operating revenues of less than $250 million but in excess of $20 million; and a Class III railroad has operating revenues of $20 million or less. By Commission definition, all "switching and terminal" railroads are classified as Class III, regardless of operating revenue levels.

[32]It was not clear from the AAR presentation what type of technology was contemplated.

[33]Again, the AAR did not specify what technologies were deemed least expensive.

Communication-based systems (particularly those involving central office functions) are also capable of far more applications than PTC, many with economic benefits to railroads.

In evaluating communication-based systems AAR made the following assumptions:

(1) The installation of specialized on board computers and communication equipment in 15,335, of 20,289 locomotives--about 76 percent of the U.S.-Canadian Class I fleet;

(2) A transponder train location system; and

(3) A communication system utilizing UHF (900 MHz) technology.

The two communication-based systems can be constructed under three levels of PTC--"warning," "enforcement with signals," and "enforcement without signals." Depending on which level of PTC is selected, the AAR estimates field communication-based system investment costs of Class I railroads for a safety-only system to range from $1.2 billion to $1.5 billion for initial hardware and start-up costs. No annual maintenance expenses were estimated for this option.

According to the AAR, the least costly of the PTC architectures is central communication based. The cost of a safety-only PTC central communication-based system for all Class I railroads range from $843 million to $1.137 billion for initial hardware and start-up costs.[34] On a per route mile basis, the initial hardware and start-up costs would range from $5,660 - $7,630. Annual maintenance expenditures for this system are estimated to range from $176 million to $236 million ($1,200 - $1,600 per route mile).

By comparison, U.S. Class I railroads reported $28.8 billion in revenue, $4.3 billion in net revenue from operations, and $2.5 billion in net railway operating income in 1993.

The AAR's study estimated the safety benefits of PTC using the data evaluated by AAR, rail labor, and FRA, and adjusted to consider Canadian exposure. Depending on which of the three PTC scenarios was adopted, the U.S.-Canadian Class I railroads would reduce up to 23 accidents, lower injuries and fatalities by up to 83 and 7, respectively, and reduce payouts due to PTC-preventable accidents by up to $30 million. A synopsis of this data is presented in Table V-3 (on page 65).

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[34]Based upon the break-down of costs discussed with the AAR, it appears that the less costly central communications-based systems would utilize data from existing signal systems, where available. Depreciation or maintenance of those existing systems is not included in the AAR cost estimates.

Business Case Benefits

As reflected in this report, ATCS offers significant potential business benefits to railroads with pertinent needs not otherwise addressed through alternative technology. These include fuel savings, better utilization of track and equipment (such as work order reporting, locomotive health monitoring, and traffic control), reduced wear on track and equipment, on-board hot bearing detection, car/trip scheduling, more precise scheduling of employee deployment, reduced job stress for train dispatchers, and better service for customers (such as more reliable schedules and decreased transit time). All of these potential benefits offer possibilities for additional cost savings and managerial efficiency through increased network intelligence and enhanced information flows.

AAR and the freight railroad companies' strong message to FRA during the process of consultation leading to this report is that "business case" benefits of ATCS cannot be estimated at the national industry level. Therefore, they reason, these benefits should not be credited in the overall benefit/cost computation for PTC, and that this computation should focus on the safety improvements expected alone.

AAR and the freight railroads state first that the business benefits of ATCS are rapidly being implemented with separate, need-specific systems. For example, pole line elimination can take place without ATCS if a railroad has granted use of its right-of-way for fiber optic cable and has reserved for itself a certain amount of the cable's communications capacity; similarly, a railroad will not need a work order reporting system if it is able to determine car location and status through cellular telephone data links. This type of technology substitution is becoming widespread.

Secondy, they contend that different railroads will realize different levels of benefits (and costs) from ATCS. A finding that railroads will benefit by a certain amount "on average" would mean very little to the individual companies because railroads differ significantly in their operating structure, facilities, business requirements, markets, and profitability. For example, the capacity-increasing potential of ATCS would prove profitable to those railroads adding second main tracks or additional passing sidings, but would have no value to the major western railroad removing its second main track over a major route. In addition, railroads vary in their capacity to make investments in new technology.

