related issues. ***Chapter IV*** describes the need for more capable train control systems (incorporating "positive train control" or "PTC"), and recounts the efforts of the industry to develop them. ***Chapter V*** estimates costs and benefits of positive train control. ***Chapter VI*** suggests conclusions and future actions regarding the future of communications technologies in the safety of railroad operations, including the role of Federal regulation and investment policy.

Safety Requirements

In the contemporary operating environment it is essential that railroads have available effective means of communication and that they use those means wisely. Sometimes, however, merely communicating information is not sufficient. In those instances where it is critical that operational commands or authorities be acted upon in a timely and precise manner, it may be appropriate to provide back-up systems that provide "enforcement" if the human recipient is unable, unwilling or insufficiently motivated to act properly. Advanced train control technologies unite features of digital data communication with attributes of present signal and train control systems. They permit enforcement of movement authorities and instructions from compatible wayside detectors.

Depending upon whether the information communicated is an instruction, warning, display of track occupancy, indication regarding switch position, or other message, etc., and depending further on the technology employed, a contemporary railroader might refer to the medium as "track warrants" (paper copy), "fax," "radio" (voice radio), telephone (line or cellular, commercial or private), wayside signal system, cab signal system, or "OBT" (on-board terminal of a data communications network).

It is important to recognize that all communications media must be considered when railroad communications and train control functions are evaluated. Only by recognizing this inter-relatedness can railroads make decisions that will ensure optimum use of capital; and, only by recognizing this interrelatedness can Federal policy properly determine minimum safety criteria for railroad communications and train control that should be applicable to different types of railroad operations.

Table I-1 describes some of the most important communication and train control functions that are relevant to safe operations on the railroad and involve communication of information or instructions. The table indicates the means by which communication can be effected using the means most commonly employed in the industry today: voice radio, and signal and train control (S&TC) systems. In addition, entries are provided for digital data radio--a rapidly emerging technology. For purposes of this "data" entry in the table, we assume that the train's controlling locomotive is equipped with an interactive terminal.

TABLE I-1

COMMUNICATIONS MEDIA AND FUNCTIONS

Legend: Y = Yes (the function is supported)
N = No (the function is not supported)

COMMUNICATIONS FUNCTION	VOICE	DATA	S&TC	COMMENT
DISPATCHER TO TRAIN				
Train movement authorities	Y	Y	Y	Data communication may be more reliable than voice, due to direct input from a computer-aided dispatching system and elimination of misunderstandings; during 1994 or 1995, the first use of digital data radio to transmit train movement authorities will be implemented. In automatic train control systems, information regarding switch position and track occupancy is used to display appropriate signal indications and to enforce them. Advanced features include positive stop and enforcement of temporary speed restrictions.
Obstruction and other emergency warnings from third parties (fires, impending floods, objects on the track, objects fouling the track)	Y	Y	*	*In centralized traffic control territory, the dispatcher could set the signal system to stop a train short of problems in distant "blocks." The same capability does not exist in automatic block territory.
FIELD TO TRAIN				
Wayside detector warnings (hot wheel, hot bearing, slide, high water, dragging equipment, etc.)	Y	Y	Y	Wayside detector readings can be communicated through the signal system, a prerecorded transmission over the voice radio, or through data transmission.

COMMUNICATIONS FUNCTION	VOICE	DATA	S&TC	COMMENT
LOCOMOTIVE TO GROUND CREW				
Switching movements	Y	N	N	Conductors and brakemen rely heavily on voice radio communication with the locomotive engineer during switching operations. FRA radio rules require that movements be stopped if radio continuity is lost.
TRAIN TO DISPATCHING CENTER / EMERGENCY RESPONDERS				
Emergency warning (e.g., train derailed and fouling adjacent track; shifted lading; problem with passing train; fallen tree)	Y	Y	N	Operating rules require train crew members to inspect their train and passing trains in route and to provide information concerning other unsafe conditions. Currently, voice radio is the only means available to communicate this kind of information.
Security concerns	Y	Y	N	Trespassers endanger themselves, and vandals endanger both themselves and others. Having available a ready means of communication will permit train crews to pass information through the dispatching center or other channels to railroad police and local law enforcement.
Emergency request (e.g., crew member or bystander injured, train derailed, hazardous materials release, collision with highway vehicle)	Y	Y	N	Very often, the first notice of a serious accident or casualty is provided by voice radio, which may be the most flexible medium for eliciting and providing information necessary for emergency response.

Safety Performance

Though the rate of progress has been neither steady nor uniform, the railroad industry has made enormous strides in preventing serious human factor accidents--particularly those involving collisions of trains. These advances have resulted from a variety of sources, including more capable signal systems, tighter operating rules, computer-aided dispatching (CAD), improved voice radio communication, reductions in use of alcohol and drugs, and the increasing professionalism of railroad operating employees.

FRA train accident data is available in comparable form since 1975, when the current reporting system became effective. A reportable "train accident" is one exceeding the current threshold for railroad property damage (since 1991, $6,300). Figure I-1 illustrates the decline in reportable collisions, most of which occur during low-speed yard switching operations. Figure I-2 displays the much smaller number of main line collisions, which tend to be the most hazardous to persons.

Figure I-3 displays fatalities in collisions. The increase in 1987 resulted from the accident of January 4 at Chase, Maryland, in which one crew member and 15 passengers died. The total for 1993 is strongly influenced by the collision between two commuter passenger trains at Gary, Indiana (7 fatalities) and the collision between two freight trains at Longview (Kelso), Washington (5 fatalities).

Figure I-4 shows fatalities in collisions on main tracks. These are the collisions responsible for most fatalities and those most likely to be preventable by positive train control technology (discussed in Chapter IV).

