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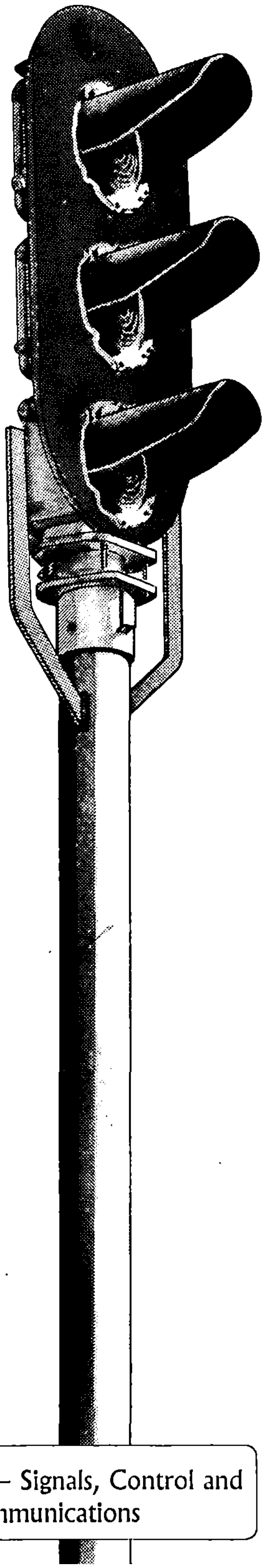

TASK 5
Economic Studies

DECEMBER 1980

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16. Abstract

Economics form an important aspect in the comparison of new technologies with those which are subject to possible replacement. This report presents an economic analysis of candidate state-of-the-art signal/control systems which were selected in preceding tasks of the project. The report focuses on passenger service improvements, capital and operating costs, reliability and maintainability, vandalism and the impact of standards. Consideration of these aspects leads to a cost/benefit analysis in which the technologies are configured in systems ranging in complexity from cab signaling with overspeed control to total monitoring and control from a remote point.

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PREFACE

This report results from research supported by the Department of Transportation, Federal Railroad Administration, Office of Research and Development, on seven separate but interrelated tasks under Contract DOT-FR-773-4236, "Evaluation and Assessment of Signal/Train Control System Equipment and Technology".

The contract covers the first phase of a multi-phased program directed at the upgrading of signal and control systems on Amtrak intercity rail routes for high speed 255 Km/h (160 MPH) passenger train travel. The seven tasks are as follows:

Task 1 - "Assessment of Signal/Control Technology and Literature Review"

Survey and assessment of the technologies incorporated in current signal and control practice; literature review and reference.

Task 2 - "Status of Present Signal/Control Equipment"

Review and analysis of major domestic and foreign railroads of the signaling systems now in use; discussion of candidate systems for adaptation by Amtrak; recommendations for further activity.

Task 3 - "Standardization, Signal Types, Signal Titles"

Analysis with emphasis on standardization of domestic and foreign operating rules and equipment, including signal types, aspects, titles and standards; analysis of impact of FRA Rules, Standards and Instructions (RSI) on development of improved systems; recommendations for standardization.

Task 4 - "Electrical Noise Disturbance"

Study of causes of electrical noise disturbance or EMI (Electro-Magnetic Interference) as it relates to signaling; recommendations on both rolling stock and wayside signaling equipment to reduce and limit the effect of EMI radiation to acceptable levels.

Task 5 - "Economic Studies"

Economic aspects of potential improved signaling systems including capital and operational costs, reliability and maintainability, effects of standards, costs savings and benefits.

Task 6 - "Specification Development"

Functional specification for an improved signal/control system to be used by Amtrak in intercity passenger rail operation at speeds up to 255 Km/h (160 MPH).

Task 7 - "Final Report"

Final report incorporating findings of Task 1 through 6 of this study and including recommendations for further work that may be usefully pursued in support of improved signaling systems, their application and utilization.

This document reports the findings of Task 5 -- "Economic Studies." The task was accomplished through interviews with railroad technical and managerial personnel, reviews of technical reports and papers and on-site visits to domestic and foreign railroads and transit systems, manufacturers, government agencies, and engineering associations.