The railroads have been analyzing the benefits of ATCS since first developing the concept, and found that those benefits were difficult to predict even on specific railroads. The Burlington Northern (BN) stated that its ARES project (described in Chapter 4) promised "improved service, with higher revenue potential, and cost reductions [and] the elimination of train accidents caused by violations of movement authority." However, BN's consultants (SDG) concluded that "the potential benefit of ARES is large but highly uncertain. . . . The benefits depend greatly on implementation success: The system design must be sound, a strong implementation plan must be developed, and functional groups across the BN system must be committed to using it to full advantage." As previously stated, BN decided not to continue with the project, primarily because the benefits were so uncertain.[35]

Accordingly, to determine the extent to which PTC should be implemented--whether through the voluntary action of a railroad or a Federal mandate--consideration must be given to each specific application. Although incidental business benefits should be taken into consideration, nonsafety benefits must not be assumed in a speculative way.

In the long term, the development of an integrated and interoperable communications network such as ATCS, which will produce safety benefits, is likely. Commercial needs are growing; high quality service is essential to market growth in many sectors, as shippers increasingly demand precision with respect to both pick up and delivery schedules. The rapid increase in intermodal service using containers, trailers, and other intermodal options places a premium on higher average train speeds, which requires better use of plant capacity and increasingly competent signal systems (as reflected by continuing investments in new traffic control systems on high density routes). As service requirements become more demanding on railroad plant, equipment, and personnel, the business benefits of flexible, interoperable, communication-based PTC should become more evident and more readily quantifiable.

Just as the freight railroad industry's need for competent and flexible communications is growing, so too is the industry's use of cutting-edge communications technology. Freight railroads are sharing traffic data with their shippers and one another using electronic data interchange (EDI). They are tracking rail cars over their main lines using AEI; and, with cooperation from trucking and maritime interests, similar tracking of containers and trailers is possible. In 1992, the rail industry launched an effort to bring all of these systems together. Known as interline service management (ISM™), this undertaking is to develop and foster the implementation of business processes and supporting information systems that will allow interlining carriers to provide reliable, competitive, seamless service. Communication-based PTC systems should fit well with that series of initiatives.

Public sector benefits can also be expected from the implementation of interoperable PTC. Rail commuter service is a growth industry due to the saturation of urban highways and the high cost of heavy rail transit starts. Enhanced PTC systems can help reduce the cost and improve the quality of commuter rail expansion. With Amtrak's Northeast Corridor service leading the way, high speed passenger service has emerged as a favored planning option for certain congested corridors among major U.S. cities. Highly capable, interoperable PTC systems can provide necessary safety features while holding down costs associated with mixed freight and high speed passenger service.

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[35] Burlington Northern: The ARES Decision (A), Copyright 1991 by the President and Fellows of Harvard College. Report 9-191-122, dated 2/21/91.

To the extent PTC is deployed over major freight routes used by Amtrak, conventional passenger service reliability might increase, and in some cases trip times might be improved (though speed is generally not a major competitive issue for Amtrak service outside of high-speed corridors).

Additional impetus for concerted railroad industry action will come from external forces. The Intelligent Vehicle Highway System (IVHS), now under development through the leadership of the Federal Highway Administration, promises a plethora of technologies, some of which may have direct implications for the railroad industry. For instance, should IVHS offer innovative approaches to enhance safety at highway-rail crossings, the need for a new communications interface could be presented at 170,000 public crossings nationwide. Should the railroad companies find it necessary to respond individually to this challenge, the cost implications of PTC would likely pale by comparison.

The basic thrust of the AAR/RAC ATCS program has not been rendered obsolete; however, technological opportunities and business demands have grown at a faster pace than ATCS planning had proceeded. The need remains for an accelerated, industry-level effort to integrate telecommunications systems, guiding investments in technology by ensuring the forward compatibility of software and interoperability of related systems.

Analysis

The AAR and major railroads are justified in insisting that the PTC debate include a clear focus on safety costs and benefits. However, the architecture identified by AAR as least costly for safety purposes (central communication-based) is also the architecture most likely to yield nonsafety benefits. Should ATCS architecture prove insufficiently flexible to meet emerging needs, railroads will find ways to lend it new flexibility. That is already happening in the BN/UP positive train separation project. It is imperative that such efforts be coordinated at a wider industry level in order to ensure maximum efficiency and thus promote broader application.