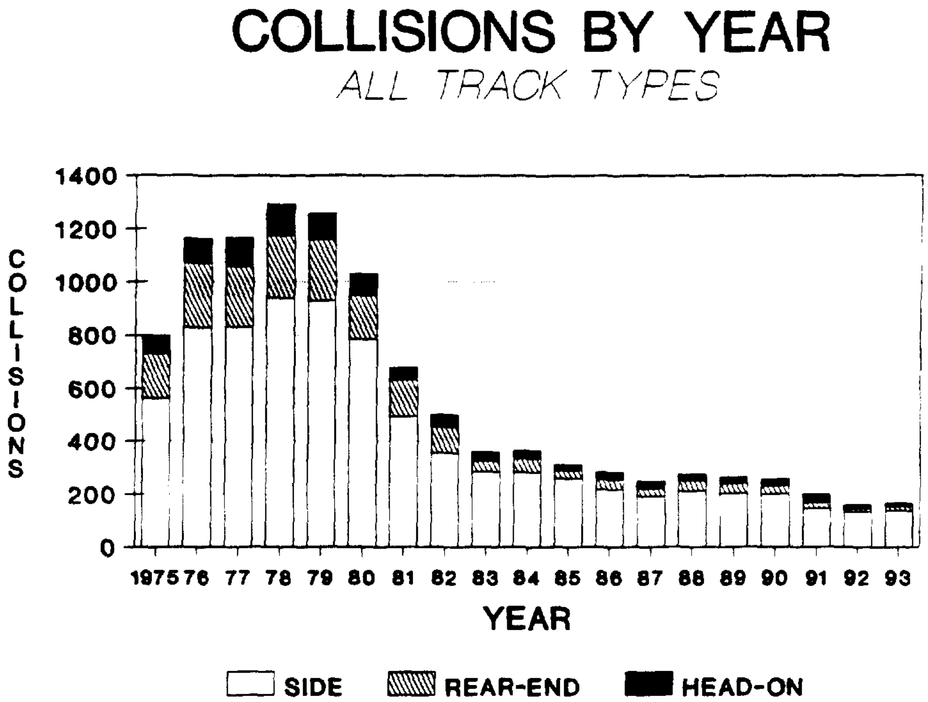

Figure I.1

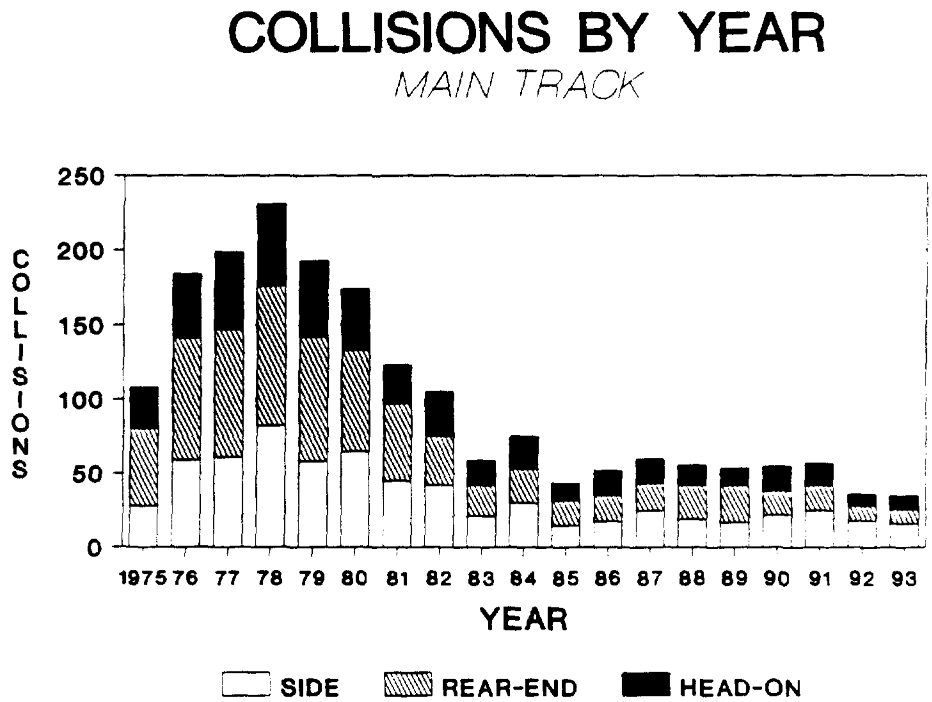

Figure I.2

FATALITIES IN COLLISIONS

ALL TRACK TYPES

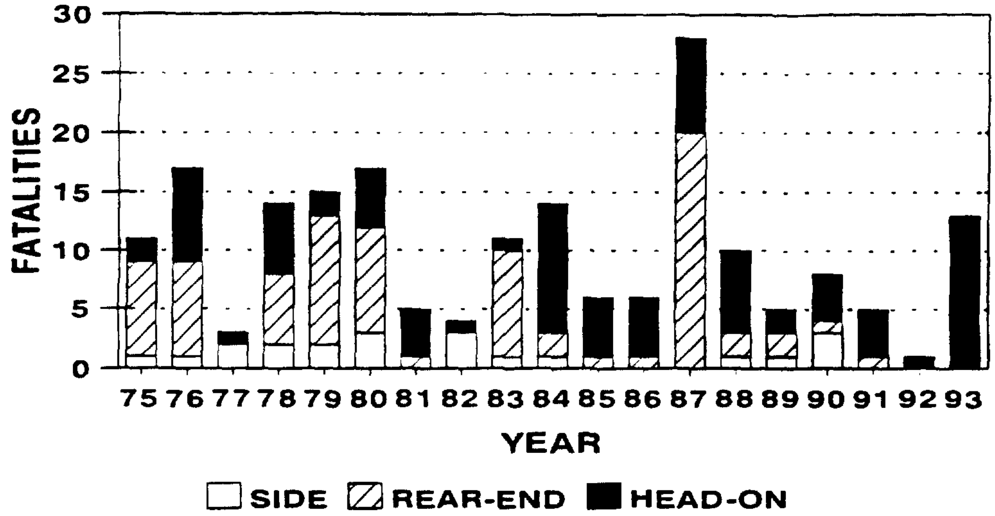

Figure I.3

FATALITIES IN COLLISIONS

MAIN TRACK

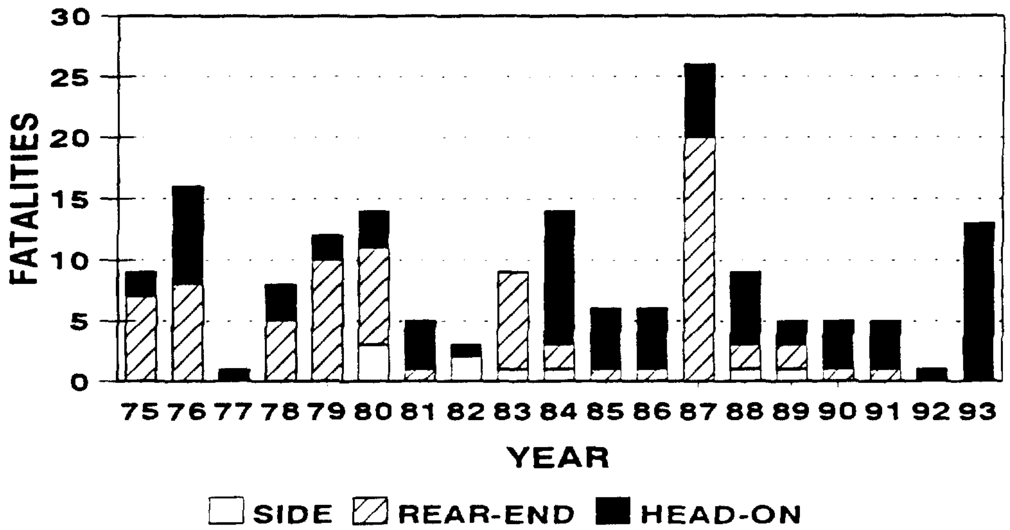

Figure I.4

CHAPTER II

Development of Railroad Communications and Train Control

This chapter briefly describes the development of railroad communication technologies, signal and train control systems, and operating rules. It also traces the development of pertinent Federal statutory and regulatory requirements and outlines the residual safety risks associated with current methods of operation.

The Early 20th Century

At the turn of the century the railroad industry was rapidly expanding, and experimentation prevailed. Faster, more powerful locomotives were being introduced to meet the demands for high speed passenger trains and the hauling of heavier tonnages. Greater use of the telegraph as the primary means of communication was being made to eliminate the costs of closely spaced stations to control the movement of trains and to cope with higher speeds and train densities, changing schedules and traffic patterns, and competitive pressures. Operating rules were primitive, often adopted as the result of tragic accidents.

In 1906, the Congress passed the Block Signal Resolution which directed the Interstate Commerce Commission (ICC) to investigate and report on the use of block signal systems and appliances for the automatic control of trains. Thus began the initial Federal effort at curbing train accidents caused by human error. For the next 14 years, the ICC studied existing trainstop and train control systems and submitted its findings in reports to each Congress. On the basis of these findings the Congress enacted legislation in the Transportation Act of 1920 that authorized the ICC to require the installation of trainstop and train control systems where found necessary in the public interest.

In issuing the first order for trainstop and train control systems, the ICC summed up the accident experience as follows:

> The accident reports made by the railroads show that from January 1, 1906, to December 31, 1921, there were 26,297 head-on and rear-end collisions. These resulted in death to 4,326 persons and injury to 60,682. The damage to railroad property alone amounted to $40,969,633. The annual average of these collisions amounted to 1,643; the average number killed, 270; and the average number injured 3,792. The average damage to railroad property alone amounted to $2,560,603 per year.[2]

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[2]69 I.C.C. 258, 272 (Docket No. 13413; decided June 13, 1922).

The trainstop and train control devices of the early 1900s were mainly mechanical and electromechanical devices of a crude design compared to modern engineering. Several systems required wayside structures of inductors, ramps or trips to activate mechanical or electrical devices installed on steam locomotives. The harsh environment of steam locomotives and increasing train speeds were punishing to the onboard devices necessitating daily inspections, maintenance and repair. Failures were frequent.