The authors wish to acknowledge with appreciation the efforts and cooperation given by the many individuals in governments, railroads and elsewhere who contributed so greatly to the overall effort. To single out individuals who were especially helpful would risk overlooking others who also provided valuable assistance. Therefore, our sincere gratitude is extended to all who were contacted and assisted on the project.

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SECTION 1.0

INTRODUCTION

This report presents the results of Task 5 of the DOT contract DOT-FR-773-4236, entitled "Economic Studies". Task reports 1, 2, 3 and 4 assess the specific technologies available for use in the design of signal and control systems; determine the status of present signal/control systems; analyze standardization and signal aspects and titles; and study electrical noise disturbance. This report presents the direct costs associated with the development, installation and operation of candidate signal/control systems for high-speed passenger train operations.

1.1 Purpose and Scope

The purpose of this report is to investigate the economic aspects of the various signal/control technologies that have been assessed for domestic service. Areas of particular interest include passenger service improvements, capital costs, operating costs, reliability and maintainability, and the significance of standards. Considered also is an estimation of the cost/benefit ratio of the proposed technologies including possible effects caused by vandalism.

1.2 Procedure

As in tasks 1, 2, 3, and 4 (document references 394, 395, 403 and 410, Appendix A) initial activity was concentrated on a review of existing literature. Railroad Research Information Service (RRIS) bulletins were utilized to identify applicable documents in the time period 1973 to 1978. Since these bulletins are issued biannually, a separate search was conducted by RRIS to identify documents released during the calendar year 1978. Other sources of data were also identified and utilized such as the National Technical Information Service (NTIS), and various public, private, and university libraries. Technical publications were received from several sources. The principal contributors were the Northwestern University Transportation Center Library and the International Union of Railways (UIC), Office of Research and Experiment (ORE) Library. Over 400 documents were accumulated and reviewed in the conduct of the overall program. Additionally, 14 transportation periodicals were reviewed continuously to obtain current technical data.

From these data detailed questionnaires were developed and distributed to Amtrak-contracted railroads, transit properties and suppliers to obtain specific information for signal systems. Valuable information was received from both domestic and foreign respondents. Further analysis resulted in a narrowing of focus, and survey trips were then made to obtain additional data and to physically inspect specific systems. In the U.S., the Chicago Transit Authority and the Bay Area Rapid Transit system in San Francisco were surveyed. Certain railroads on which Amtrak operates were included in the U.S. portion of the railroad survey. These were the Union Pacific, Chessie System, Burlington Northern and Southern Pacific railroads. The European properties visited included: British Rail (BR), London Transport, French National Railroads (SNCF), German Federal Railroad (DB), Munich S-Bahn and U-Bahn systems, and the Italian State Railways (FS). The British Columbia Railway (BC) in Canada was also visited.

U.S. suppliers interviewed were General Railway Signal Company (GRS), Union Switch and Signal (US&S) Division of Westinghouse Airbrake Company (WABCO), Westinghouse Electric Company (WELCO), Harmon Electronics, Transcontrol Corporation, Safetran Systems Corporation, and Thompson-Ramo-Woldridge (TRW). Foreign suppliers visited were General Signal Company (GSC) Division of General Electric Company (GEC), and Westinghouse Brake and Signal

Company in England; Seimens Corporation and Standard Electric Lorenz (SEL) in Germany; and WABCO in Italy.

1.3 Background

Present day signal/control systems vary in complexity from fixed signs and written train orders to the more sophisticated computer aided traffic control systems (TCS). In all of these systems the philosophy of control circuitry and technology employed in the application of the design vary considerably. For example major differences exist between signaling and control systems implemented in the U.S. and Europe. They are due, in large part, to the design philosophy involved. It is therefore important that the reader have knowledge of the philosophical background involved.

In the United States, railroad signal and control systems began to evolve in the last decade of the 19th century. At the turn of the century, railroad signal engineers were well organized in the development of safe and efficient movement of trains by signal indication. While safety, as a primary objective, prevailed during evolution of signal systems, different operating philosophies and requirements produced a variety of aspects and rules. As early as 1906 Congress authorized a study of signal systems, and the first regulation appeared following enactment of the Transportation Act in 1920. This Act gave the Interstate Commerce Commission (ICC) authority to establish and enforce specifications for signaling equipment and to establish requirements for operation and maintenance of these equipments.