Previous rail industry technological advances produced benefits that were also difficult to estimate; the benefits of dieselization far exceeded predictions. FRA believes that the benefits of a central communications system--or flexible networks capable of functioning as a single system--can be expected to exceed the modest expectations of those advocating individual subsystems. Investments in safety and efficiency can produce synergies that result in unexpectedly high returns.

As indicated previously, the application of PTC to all rail lines has not been shown to be cost beneficial at present based on safety alone. Business advantages to the railroad industry from such universal implementation can be expected, but the specific extent and nature of such advantages will differ greatly, depending on the particular circumstances. In the final chapter, the report considers whether, and under what conditions, individual line segments should be considered ripe for PTC implementation.

Table V-2

Estimated Investment Costs
Positive Train Control
Signal Control-Based Versus Communication-Based
Class I Railroads--United States and Canada

(Dollars in Millions)

SIGNAL CONTROL BASED			
SIGNAL CONTROL-BASED		$ 2,064	
COMMUNICATION BASED	**WARNING**	**ENFORCEMENT WITH SIGNALS**	**ENFORCEMENT WITHOUT SIGNALS**
FIELD COMMUNICATION-BASED	$ 1,196	$ 1,212	$ 1,490
CENTRAL COMMUNICATION-BASED	$ 843	$ 859	$ 1,137

Source: Association of American Railroads ***Interim Report of Railroad Industry ATCS Strategic Planning Committee***, April 1994.

Note: Figures vary slightly from those in the narrative because Canadian railroads are included.

Table V-3

Estimated Cost and Benefits of
Central Communication-Based Positive Train Control
Class I Railroads -- United States and Canada
(Dollars in Millions)

COSTS[36]	WARNING	ENFORCEMENT WITH SIGNALS	ENFORCEMENT WITHOUT SIGNALS
One-Time Costs			
Railroad Industry	$ 30	$ 50	$ 50
Individual Railroads	803	809	1,087
Total One-Time Costs	$ 843	$ 859	$ 1,137
Annual Operating Costs[37]			
Individual Railroads	$ 176	$ 180	$ 236
BENEFITS (Annual)			
Monetary Savings	$ 23 [38]	$ 30	$ 30
Reduction of Accidents	14 [37]	23	23
Reduction in Injuries	65 [37]	83	83
Reduction of Fatalities	6 [37]	7	7

Source: Association of American Railroads ***Interim Report of Railroad Industry ATCS Strategic Planning Committee***, April 1994.

[36] All costs have been identified on an industry-wide basis. Individual railroads were not analyzed--too carrier specific and variable in application.

[37] Includes amortized capital expense and annual maintenance.

[38] Maximum annual benefits. True experience may be less due to crew inaction following warning.

CHAPTER VI

Conclusions and Future Actions

Railroad communication systems and signal and train control systems serve important safety purposes while playing a critical role in the efficiency of railroad operations. The safety relationships between the two systems have been addressed through railroad operating rules, supplemented by Federal radio standards and procedures. Working together, today's signal systems, voice radio communication, and railroad operating rules provide for good safety performance and low safety risk.

Further reductions in risk can be achieved with PTC systems. PTC systems with enhanced features can also increase rail system capacity, facilitate the growth of high speed passenger service and commuter service, and help position freight railroads to compete and form additional partnerships in an intermodal marketplace. As the railroad companies are making investments that will permit full PTC capabilities, opportunities should be exploited to use data communication paths to transmit critical movement authorities, in lieu of voice radio.

Even as technology becomes more sophisticated, however, investment should be scaled to safety need and, secondarily, other business requirements. Federal regulations and railroad rules should maintain a clear focus on the functional requirements that communication and control systems are intended to fufill. Where technology of lesser cost will do as well as more sophisticated and costly technology, suitable flexibility should be provided.

Based on this study and its findings, FRA will take the following actions, detailed later in this chapter:

- Revise radio operating rules to be more flexible and to include requirements regarding the presence of radios as safety equipment.

- Seek to test transmission of orders via digital data radio in place of voice radio on a major railroad.

- Identify high-risk rail corridors which may warrant mandatory PTC application.

- Maintain an interest in all ongoing tests of PTC-related technology, and include PTC technology in the Next Generation High Speed Rail Program.