The wayside block signal systems were of a wide variety--mechanical, pneumatic, hydraulic, electromechanical and electropneumatic. Few systems had continuous track circuits.[3] Technology in the application of electricity to signal and train control systems was in the developmental stage. The reliability of the interconnection of onboard devices with wayside equipment was poor.

There was an intensive search for a means of operating trains safely and efficiently. As a result, thousands of patents were applied for to cover railroad equipment, particularly signal and train control devices. The ICC reviewed and reported its findings on 85 trainstop and train control devices. Some railroads had as many as three incompatible systems. There was even more disparity in the types of block signal and interlocking systems.

The prevalent methods of operation were by timetable and train orders or timetable schedules only. Train orders required a thorough understanding of a complex set of rules involving the rights of trains, and orders were often misinterpreted. Timetable schedules were based on a time interval scheme which was heavily dependent on accurate time and flag protection when a train was delayed.

The organizational structure of the typical railroad further complicated this situation. Railroad management and employees were initially antagonistic toward signal systems. Mechanical departments saw little value in proper maintenance of trainstop and train control devices on locomotives. Communication engineers tasked with the installation and maintenance of wayside signal systems generally viewed the responsibility as burdensome. In general, railroad companies had not yet recognized that signal systems can increase track capacity, improve safety, save fuel and expedite train movements.

Efforts to Improve Technology and Rules

In 1895, a group of young signal engineers formed a signaling club in Chicago, Illinois, to share experiences and standardize signal equipment. Among their first undertakings were the preparation and adoption of a standard and uniform set of rules and practices for interlockings in the Chicago area. Using sound engineering principles, various committees also set standards for signal aspects and indications and automatic block signal systems (ABS). As a result, train collisions, which frequently occurred at crossings-at-grade, were

[3]Contemporary signal systems utilize the rails as conductors, a design that permits detection of trains and broken rails.

significantly reduced. The success of the signaling club did more than any other group in dispelling antagonism toward signal systems. The club became widely recognized and respected, and subsequently was accepted into the American Railway Association (now the Association of American Railroads) (AAR) as that organization's Signal Section.