The Congressional study was confined to development and application of train stop and/or train control devices. Based on this study, the Federal government, in cooperation with the Signal Section of the American Railway Association, developed specifications and requirements for train stop, train control, and cab signaling systems. In 1922 the ICC, after conducting hearings on the subject, ordered 49 railroads to install automatic train stops or train control devices on at least one of their passenger service divisions. A revision to this order was issued in 1924 to expand the total number of railroads to 91 and permitted use of forestalling devices on engines. Given this impetus, suppliers and railroads developed both continuous and intermittent cab signaling systems. Prior to World War II the most common cab signal system applied code rated ac energy superimposed, within the rails, on the basic track circuit. In most cases the track circuit has been dc.

The Signal Inspection Act of 1937 gave the ICC additional authority to control signal systems by regulation. After World War II the character of railroad operations changed dramatically. The impact of the increased availability of automobiles and Federally-funded highways, including expressways, resulted in a decreased demand for passenger railroad service. This trend was accelerated by the rapid, government assisted development of air transportation and intercity bus systems. Meanwhile the railroads, faced with ever mounting maintenance costs, concentrated on freight traffic with fewer but longer and heavier tonnage trains. In 1947, ICC Order No. 29543 mandated train stop, train control, or cab signals for trains exceeding 80 MPH. One result of this activity was a decrease in train speeds, and since automatic train stop, train control, or cab signal systems were not required below the maximum speed, most automatic train control equipment was removed after formal hearings before the ICC. The end result is that the residual wayside portion of cab signaling equipment in use on the majority of U.S. railroads is based on 30-to-40 year old technology. Except for the newer, composite on-board cab signal packages developed to enable Amtrak locomotives to operate with various types of wayside cab signaling, no notable advances have been made in on-board cab signal equipment employed on U.S. railroads.

On the other hand, the need to move freight efficiently and economically has led to a rapid development of sophisticated, centralized traffic control systems. These systems came into being in the early 1930's using synchronous coded carrier systems. The recent availability of minicomputers and microprocessors have expanded the functional capabilities of TCS. TCS implementation has eliminated many manned signal control points and provided information in real time to the operating center for traffic management and maintenance operations, and utilization of TCS has eliminated the need for train orders to govern train movement. The efficiency provided by TCS has permitted reduction of main route trackage with a negligible loss of train capacity.

In Europe and Japan the development pattern of railroads was somewhat similar to that in the U.S. prior to World War II. The principal difference was that priority was placed on passenger train operation, and the traffic density in these countries was somewhat higher than in the U.S. After World War II, the development patterns markedly diverged. Because of wartime devastation in Europe and Japan, the top priority was placed on redevelopment of the rail transportation systems. This resulted in a continued passenger train market and the need for much higher train densities (shorter headways) than were utilized prior to World War II. These requirements forced a rapid growth in cab signaling and ultimately a high degree of automatic train control.

The UIC, through ORE, developed standards for new signaling systems for the European countries and a similar effort took place in Japan. Since the purpose of such systems is to provide increased safety the development program was appropriately directed, and the design standards were rewritten to reflect the new technologies as they became available. In both Europe and Japan the use of redundancy to achieve fail-safe operation is common and implementation of redundant voting computers and microprocessors is becoming a standard means of achieving fail-safe, fail-operational system capability.

The first use of a fully computerized train control system took place in Japan on the Shinkansen line which became operational in 1964. This high speed system operates up to 220 Km/h (135 MPH) on seven-minute headways and has proven to be so successful that the Japanese National Railways (JNR) have implemented the basic design of the signal/control and communication system as the standard for all JNR passenger train service. In Europe the intermittent cab signaling system which was standard prior to World War II has been upgraded to reflect current technology and is widely used for medium density operation. High density operation, which requires continuous cab signaling, is achieved most commonly by the use of ac coded systems with the running rails as the transmitting media or by use of digitally modulated audio frequency carriers using inductive loops as the transmitting elements. The latter is standard for the German federal railways for those lines carrying their high speed passenger trains.