- Promote continued effort by the AAR to ensure compatibility and interoperability in specifications for PTC systems.

- Establish as a priority agency objective the deployment of PTC technolgy on major high-risk rail corridors by the year 2000.

RESPONSE TO CONGRESSIONAL MANDATE

In addition to reviewing the broader issues of railroad communications and train control, section 11 of the RSERA required the Secretary to assess specific issues related to railroad radio standards and procedures.

> ***"(1) the advantages and disadvantages of requiring that every locomotive (and every caboose, where applicable) be equipped with a railroad voice communications system capable of permitting a person in the locomotive (or caboose) to engage in clear two-way communications with persons on following and leading trains and with train dispatchers located at railroad stations...."***

Current practice among major railroads provides for equipping lead locomotives with all-channel radios (generally with transmitters rated at 35 watts and equipped with an effective externally-mounted antenna which is necessary both for effective tranmission and reception).[38] Radio communications are established between trains and the dispatching center. The quality and reliability of this communications link is important to ensure that movement authorities are clearly understood (if applicable), to provide a means of requesting emergency assistance in the event of an accident, to provide a means of transmitting and receiving emergency and security warnings, and to ensure receipt of messages from wayside detectors (particularly in non-signal territory).

The lead locomotive of any consist should be so equipped upon departure from a terminal. If the radio should fail en route, a standby radio or radio in another locomotive (or an alternative means of communication, such as a work order station or cellular phone) would be important to provide an emergency communications link from the train to the dispatch center. Reasonable provision should also be made for the crew to receive warnings of unsafe conditions that might affect the operation of the train.

On balance, there is no supportable safety rationale for requiring train-to-train communications if an effective link exists from each train to a operational dispatching office. Currently, locomotive radios and retransmission facilities are not designed to ensure train-to-train communications for extended distances. It is true that train crews listen for and to other train communications avidly; however, train crews do not receive track warrants or signal indications from one another. They should not be engaged in casually passing information that, if relied upon, could cause them to operate in excess of their authority. A

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[38]Cabooses are rapidly disappearing from service, but where used they are generally equipped with 25- or 35-watt radios. This would appear to be prudent to ensure good front-to-rear and dispatcher-to-caboose communications.

major danger in this regard is that train crews of following trains will rely upon voice radio communications rather than observe rules for restricted speed.

When train crews become aware of developing safety or security concerns, that information may be passed through the dispatcher to other train crews. To the extent there is insufficient time for an emergency message to be passed through the dispatcher, in the great majority of cases train-to-train communication will be available over the short distances involved as an adjunct to train-to-dispatcher communication capability.

It should be emphasized that railroad operating rules, rather than any communications system, provide the first line of defense for the integrity of movement authorities. While many territories trains are "run by radio," it would never be proper to create a trap in which safety of operations depends on the ability to reach a train to cut short its previously granted movement authority. Rather, orders may be issued only if not in conflict with orders previously issued and still in effect. If it becomes expedient to change orders, all prior orders must be canceled prior to issuing fresh orders that might in any way conflict with previous orders.

"(2) a requirement that radios be made available at intermediate terminals...."

This requirement would provide replacement radios for trains whose radios fail en route, so that crews not be required to operate without a functioning locomotive radio unnecessarily. As stated above, each train should be equipped with an operating radio. Should the voice radio of the lead locomotive fail, several factors should be considered:

- What other communications capability is available to the crew? (Operative radio in trailing locomotive, on-board work order computer, cellular telephone, portable low-power radios, etc.)

- What is the length of haul to the train's final terminal or other known repair point?

- What work will the crew perform along the way? (Switching may be performed using only low-power portable radios ("handitalkies"), but total absence of radio communication may render the work too hazardous, including unplanned switching to set out defective equipment.)

Railroads should have in place communications plans that consider the safety communications requirements outlined above and that address these concerns, ensuring appropriate redundancy.

"(3) the effectiveness of radios in ensuring timely emergency response...."

Information available does not provide a basis on which to quantify the extent of reliance on radio communications to summon aid in emergencies. However, FRA is aware that railroad dispatching centers maintain extensive listings of emergency responders in all of the jurisdictions through which railroads operate. Further, given the vast distances over which railroads operate, radios very frequently offer the only immediate means of summoning assistance.