The primary duty of the Signal Section was to develop recommended practices for equipment and materials for signal systems. However, within the AAR it was better able to influence the various committees of the AAR's Operation and Mechanical Divisions, resulting in a higher standard of recommended practices for operating rules and maintenance of trainstop and train control devices installed on locomotives.

Over time, the AAR's Standard Code of Operating Rules, prepared and adopted by the Operating Rules Committee that was composed of member railroads' top rules officers, was revised to provide succinct rules for train operations at interlockings and in various types of signal, trainstop and train control systems. Each railroad had its own book of operating rules and rules officers could adopt an AAR rule or modify it to their railroad's needs. The effect of the AAR's improved Standard Code of Operating Rules resulted in an overall improvement of its member railroads' rules. The AAR even provided written responses to rules officers who made inquiries for interpretations of special situations, further standardizing acceptable rules practices.

The AAR's member railroads' Chief Mechanical Officers (CMOs) focused seriously on trainstop and train control devices for locomotives. Beginning in 1920, the CMOs played a major role in setting standards for the design, construction, installation and maintenance of those systems. Working in conjunction with the signal engineers, the application of electrical technology in trainstop and train control devices was improved--even a vacuum tube-driven electronic amplifier was introduced that was used for more than 30 years until replaced by solid state equipment.

By 1920, the telegraph was widely used in the industry for issuing train orders. The telephone was rapidly expanding, and voice transmissions of train orders commenced, with the telegraph being relegated to other communication purposes. Train order stations were becoming further apart as the railroad companies realized the economic benefits from the application of dependable signal systems, communications and operating rules. Still, the failure of train crews to interpret train orders properly, obey speed limits, comply with signal indications, and the failure of railroads to enforce compliance with operating rules, plagued the industry with frequent and sometimes catastrophic accidents.

Federal Intervention in Train Control

In 1922, under authority of the Transportation Act of 1920, the ICC issued Order 13413 requiring 49 respondent railroads to install either a trainstop or train control system on at least one division over which passenger trains were operated. The Order was expanded in 1924 to include an additional passenger division on each railroad.

The ICC set minimum standards that required ***trainstop*** systems to operate automatically, upon the failure of an engineer to acknowledge a restricting signal, to apply the brakes until the train was brought to a stop. A ***train control*** system was required to apply the brakes until the train was brought to a stop in the event an engineer failed to take action to control the speed of the train in accordance with signal indications. (Train control systems by design do not operate to enforce signal indications when the speed, under control of the engineer, has been reduced below 20 MPH to Restricted Speed, a feature found acceptable on the theory that train movements are safe when all trains are operating prepared to stop in one-half the range of vision.)

Many of the railroad companies objected to the Order and filed appeals, mainly on the basis of poverty. Some argued successfully and were waived from the requirements. A few railroads saw the value of trainstop or train control and made installations systemwide. Other railroads made more than the required number of installations but most railroads met only the requirements of the Order.

Certain railroads elected to install trainstop systems; others installed train control systems; and a few installed systems that had the features of both. Five railroads sought and obtained ICC approval to install trainstop or train control devices only on passenger locomotives. All other railroads installed them on both passenger and freight locomotives used in the equipped territory.

The Pennsylvania Railroad pioneered the development of a four-aspect cab signal system with an audible alarm that sounds when the cab signal changes to a more restrictive indication. The railroad petitioned the ICC for approval to install the automatic cab signal system (ACS) on its line in lieu of a trainstop or train control system. After investigation, the ICC approved the cab signal system in 1930. Subsequently, two other railroads also adopted the cab signal system.

The reliability of cab signal, trainstop and train control devices are dependent not only on the quality of maintenance and repair performed by mechanical department employees, but also by the quality of installation, maintenance and repair of wayside signal equipment. While the affected railroads complied with the ICC's order to install the systems, many railroads did not install or maintain the wayside systems in a manner to assure the cab signal, trainstop and train control devices functioned as intended. The ICC had no authority to require safe and proper installation, maintenance and repair of interlockings and block signal systems with the result that cab signal, trainstop and train control installations frequently functioned with less than the desired results expected by the Government.

Acting on the basis of reports from the ICC, in 1937 the Congress passed the Signal Inspection Act giving the ICC almost plenary authority over signal and train control systems. In 1939, the ICC promulgated rules, standards and instructions (RS&I) governing the installation, maintenance and testing of block signal, interlocking, cab signal, trainstop and train control systems. The impact of the RS&I resulted in the wayside and onboard equipment becoming highly reliable operating tools for the safe movement of trains. In addition, in order to meet the requirements contained in the RS&I, carrier operating rules pertaining to train operations in these systems were revised to clearly indicate the actions to be taken.

Post-World War II Developments

Traffic control systems were developed in the 1930s and successfully utilized during World War II to increase track capacity and expedite train movements. The post-war years confronted the railroad companies with the need to downsize as the volume of traffic diminished. One means of reducing plant was by the expansion of traffic control systems.

A traffic control system (TCS) is controlled from a machine operated by one person, usually the dispatcher. Frequently used switches, such as siding switches, are power-operated and also positioned from the control machine. The method of operation is by signal indication, eliminating the need for train orders and train-order situations.

By 1954 there were over 17,000 miles of railroad equipped with automatic cab signals (ACS), automatic train stop (ATS) or automatic train control (ATC). The industry began to petition for removal of equipped territory and installation of TCS, resulting in more than 7,000 miles of equipped territory being discontinued.

The expansion of traffic control systems signaled the demise of traditional methods of operation whereby train orders were issued using the telephone and telegraph. Significant returns on the capital investment for traffic control was earned by the closing of train order stations, remote control of manual interlockings and the reduction of multiple tracks to fewer or single main tracks. Operating rules in traffic control systems are much more succinct than train order rules, which improves operating safety.

In addition, the railroad companies began to introduce radio to railroad operations as a means of communication. In territory where signal systems were not in use, and in automatic block signal territory, radio was increasingly relied upon as an adjunct to telegraph and telephone for the purpose of delivering the text of movement authorities (initially train orders).