The development of transit systems in the U.S. and Europe has followed patterns similar to those of the railroads. European transit systems utilize essentially the same signaling design as the railroads except that fully automatic train operation is standard. U.S. transit properties either utilize standard railroad signaling equipment with automatic train stop or cab signaling and automatic train operation employing coderated frequency track circuits on the newer systems (or upgraded existing systems). A few U.S. transit systems also utilize computer technology in their train operation systems.

There are two basic functions in a railroad signal system: the first is train detection, and the second is to convey information to the train engineman or operator. The train detection function can be accomplished in different ways. In the United States and throughout much of the world the track circuit is employed to detect the presence or absence of a train and to provide broken-rail protection. A track circuit is defined as an electrical circuit of which the rails form a path. Basically, three types of track circuits are employed:

- DC track circuits
- AC track circuits
- AF track circuits

The dc track circuit can be further classified as a neutral, polarized or coded circuit and the ac can be further classified by its frequency (normally below 200 Hz) and the code rate. AF track circuits use audio frequencies usually above 500 Hz and are normally coded.

In most foreign countries, the track circuit is used for train detection; however, in some instances train detection is accomplished by axle counters in conjunction with inductive loops. This type of detection does not use the rails as part of the circuit.

The other function of signaling is to convey information to the engineman through visual aspects displayed by color light, searchlight, position light, semaphore or cab signals. The aspect of the signal indicates to the engineman the condition of the track ahead, and in turn he controls the train in accordance with the indication conveyed by the aspect. Additionally, the wayside signal can also indicate to the engineman the route his train will take and/or the speed at which the train may proceed. In the U.S. signal aspects are normally used to provide indications of authorized speed (speed signaling), while in Europe wayside signal aspects at interlockings normally provide route information (route signaling).

For higher speed operation on domestic and foreign railroads some form of cab signaling with or without enforced overspeed control is employed. Such systems are commonly used in conjunction with wayside block signals but may be used without them.

1.4 Definitions

For the purpose of this report, the following definitions of words, terms and phrases used in railway signal and train control systems apply. These definitions are intended only as an aid to the material contained herein.

Aspect, False Restrictive - The aspect of a signal that conveys an indication more restrictive than intended.

Aspect, Signal - The appearance of a roadway signal conveying an indication as viewed from the direction of an approaching train; the appearance of a cab signal conveying an indication as viewed by an observer in the cab.

Automatic Block Signal System (ABS) - A block signal system wherein the use of each block is governed by an automatic block signal, cab signal, or both.

Automatic Train Control (ATC) - The system for automatically controlling train movement, enforcing train safety and directing train operations. ATC includes subsystems for Automatic Train Protection, Automatic Train Supervision, and Automatic Train Operation.

Automatic Train Operation (ATO) - The subsystem within Automatic Train Control which performs the on-board functions of speed regulation, program stopping and performance adjustment.

Automatic Train Protection (ATP) - The subsystem within Automatic Train Control which maintains safe train operation. ATP subsystems include train detection, train separation, interlocking, and speed limit enforcement.

Automatic Train Supervision (ATS) - The subsystem within Automatic Train Control which monitors and provides controls necessary to direct the operation of a system of trains in order to maintain intended traffic patterns and minimize the effects of train delays on the operating schedule.

Block - A length of track of defined limits which may consist of one or more track circuits.

Block, Absolute - A block in which no train is permitted to enter while it is occupied by another train.

Cab - The compartment of a locomotive from which the propelling power and power brakes of the train are manually controlled.

Cab Signal - A signal located in the engineman's compartment or cab, indicating a condition affecting the movement of a train and used in conjunction with interlocking signals and in conjunction with or in lieu of block signals.

Cab Signal System - A signal system so arranged that wayside conditions are indicated in the cab or compartment of a locomotive.

Capital Cost - The investment necessary for the procurement, installation and replacement of fixed tangible assets.

Circuit, Acknowledgement - A circuit consisting of wire or other conducting material installed between the track rails at each signal in territory where an automatic train stop system or cab signal system of the continuous inductive type is in service to enforce acknowledgement by the engineman at each signal displaying an aspect requiring a stop.

Circuit, Control - An electrical circuit between a source of electric energy and a device which it operates.