In most cases, FRA and NTSB reports reflect that radios function as intended following serious accidents. However, when that is not the case, critical delays can ensue. Railroads should include communications strategies in their emergency preparedness plans; in most cases, those strategies will require heavy dependence on voice radios.

"(4) the effect of interference and other disruptions of radio communications on safe railroad operations..."

In FRA's field review of railroad radio communications and train dispatching offices, FRA determined that improvements in radio technology have improved the clarity of voice communications. However, FRA continues to view with concern the extent to which congestion of dispatcher frequencies disrupts normal dispatching functions, including communication of track warrants and other authorities. Although Federal and carrier rules prohibit acting upon authorities that are not complete, well-disciplined communication is necessary to ensure proper delivery and receipt of movement authorities.

Interference with communications on channels assigned for switching in yards, terminals or intermediate points, whether as a result of improper use of adjacent channels or congestion, is a particular concern. Every year railroad employees die while conducting switching movements, and factors related to communications are often at issue in the ensuing investigations. Good radio discipline by all railroad employees and careful control of technical factors (e.g., coverage overlaps and adjacent channel interference) are essential to safe switching operations.

"(5) how advanced communications technologies such as digital radio can be implemented to best enhance the safety of railroad operations...."

Digital data radio as a part of a central communications platform can serve as a highly competent element of a PTC system. The UP/BN test bed will evaluate this potential further.

Prior to the full implementation of PTC, digital data radio can be used to transmit movement authorities to trains directly from the Computer-Aided Dispatching (CAD) system in a much more secure manner than is possible using voice radio. FRA believes that digital radio will be employed to transmit track warrants on a major railroad within the next year, and FRA will work with that railroad to ensure the success of the project.

"(6) the status of advanced train control systems that are being developed, and the implications of such systems for effective railroad communications....

AAR ATCS specifications are well suited to achieving the safety objectives of positive train control. Independent modeling and validation of the control flow specifications and demonstration of ATCS in one or more test-bed applications are recommended. In addition to supporting PTC, technology such as ATCS will reduce capacity demands on voice frequencies, further improving emergency and other radio traffic flows (see Chapter IV).

"(7) the need for Federal standards to ensure that [ATCS] systems provide for positive train separation and are compatible nationwide ...."

PTC technology can prevent train accidents, including train accidents of the type most likely to result in employee or passenger fatalities. PTC technology can also enhance protection provided to roadway workers performing their duties under specific authorities.

Under applicable executive orders, Federal regulations may be issued only when they are required by law or where it is determined that the benefits achieved outweigh the costs. As illustrated by the data presented in Chapter V, the safety benefits of PTC are substantial, but the costs of applying current technology to all rail lines are far greater. As further discussed below, a number of options exist to hasten the implementation of PTC.

Requiring that PTC be implemented *universally* across the national system at the present time could result in a misallocation of national resources. There is no guarantee that the overall safety of the American people would benefit from such a requirement, since one likely outcome would be diversion of large quantities of freight to other means of transportation, with adverse safety impacts for the transportation system as a whole. Another likely outcome would be diminished railroad investment in track and rolling stock, increasing the risk of train accidents from other causes.

Application of PTC to freight railroads will require determining which categories of operations have risk characteristics that warrant early PTC implementation.[39] Modification of existing signal and train control regulations to require PTC implementation on those lines will then be appropriate. To the extent the business benefits of PTC and related technology become more evident or implementation costs fall, gradual extension to other segments of the freight railroad industry might be warranted.

PTC is clearly necessary in the context of high speed rail, as illustrated by Amtrak's modifications to an existing ATC system for high speed operations on the Northeast Corridor. Expansion of high speed rail to other mixed service corridors will require making PTC more affordable. This, in turn, will require that the PTC system be fully interoperable

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[39]The President's Budget for FY 1995 requests funding for this purpose ("corridor risk analysis model").

with PTC systems adopted by freight railroads. Full interoperability will ensure the highest level of safety, since all movements over lines used for high speed service will be equipped to respond to the PTC system.

REQUIREMENTS FOR COMMUNICATIONS AND TRAIN CONTROL SYSTEMS

One major goal of this report is to identify the particular communications and ATCS technologies best suited to fulfill particular operating safety requirements. These requirements include:

<u>Requirement No. 1</u>: **Communicate train movement authorities from dispatcher to train.**

<u>Risk</u>: Introduction of inaccuracies.