As the use of the radio expanded, the railroad companies began to adopt rules for its use. As a result of incidents that occurred and the disparity of radio rules among the carriers, the FRA, the successor to the ICC in matters concerning railroad safety, promulgated rules in 1977 for the use of the radio (49 CFR Part 220). The rules provided --

- Standard protocols for radio discipline;

- Procedures for sending movement authorities; and

- Rules for use of radio during switching operations.

Radio technology continued to develop and its reliability grew as new installations were made and existing installations were updated. Today on many carriers almost 100 percent coverage exists along their lines.

As a result of almost complete coverage, in 1974 one railroad pioneered Voice Control Radio System operating rules in which directives were given to train crews (through block or "relay" operators) authorizing limits of authority to operate, including whether to hold the main track or take sidings for the purpose of meeting other trains. After investigation and examination, the Voice Control Radio System received the approval of FRA for three primary reasons: (1) radio communications across the line involved were excellent; (2) instructions were presented simply, reducing the risk of human error about actions to be taken in the movement of trains; and (3) maintenance-of-way personnel were brought under the same protection as trains which greatly enhanced the safety of those employees.

In 1983, several western railroads also received the approval of FRA for the use of a radio-based operation termed "track warrant control" for the same reasons. Track warrant control differed from the Voice Control Radio System in that dispatchers communicated directives directly to train crews rather than to a relay operator to do so. While the check and balance of the relay operator was eliminated, FRA still favored implementation of track warrant control for the above reasons. However, full protection of maintenance-of-way employees was never implemented mainly because of the workload imposed on dispatchers.

Present Methods of Operation

Track warrant control systems, under various names, are now widely established in the industry. The security of track warrant operations is enhanced through the use of computer-aided dispatching systems. CAD systems utilize computers to verify movement authorities against one another and (in traffic control system territory) against occupancy and switch position information. Properly configured and employed, they can also ensure against mistaken routing of a train onto a track subject to repair by maintenance-of-way forces.

Railroad signal systems continue to play a very important role in the safety and efficiency of the railroad industry. Under the current signal and train control regulations (49 CFR Part 236), signal systems are mandated based on train speed as follows:

	Speed (MPH)	
Signal system	Freight	Passenger
None required	to 49	to 59
Block signals or manual block	50-79	60-79
Automatic cab signal, train stop or train control	80-110	80-110

(Under the Track Safety Standards, operations are permitted up to 110 miles per hour. A railroad seeking approval to operate at greater speeds must receive special approval from the FRA, and the application must include information on signaling of the territory (49 CFR sec. 213.9(c)).)

The Signal Inspection Act and implementing regulations (49 CFR Part 235) bar discontinuance of signal systems without FRA approval. FRA regulations also requires reporting with respect to methods of train operation (49 CFR Part 233). Reports as of January 1, 1993 revealed the information displayed in Table II-1 for railroads in the general system of rail transportation.

Table II-1

METHODS OF OPERATION

Method of operation	Track miles	Road miles
Track warrant (direct traffic control)	48,735	48,183
Train order (timetable)	25,589	24,953
Total dark territory	**74,324**	**73,136**
Automatic block signals	28,506	21,626
Traffic control systems	60,313	49,031
Total signal territory	**88,819**	**70,657**
Total miles operated	**163,143**	**143,793**

The total miles of signal territory listed above include several thousand miles of railroad where wayside signals are supplemented by automatic cab signals and/or where wayside or cab signals are supplemented by automatic train control or automatic train stop systems. These systems are deployed on some of the highest density lines in the United States; and, as noted above, one or more of these systems are required for operations at greater than 79 miles per hour. Automatic cab signals provide warning when the signal aspect becomes more restrictive, and ATC and ATS provide enforcement where the engineer fails to respond properly.

FRA conducts inspections to determine compliance with signal system regulations. The agency also investigates "false proceed" reports (indicating an unsafe malfunction of a system) for which cause or remedial action may be in doubt. Actual signal system malfunctions are responsible for fewer than one percent of reportable train accidents each year. This record is a great credit to the fail-safe design of the systems and the skilled work of railroad signal maintainers.

Remaining Safety Risk

Capable signal and train control systems, improved radio communication, strengthened operating rules, and CAD technology, along with committed employees, have contributed greatly to railroad safety. Accidents involving train collisions continue to occur mainly at lower speeds.

However, train collisions with significant consequences have occurred sufficiently often to raise public concern for employee and passenger safety and damage to the environment as a result of hazardous materials spills. Although most of these accidents continue to be attributed to "human error," they also represent failures of safety systems that seek to provide, where possible, multiple layers of safety assurance.

Table II-2 describes, in summary form, the principal methods of operation currently in use on U.S. railroads and their vulnerabilities with respect to collision risk. Similar comparisons can be made for overspeed derailment risk or for events involving maintenance-of-way personnel and equipment. Note the interrelationships among railroad operating rules, signal systems, and other communications media.

TABLE II-2

SAFETY RISK FACTORS AND COUNTERMEASURES UNDER DIFFERENT METHODS OF OPERATION

RISK FACTOR	CURRENT COUNTERMEASURE	COMMENT
TRAIN ORDER/TRACK WARRANT (NO SIGNALS) Description: Trains are operated in accordance with written authorities, which may be transmitted directly, via FAX or telegraph, or by voice (radio, telephone) and transcribed by the receiving employee.		
Improper authority (e.g., "lap order")	CAD	Increasingly capable CAD systems are in use
Incomplete orders	Rules require comparison of orders with a clearance document; may not act on orders unless all are received	Clearance document must be the final, pertinent document, must be complete, and must be carefully reviewed by conductor and engineer
When passed by voice, misstated by dispatcher	Rules require read-back; dispatcher should catch error	Dispatcher may not catch error
When passed by voice, misunderstood by crew	Rules require read-back; dispatcher should catch error	Dispatcher may not catch error
When passed by voice, mistranscribed	Rules require read-back; dispatcher should catch error	Dispatcher may not catch error
Correctly transcribed, but misunderstood by engineer or conductor	Conductor and engineer required to have copy of all orders; entire crew required to discuss, resolving conflicts before proceeding	Usually effective, not always