Circuit, Cut-in - A roadway circuit at the entrance to automatic train stop, train control or cab signal territory by means of which locomotive equipment of the continuous inductive type is actuated so as to be in operative condition.

Circuit, Line - Any circuit the function of which affects the safety of train operation.

Circuit, Non-vital - Any circuit the function of which does not affect the safety of train operation.

Circuit, Track - An electrical circuit of which the rails of the track form a part.

Circuit, Track; Coded - A track circuit in which the energy is varied or interrupted periodically.

Circuit, Track; High Level AC/DC - A track circuit which employs relatively high alternating circuit voltage on rails, low impedance energy source, and transformer-rectifier unit between rails and direct current track relay.

Circuit, Track; Impulse - A track circuit into which high voltage, high current pulses of extremely short duration are fed to a receiver with a differential track relay which can distinguish working pulses from interference.

Circuit, Track; Phase Selective - An ac track circuit consisting of a discrete ac signal frequency, code transmitters, code following relays, and a phase selective detector unit. Local and operating energy applied to the phase selective unit must be in proper phase relationship in order that the code following track relay will respond to the track circuit command codes.

Circuit, Vital - Any circuit the function of which affects the safety of train operation.

Code, Transmitter - A device to periodically vary an electrical circuit at a definite predetermined code frequency.

Contact - A conducting part which functions with another conducting part to open or close an electrical circuit.

Continuous Control - A type of control in which the locomotive apparatus is constantly in operative relation with the track elements and is immediately responsive to a change of conditions in the controlling section which affects train movement.

Cost/Benefit - The ratio between capital cost and revenue or benefit used in determining the cost effectiveness of investments.

Cost Effective - When the cost to revenue ratio is sufficient to generate net profits or benefits above capital and operating costs.

Cut-section - A location other than a signal location where two adjoining track circuits end within a block.

Device, Acknowledging - A manually operated electric switch or pneumatic valve by means of which, on a locomotive equipped with an automatic train stop or train control device, an automatic brake application can be forestalled, or by means of which, on a locomotive equipped with an automatic cab signal device, the sounding of the cab indicator can be silenced.

Distance, Stopping - The maximum distance on any portion of any railroad which any train operating on such portion of railroad at its maximum authorized speed, will travel during a full service application of the brakes between the point where such application is initiated and the point where the train comes to a stop.

Economic Life - The period of time that equipment, products or services generate satisfactory earnings or benefits.

Economic obsolescence - When equipment or systems cannot generate profits or benefits because the physical, technological or market life has been exceeded.

Element, Roadway - That portion of the roadway apparatus of automatic train stop, train control or cab signal system, such as electric circuit, inductor, magnet, ramp or trip arm, to which the locomotive apparatus of such system is directly responsive.

Enforced Cab Signaling - A signaling system so arranged that its operation will automatically result in the application of the brakes until the train has been brought to a stop.

Fail-Safe - A term used to designate a railway signaling design principle, the objective of which is to eliminate the hazardous effects of a failure of a component or system.

False Restrictive (FR) - A failure of a system, device or appliance to indicate or function as intended which results in greater restriction than is required.

False Proceed (FP) - A failure of a system, device or appliance to indicate or function as intended which results in less restriction than is required.

Forestall - As applied to an automatic train stop or train control device, to prevent an automatic brake application by operation of an acknowledging device or by manual control of the speed of the train.

Frequency - The number of cycles through which an alternating current passes per second.

Impedance - The apparent resistance in an electric circuit to the flow of an alternating current, analogous to the actual electrical resistance to a direct current, being the ratio of electromotive force to the current.

Indicator, Cab, Audible - A device (usually air whistle) located in cab equipped with cab signals designed to sound when cab signal changes and continues to sound until acknowledged.

Insulated Joint - A rail joint in which electrical insulation is provided between adjoining rails.

Interlocking - An arrangement of signals and signal appliances operated from an interlocking machine and so interconnected by means of electric locking that their movements must succeed each other in proper sequence, and train movements over all routes are governed by signal indication.

Interlocking, Automatic - An arrangement of signals, with or without other signal appliances, which function through the exercise of inherent powers as distinguished from those whose functions are controlled manually, and which are so interconnected by means of electric circuits that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication.