<u>Redundancy</u>: Total failure of a delivery system does not create immediate hazard due to limitations contained in the operating rules, but poor functioning of a system may result in a garbled message. The failsafe condition is assurance that incomplete or garbled messages are not acted upon. Only selections 1 and 2 meet this requirement with a high degree of confidence.

<u>Selection</u>:

1. Traffic control system with CAD or PTC.
2. Digital data with CAD.
3. Voice radio.

<u>Requirement No. 2</u>: **Enforce train movement authorities and operating restrictions.**

<u>Risk(s)</u>: Collision, overspeed derailment, impact with roadway workers or their equipment.

<u>Redundancy</u>: This requirement is itself a redundant feature. Should PTC fail, operating rules should provide appropriate restrictions (e.g., limit train speeds).

<u>Selection</u>: PTC technology.

Requirement No. 3: **Communicate emergency warnings (train to dispatcher and reverse).**

Risk: Known hazards will not be communicated in time to prevent harm.

Redundancy: Requirement is intermittent and relatively rare. A redundant means of communicating would be desirable should the primary means fail.

Selection:
1. Voice radio or cellular telephone (preferred due to flexibility of medium).
2. Digital data radio, PTC technology (where pertinent).

Requirement No. 4: **Receive wayside detector readings.**

Risk: Wayside detector warning will be missed or disregarded, resulting in train accident.

Redundancy: None is currently provided in most systems, but at least one level of redundancy is desirable.

Selection: More information is required; however, digital data radio with continuous PTC enforcement appears desirable. Current warning systems will continue to serve valuable purposes, however, without those enhancements.

Requirement No. 5: **Communicate between locomotive engineer and ground person to control switching.**

Risk: Incomplete or garbled transmission or failure to maintain continuous communication may result in serious personal injury or death.

Redundancy: Hand signals and lanterns are no longer viable alternatives to radio for many switching moves, particularly given reductions in crew size and increases in car lengths and heights that restrict vision of crew members on the ground. Federal radio rules and carrier operating rules require immediate cessation of switching move if radio contact is lost. Where switching is required, back-up portable radio (or duplicative circuitry) may be warranted; or operating rules should place limits on switching conducted.

Selection: Voice radio.

Requirement No. 6: **Emergency requests (call for help following crossing accident, train accident, personal injury to crew member or in the event of release of hazardous material through valves or fittings).**

Risk: Inability to summon aid.

Redundancy: Need is intermittent and infrequent, but urgent. A second radio on another locomotive in the consist should provide adequate redundancy. A cellular phone within its coverage area should also be adequate.

Selection:

1. Voice radio or cellular telephone.
2. Data radio terminal with keypad or other means of flexible communication.

Signal and train control systems address additional requirements through vital circuits. For instance, signal systems automatically perform the following functions and display appropriate signal indications to trains --

- Detect and communicate track occupancy, spacing trains;
- Monitor switch position;
- Verify route integrity;
- Indicate wayside detector status; and
- Assist in detecting broken rails.[40]

Properly configured and augmented, central communication-based PTC is also capable of performing these functions or their equivalent.

The discussion above illustrates the fact that the safety of railroad operations currently depends upon a mix of communication and train control capabilities. Even under the optimum case in which all requirements stated above are met with the desired level of redundancy, more than a single type of technology will likely be necessary.

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[40]It is estimated that roughly half of all broken rails in signal territory may be detected through the signal system.

VOICE RADIO COMMUNICATIONS

The major railroads have invested heavily in traditional communications and S&TC technologies. Voice radio systems are widely deployed on all major railroads. All-channel capability is the norm, dead spots along the railroad are far fewer than in prior years, and crew members are provided with portable radios to facilitate switching operations. Radios are more reliable than ever before, and increasingly capable technology permits automatic prioritization of emergency calls.

Yet some railroads continue to permit the misuse of available channels, resulting in excessive congestion and interruptions of safety-related communications. Radio discipline remains poor on many railroad divisions, increasing the likelihood that misspoken or misunderstood directives will lead to an accident. Further, while generally acting in the interest of safety by investing in communications technology, railroads continue to deny that voice radio communications are important for safety. Instances continue to occur where trains are dispatched without operative locomotive radios (at least in the lead unit). Though generally small, gaps remain in the application of state-of-the-art voice radio technology.