RISK FACTOR	CURRENT COUNTERMEASURE	COMMENT
TRAIN ORDER/TRACK WARRANT W/ AUTOMATIC BLOCK SIGNALS (ABS) Description: Trains move in accordance with train orders or track warrants subject to restrictions imposed by signal indications.		
As a result of risk factors listed above under train orders, crew is provided erroneous order or misunderstands	Automatic block signals will indicate presence of train in block ahead, permit train to stop or slow	Ineffective if signals are not observed
TRAFFIC CONTROL SYSTEM Description: Trains are routed by signal indication from a dispatching center.		
Engineer fails to note, misperceives, or wrongly recalls signal indication	Other front end crew members, if any, are required to call signals and intervene with use of emergency brake valve if necessary; control operator may detect an overrun signal and radio train to stop, divert train to another track, or divert/stop conflicting movements	Higher risk than under ABS with train order/track warrant, since reliance is exclusively on wayside signal indication; intervention by traffic control before an accident cannot be depended upon in all situations
Risks common to the following methods of operation: TRAIN ORDER/TRACK WARRANT TRAIN ORDER/TRACK WARRANT WITH AUTOMATIC BLOCK SIGNALS TRAFFIC CONTROL SYSTEM		
Single crew member incapacitated, inattentive, or distracted	Other crew members, if any, are required to note and call signal, use emergency brake as necessary	Residual risk is related to distraction or lack or alertness by other crew member(s), if any Danger is greatest during early morning hours
All crew members incapacitated, inattentive, or distracted	Alerting device, if any	Engineer may reset reflexively

RISK FACTOR	CURRENT COUNTERMEASURE	COMMENT
AUTOMATIC TRAIN CONTROL WITH CAB SIGNALS Description: Trains are routed by signal indication, with continuous display in the cab. Failure to control train within speed range dictated by the signal system will result in enforcement (full service brake application).		
Engineer acknowledges warning but fails to stop train short of control point or other train	Other crew members, if any, are required to note and call signal, use emergency brake as necessary	Low risk of occurrence, but possible if engineer acts reflexively and other crew member (if any) is distracted and fails to intervene in time

Table II-2 is not a complete listing of risk factors within the scope of this report.[4] For instance, a signal system may function properly but the train crew may fail to observe operating rules that would have provided protection (e.g., failure to wait prescribed time after requesting signal at rail-rail grade crossing interlocking, failure to secure freight cars standing on sidings and industrial spurs, leaving hand-throw switches providing access to the main line misaligned). In addition, the actions of vandals may result in collisions or derailments.

Overspeed operation is also responsible for many train accidents, such as the Amtrak accidents at Back Bay Station, Boston, Massachusetts, on December 12, 1990 and at Palatka, Florida on December 17, 1991. Injuries and fatalities have also occurred when the presence of roadway workers or their on-track equipment was not properly accounted for by dispatchers or train crews, or where roadway workers operated their equipment outside of assigned limits.

The railroad companies, their employees and rail suppliers have greatly reduced the number of collisions, overspeed derailments, and other life-threatening events through prudent

[4]This report considers risks that can be avoided or controlled through enhanced communications and train control. Track and equipment-caused accidents are not the only type of risks beyond the scope of the report. For instance, there is no doubt that improper train handling (e.g., proper management of in-train forces taking into consideration grade and curvature, train make up, proper use of brakes and proper use of throttle) is a "human factor" responsible for train accidents. But there is no automated system, existing or planned, as competent as a well trained and experienced engineer to ensure proper train handling.

application of railroad operating rules (including radio rules) and through advances in contemporary signal and dispatching technology. The continuing challenges and opportunities associated with intelligent use of radio communications, including the prospects for cost effective advanced train control technologies in the near future, are the subjects of the chapters that follow.

CHAPTER III

Voice Radio Communications

Background

In the context of railroad operations, communications historically concerned two major areas: train movement authorities and intracrew directives (i.e., crewmember to crewmember on when to go, stop, backup, slow down, etc.).

- **Train Movement Authorities**: Railroads traditionally depended on hand-printed or typed orders to convey important information to employees engaged in the movement of trains. Train order operators copied orders transmitted by train dispatchers over land lines and then hand delivered them to the engineers and conductors. The telegraph was used initially, followed by dedicated railroad owned telephone lines (dispatcher lines), which linked the dispatchers with the various block operators. To complement this system, wayside telephones were installed so that train crews could communicate with dispatchers and operators in the event of accidents and other unexpected circumstances.

- **Intra-Crew Directives**: Over the years a number of hand and lantern signals evolved which enabled operating crews to communicate with each other. While some of these signals varied slightly from railroad to railroad, the majority were similar enough to be recognized by railroaders throughout the country. Railroads typically formalized and published the hand and lantern signals in operating rule codes.

Voice Radios: The utilization of two-way radio communications was a significant technological advancement for railroads that began in the 1950s. Radios provided a means of reliable communication between the dispatcher and crews and enabled the elimination of thousands of wayside dispatcher telephones.

When railroads began utilizing radio systems, operating divisions were generally much smaller than they are today. Train dispatching districts were also smaller and the dispatching offices located more closely to each other. There were usually several train order and interlocking operators located along any given route. Although a railroad might have a few remote radio base stations linked to a train dispatching office, the number of remote base stations did not provide complete radio coverage.

During the early era, radios limited to two-channel capability were installed on locomotives. Normally, one channel was utilized for road communications with operators and dispatchers, while the other was used for yard switching operations. About 1970, railroads began installing four- or eight-channel radios on locomotives. The industry also began purchasing portable radios for use by conductors, trainmen, and maintenance employees. For the past several years, the recommended standard of the AAR has been to equip new locomotives with 97 channel radios. This standard ensures good communication in joint operations and in the event of mergers. Many railroads have underway a comprehensive program of replacing older radio hardware installed on existing locomotives.

Safety-Relevant Uses of Voice Radio

The railroad industry has experienced significant changes during the last decade. Technology has rendered many traditional railroad operating methodologies obsolete, leading to substantial changes in structure and organization.