Federal radio standards and procedures have stood unreviewed for many years, and railroad officers contend that they are inflexible, leading to disrespect and poor compliance. Although the basis of widespread noncompliance with sound radio procedures (including carrier rules) is subject to dispute, Federal safety standards should not be an impediment to sound practice; and their review is overdue.

Future directions in Federal regulatory policy should be guided by a clear understanding of functional requirements, levels of risk, and levels of redundancy of existing and planned communications systems. Regulatory activity should be directed at closing gaps and improving the performance of existing communication systems, while avoiding unnecessary burdens. For instance, FRA should propose that railroads be required to develop communications plans that address safety communication needs and implement them. Technology must not be required simply because it is available, but only when it is needed. Many smaller railroads may be able to meet their communication needs using portable low-power radios and cellular telephones. Major railroads may require more sophisticated systems, including data radio and appropriate provisions for redundant communications capability on long-distance trains. Through a cooperatively developed rulemaking, a safety minimum can be established for such plans.

Future Actions

As a result of the findings of this study, FRA will--

- ***Revise the Radio Standards and Procedures to make the regulations more flexible and to promote improved compliance.***

  - Work with representatives of labor and management to identify those aspects of the current rules that may discourage compliance because they lack flexibility.

  - Revise the regulations through a public proceeding.

  - Seek commitments from employee representatives and company officers to work for improved compliance with radio rules under revised standards.

  - Monitor compliance and strictly enforce the rules.

- ***Include in the proposed rule requirements that railroads provide suitable communications capabilities between trains and dispatchers, and between locomotive engineers and ground employees, and that back-up systems be established for critical functions.***

  - Propose that railroads develop and implement communication plans that address all safety-relevant functions.

  - Consider use of a wide range of technologies, including commercial options such as cellular telephone.

  - Review the number of layers of safety required for specific functions, considering the importance of the function to safety, the extent of daily reliance on the function, and the cost of the protection.

  - Recognize distinctions among rail passenger and freight operators and different operating environments, regarding the communications technologies that may be acceptable for primary reliance and the depth of safety redundancy warranted.

- ***Propose as a part of that rulemaking that each lead locomotive be equipped with an operative radio or suitable alternate communication equipment.***

- ***Work with a major railroad and its employees to implement transmission of movement authorities by digital data radio, in lieu of voice radio communications.***

  - Ensure that movement authorities are generated by the CAD system and issued directly to the on-board terminal.

  - Review changes in operating rules.

- Determine the most effective and secure means of providing hard copy authorities to crew members without transcription errors. Include an evaluation of on-board printers.

- Determine the feasibility of transferring concept to railroads employing other types of data communication technology.

POSITIVE TRAIN CONTROL

Signal and train control systems continue to serve the railroad industry with a high degree of reliability and enviable failsafe characteristics. Positive train control is the logical extension of those S&TC systems that do not yet provide PTC features. The railroad companies are beginning to recognize the opportunities presented by integration of data radio communications platforms and existing signal systems. Approximately half of the national rail system is not signalized, and this "dark territory" is particularly in need of supplementary safety systems.

Railroads recognize the need to move in the direction of positive train control, but, with limited exceptions, have not considered the necessary investments justified. For the near future at least, safety benefits will have to be accompanied by "business" benefits for PTC investments to make business sense for widespread application to freight lines.

The promise of ATCS has thus far failed to emerge--ironically, not because the railroad companies have clung to old ways, but because the railroads have moved ahead on a variety of fronts, utilizing alternative communication technologies to meet many of the needs ATCS was designed to meet. But the alternative technologies are not necessarily as suitable as a platform for train control functions as the ATCS digital data infrastructure. Thus, ATCS may not be deployed voluntarily on the basis of business requirements. For the immediate future, this means continued heavy reliance on voice radio for many communication functions.

A central communication-based approach to PTC remains the most likely path to safer train operations. In addition, that approach has the greatest chance of returning business benefits that can help pay for a portion of the communication infrastructure needed to support safety applications. Although the application of PTC on all rail lines would not be cost beneficial at the present time based on accident avoidance, PTC is required for high speed rail service and may be warranted on heavily traveled freight lines as well. Implementation of PTC that is interoperable will facilitate more widespread realization of safety and other benefits.