As conventional practices changed, the attributes of voice radio communications became increasingly important. For example, several years ago a standard train crew consisted of up to five employees: An engineer, conductor, head brakeman, rear brakeman, and flagman. Today, the standard road train crew is commonly composed of an engineer and conductor. Where once hand/lantern signals provided adequate means of communicating from crewmember to crewmember, radios are now a vital necessity rather than a convenience. In today's railroad environment, track warrant control (or "direct train control")[5] is the most commonly accepted operational method. With the advent of this approach, voice radio has developed into a critical railroad safety component.

Train movement authorities. Traditional issuance of train movement authorities utilized private communications systems (telegraph/telephone). Today, railroads use voice radio to transmit movement authorities from the dispatcher directly to the crew in the cab of the locomotive. The stopping of the train, renewal of pole lines that carried communications wire lines along the railroad, and the associated installation and maintenance expenses inherent in the older systems are no longer incurred. Additional benefits result from the ability of train dispatchers and train crews to maintain contact throughout the trip.

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[5]This is an umbrella term for a method of operation derived from traditional timetable/train order methodology. Adopted to varying degrees by most of the major railroads over the past 10 years, these methods of controlling train movements have simplified operations by eliminating timetable schedules, train orders, superiority, train registers, operators, and the attendant array of complicated operating rules. These systems are predicated upon the train dispatcher having direct radio contact with all trains and on track equipment, hence the informal name "radio train dispatching." In place of the train order, there is a written document known variously as a "track warrant," "DTC clearance," "OCS clearance," "RCBS clearance," "track permit," "Form D," etc. There are two basic track warrant control or "direct control systems" presently in use on today's railroads: One that uses fixed blocks (f) (i.e., the limits are constant and are identified both in the timetable and by wayside signs); and, one that uses variable blocks (v) (i.e., the limits are not constant and are created by the train dispatcher for each train).

Persons not familiar with railroad operating rules sometimes assume loss of communications will create an unsafe situation because a train could not be told to stop short of another train. That is not the case. Loss of communications during the transmission of a movement authority renders the authority void. Under the rules, a dispatcher would not be permitted to issue a potentially conflicting authority to another train until the antecedent authorities issued to other trains had been executed or canceled. Thus, under most circumstances, no hazard would be presented by a train crew proceeding as specified under a valid authority without an operative radio. Nor would a train crew be authorized to move its train beyond the limit of the authority previously provided without another valid authority.

However, a wide variety of events can occur on the railroad that may render execution of an otherwise valid authority hazardous (see., e.g., Table I-1). The withdrawal of train order operators and other communications media from the rights of way, together with the reductions in train crew size and lengthening of crew districts, places a premium on availability of voice radio (or other means of communication not heretofore provided) for communication with the train dispatcher.

Switching Operations. As a result of reduced crew sizes, voice radio has emerged as a crucial element in intracrew communications, as well. Where once several crewmembers enabled the relaying of hand/lantern signals when required by the task (e.g., setting out a long cut of cars, shoving cars around a curve out of sight of the engineer, etc.), today radios must provide the means for crew communications.

The use of radio communications to transmit and receive switching related information otherwise conveyed by hand signals has produced significant gain in efficiencies for the railroad companies. Likewise, the need for trainmen to pass signals from the tops and sides of moving rail cars with the attendant risks, has been eliminated.

Communication of Wayside Detector Information. Reliance on radios to transmit automatic detector warnings for hot journal detection, high-wide or shifted loads, dragging equipment, etc., has become the norm. The safety importance of such devices has increased with elimination of manned cabooses, and railroads employ "talking" detectors on nearly all major corridors across the country.

Before introduction of automatic warning detector technology, notice of impending problems was dependent primarily upon crew observation. Even with crew members positioned in the caboose, reliability was not assured as evidenced by numerous derailments due to burned-off journals, undetected dragging equipment, etc. The advent of automatic detector technology enhanced crew awareness of impending problems. This application of radio technology has contributed significantly to the enhancement of safety through the timely and reliable information provided. The major limitation is that automatic detector placement is an inexact science in some applications. As such, the formula for determining precise detector locations leaves some track segments with less coverage than other track segments. Further, exclusive reliance on recorded voice transmission to provide warning in nonsignal territory raises issues of effectiveness, since locomotive radios may not be tuned to the channel on which the warning is broadcast.[6]

__Emergency Response__. Ideally, voice radio provides a means whereby trains in distress can summon help instantly. In many situations this is the case. The advantages of such instant notification are manifold. Not only can emergency responders be notified, but other trains approaching the distressed train can take necessary precautions (e.g., slowing or stopping until it is ascertained that adjacent tracks are clear). The use of voice radio expedites the flow of information in emergency circumstances.

Casualties on the railroad are unfortunately not infrequent. For instance, each year almost 5,000 collisions occur between trains and vehicles at highway-rail crossings, resulting in about 600 fatalities and almost 2,000 nonfatal injuries.

Further, roughly 500 times each year train accidents occur involving trains carrying hazardous materials. Although hazardous materials are actually released in only about 30 such accidents each year, prudence dictates careful evaluation of the situation by railroad and public authorities in a great many of the other instances.

Railroad operating employees also suffer significant injuries while working around moving equipment. In 1992, trainmen on duty sustained 1,707 injuries in train incidents, 163 of which were amputations and 463 of which were fractures.[7] Such injuries may occur on line of haul, at industry sidings, or in portions of railroad yards and terminals several miles from railroad offices. In some cases, promptness of emergency response may be critical.

Just as radio communications can be employed to save life after a train accident or incident, radio can be used to prevent serious accidents. Where automatic means of warning are not feasible or not provided (e.g., for broken rails, dangerously high water, fallen trees, derailed equipment fouling an adjacent main track, bridge damage from barge operations, etc.), radio communications may provide the last opportunity for accident avoidance. Although "near accident" data are not collected in the railroad industry, FRA is aware of numerous occurrences where use of voice radio has permitted accident avoidance or has significantly mitigated the severity of an accident.