The absence of highly capable positive train control systems is a major factor limiting railroads' ability to serve the public. This study has refocused FRA's attention on the importance of promoting affordable positive train control. Consider:

- Antiquated train control limits system capacity.

  - Limited capacity could foreclose options for intercity and commuter passenger service on existing, heavily used freight lines (or unnecessarily increase capital and operating costs).

  - On some major freight corridors, downsized rail plants are now straining to handle increasing volumes of intermodal freight movements, as trucking companies and international brokers recognize the value of rail as part of the intermodal team. If freight capacity becomes a limiting factor, the ability of the railroad industry to relieve pressure on congested highways and to serve the Nation's environmental goals may be compromised.

- The cost of a highly capable positive train control system is a major element of any proposed high speed passenger rail system. New technologies offer the promise of lower cost. The cost of such a system might also be greatly reduced if part of a larger, interoperable design.

Given these stakes, fragmented decision-making by agencies of the Federal Government, the railroad companies, and rail suppliers is not acceptable. If planning is not coordinated, resulting train control systems may be wholly incompatible; or the cost of effecting interoperability may become too great to bear. Inevitably, this would lead to less effective systems on many of those lines where the need is greatest, since considerations of cost might require that nonequipped trains be allowed to intermingle with equipped trains.

FRA concludes that significant opportunities exist to promote the development of communication-based PTC. FRA also concludes that rail management will increasingly recognize the value of multi-purpose data communications platforms. Even where such platforms are not put in place quickly, railroads and their suppliers will develop innovative means of achieving PTC benefits in ways that offer adequate interoperability. Based on current forecasts for technology and service demands, FRA expects that the advantages of enhanced PTC systems with respect to train and crew management will result eventually in fully developed and integrated central communications systems.

Implementation of central communication-based PTC, the first choice of the freight railroads, will permit realization of safety benefits early in the migration to more capable systems, including reductions in demands on voice radio systems that are suffering from congestion and more secure transmission of movement authorities.

The Federal Government must play a constructive role as an investor, a facilitator and a regulator. Federal investments should be strategic--capable of meeting the broadest feasible range of functional requirements and appropriately linked to other Federal initiatives. The most competent PTC systems (such as Level 40 ATCS) promise increased capacity on existing rail lines and better precision to meet future service needs; and investments that are coordinated in a way that results in maximum impact on all objectives will be most likely to satisfy Federal investment criteria.

FRA should continue to facilitate development by the private sector of PTC technologies. This role should include a strong emphasis on creating partnerships among the AAR, the railroad companies, established rail suppliers, the Federal Government, and defense industry suppliers seeking opportunities for conversion of technology to civilian use under programs administered by the Advanced Research Projects Agency, Department of Defense.

Regulatory action may also be appropriate to provide a level playing field for intramodal competition and to ensure prompt action to implement justified safety measures. In order to determine where investments in PTC may be warranted, it will be necessary to conduct a corridor analysis to examine risk characteristics (numbers of train movements, speed, passenger traffic, hazardous materials traffic). Should one or more categories of line segments stand out as presenting accident experience or future risk such that accident avoidance benefits would be greater than the cost of PTC implementation, rulemaking to require implementation should immediately follow.

Future Actions

In order to advance PTC, FRA will invest strategically, form and nurture partnerships with the industry to promote technical standards development, and aggressively prepare to exercise its regulatory responsibilities where justified by costs and benefits.

FRA will take the following actions:

- With funds requested in the President's Budget for Fiscal Year 1995, initiate development of a risk analysis model to guide determination of priorities (among major freight rail corridors) for application of PTC technology.
    - Determine cost/benefit ratio for application of PTC to priority corridors.
    - Consider factors pertinent to frequency and severity of preventable train accidents and incidents, such as train densities, passenger traffic, hazardous materials flows, etc.
    - Develop strategy for determining and applying trend lines to the analysis.
- Utilize results of risk analysis model and experience gained in review of Amtrak's enhanced ATC system for the Northeast Corridor to develop and issue a regulatory proposal requiring appropriate levels of PTC for applications where PTC is justified (including high speed rail).