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[6]Where the broadcast is made on the dispatcher channel, FRA found that detectors often interfered with dispatcher-train crew communications. Whenever interference is encountered, the risk increases that employees will take expedient actions, rather than following mandated procedures. The most effective solution to these problems would be the integration of detectors into a positive train control system.

[7]Accident/Incident Bulletin No. 161, Calendar Year 1992 (Federal Railroad Administration, July 1993), Tables 47 and 49.

The Railroad Communication Project

FRA has approached the safety inquiry on railroad radio communications in a consultative manner, involving Amtrak, freight and commuter railroads, rail equipment manufacturers, and railroad employees. A public meeting was conducted in March 1994 to enable interested parties to comment on voice radio communications. In addition, FRA has conducted a field assessment that has permitted FRA to verify actual conditions in the railroad operating environment while gathering information and views directly from working railroad employees.

Field Assessment

During the course of routine inspections, FRA inspection forces visit dispatching centers, ride trains, observe switching operations and conduct other monitoring of railroad operations on a daily basis. However, these activities are directed at a variety of compliance purposes. In order to provide a proper focus for this report, FRA conducted a special radio communications assessment during 1993, in conjunction with the Train Dispatcher Follow Up Assessment.

The scope of the field review involved FRA presence on most major railroads in the United States. FRA formulated an inspection plan which involved --

- On-site audits of 20 representative railroad dispatching offices where over 150 train dispatchers were monitored;
- Riding dozens of trains over every major traffic corridor in the country; and
- Spot visitations to local yard switching operations and yard offices.

FRA conducted on-site inspections involving teams of inspectors as well as inspectors working alone. An inspection methodology was provided to field inspectors to ensure that the information gathered was standardized and in a format consistent with project goals as outlined in Section 11. All data collected during the assessment were analyzed by FRA's Office of Safety headquarters technical staff in Washington, D.C.

Railroads audited were selected based upon a matrix which provided review of varying operational methodologies, dispatching technologies, and geographical differences. Major passenger and hazardous materials traffic routes weighed heavily in determining audit sites. Inspection methodology included the monitoring of radio traffic in the presence of railroad employees during normal operations, interviews with employees and officers, on-site observations in various terminals and yards, record reviews, and selective dispatcher desk auditing on each duty shift.

Prior to initiation of the field portion of the review, FRA contacted the American Train Dispatchers Department of the Brotherhood of Locomotive Engineers (ATDD) to obtain local labor contacts. At offices where ATDD represented train dispatchers (some train dispatchers are exempt employees), FRA's team chief visited local union officials to discuss respective concerns and recommendations. At the conclusion of each site visit, FRA conducted a detailed exit meeting with responsible railroad managers to advise them of FRA findings and recommendations. Copies of inspection reports were provided to respective officials at those meetings.

Findings

In general, FRA found railroad voice radio capabilities much improved since FRA's last programmatic review in 1987. Most major railroads have worked with suppliers and committed significant financial resources toward procurement of contemporary radio equipment. As a result, coverage, availability, and reliability of railroad voice communications have been improved. During the field study, FRA found that:

- Most trains inspected by FRA inspectors during the project were equipped with operative radios on the lead locomotive.

- Radio equipment appeared to be fairly reliable based upon employee comment and inspector observation during the project.

However, FRA found lingering issues that need resolution. Some radio-related problems remain in both hardware application and proper utilization in accordance with rules and regulations. For example, congestion of radio frequencies continues to be a concern in some dispatching districts. Sources of congestion include nonessential transmissions by a variety of officers/employees as well as improper use of assigned frequencies.

FRA also noted that on numerous occasions train dispatchers and officers/employees in the field did not comply with required radio standards and procedures. These deficiencies included improper transmission of mandatory directives in accordance with Federal requirements. Specific FRA concerns include the following:

Hardware Concerns:

- Radios at some dispatcher desks still experience "bleed-over" from neighboring dispatcher districts. In addition, some dispatchers related frustration with automatic wayside detectors which override their frequencies and interrupt radio transmissions with trains.

- There exist diverse and sometimes incompatible communication systems in some dispatchers offices. For example, FRA noted a few offices where "open speaker" systems are used, resulting in a need for constant monitoring by train dispatchers. This monitoring process created interference when dispatchers had to listen for verbatim readback of mandatory directives and critical information.

- Several dispatcher offices did not have a dedicated emergency channel. Additionally, some communication systems did not have capability to prioritize incoming calls as routine and emergency.

- In some offices, chief and assistant chief dispatchers could not monitor the shift dispatcher's radio communications from their workstation.

- Dispatchers related that reliability of locomotive onboard radios had improved considerably, but there were instances where crew communications were inhibited by weak or inoperative radios.

- Problems with the reliability of some systems were of continuing concern. Desk audits disclosed several specific locations where communications could not be initiated between the dispatcher and field personnel despite upgraded and modern systems. Similar concerns were experienced with mobile and cellular telephone systems. It appears the problem is rooted in peculiar atmospheric or terrain conditions rather than equipment malfunctions.

Human Interface Concerns:

- FRA found that some railroads continue to underutilize available frequencies. This exacerbates congestion on key channels required for safety-related communications. Specifically, during the 1993 review FRA found the following sources of interference:

    - Channels intended for road train use were used by yardmasters and terminal switching crews.

    - Channels intended exclusively for use to communicate with dispatchers were used by road crews engaged in such duties as adding or removing cars from their trains or to handle other communication of no value to the train dispatcher or other trains.

    - Maintenance-of-way employees frequently used the dispatching channel to communicate with each other, even though separate channels were available for this purpose.

    - Supervisors, administrative personnel, clerks, and even railroad taxi drivers used the dispatching channel for purposes not related to the safety of train operations.

- At most offices assessed, FRA noted frequent radio rule noncompliance. Many exceptions were extremely serious in nature, to include failure of the dispatchers and train crews to comply with 49 CFR §220.61 (transmissions of train orders by radio), and failure to assure on-track authorities are properly transmitted and repeated. These deficiencies also included occasional failure of train dispatchers and employees in the field to properly identify their stations, failure of the train dispatcher to require