Interlocking, Manual - An arrangement of signals and signal appliances operated from an interlocking machine and so interconnected by means of mechanical and/or electrical locking that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication.

Interlocking, Relay Type - An arrangement of signals, with or without other signal appliances, operated either from a control machine or automatically, and interconnected by means of electric circuits employing relays so that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication.

Intermittent Control - A type of control in which the locomotive apparatus is affected only at certain designated points, usually at signal locations.

Life Cycle - The period of time a unit can produce profit or benefits. The period between installation and replacement.

Line of Light Control - A control system wherein the route called for, and train occupancy, is displayed on the console or model board by a series of lights.

Meet - A pre-programmed or pre-determined point where one train meets another as prescribed by train orders, timetable or signal indications.

Relay - A device that is operative by a variation in the conditions of one electric circuit to affect the operation of other devices in the same or another electric circuit.

Relay, Biased - A relay which will operate to its energized position by current of one polarity only, and will return to its de-energized position when current is removed.

Relay, Centrifugal - An alternating current frequency selective relay in which the contacts are operated by a fly ball governor or centrifuge driven by an induction motor.

Relay, Code Following - A relay which will follow or reproduce a code without distortion within practical limits.

Relay, Magnetic Stick - A relay, the armature of which, remains at full stroke in its last energized position when its control circuit is opened.

Relay, Two-Element - A relay, usually alternating current, having two separate windings, both of which must be properly energized to cause the relay to operate.

Relay, Vane Type - A type of alternating current relay in which a light metal disc or vane moves in response to a change of the current in the controlling circuit.

Resistance, Ballast - The resistance offered by the ballast, ties, etc., to the flow of leakage current from one rail of a track circuit to the other.

Resistance, Train Shunt - The actual resistance in ohms from rail to rail through wheels and axles of a train, locomotive or car. The resistance will vary with rail and wheel surface conditions and with weight of equipment.

Shunting Sensitivity - Shunting sensitivity of a track circuit is:

1. Non-Coded track circuit - The maximum resistance in ohms which will cause the relay contacts to open when this resistance is placed between the rails at the most adverse shunting location.

2. Coded track circuit - The maximum resistance in ohms which will prevent the code responsive track relay from following the code when this resistance is placed between the rails at the most adverse shunting location.

Signal - An appliance which conveys information governing train movements.

Signal, Approach - A fixed signal used in connection with one or more signals to govern the approach thereto.

Signal, Cab - A signal located in engineman's compartment or cab, indicating a condition affecting the movement of a train or locomotive and used in conjunction with interlocking signals and in conjunction with or in lieu of block signals.

Signal, Color Light - A fixed signal in which the indications are given by the color of a light only.

Signal, Color Position Light - A fixed signal in which the indications are given by color and the position of two or more lights.

Signal, Distant - A term synonymous with approach signal.

Signal, Dwarf - A low home signal.

Signal, Home - A fixed signal at the entrance of a route or block to govern trains or locomotives entering and using that route or block.

Signal, Position Light - A fixed signal in which the indications are given by the position of two or more lights.

Signal, Semaphore - A signal in which the day indications are given by the position of a semaphore arm.

System, Absolute Permissive Block - A block signal system under which the block is usually from siding to siding for opposing movements, and the fixed signals governing entrance into the block display an aspect indicating Stop when the block is occupied by an opposing train. For following movements the section between sidings is divided into one or more blocks and train movements into these blocks (except the first one) are governed by intermediate fixed signals, cab signals, or both. For their most restrictive indications the intermediate fixed signal usually displays an aspect indicating Stop then Proceed at Restricted Speed, and the cab signal displays an aspect indicating Proceed at Restricted Speed.

System Cost - The cost associated with the development, procurement and installation of a tangible asset usually composed of several elements arranged to perform as a functional unit within given performance specifications.

System, Enforced Cab Signal - A system so arranged that its operation will automatically result in the application of brakes until the train has been brought to a stop.

System, Block Signal - A method of governing the movement of trains into or within one or more blocks by block signals or cab signals.

System, Universal Code - A signal system employing continuously coded track circuits, code following relays and decoding units.

Traffic Control System (TCS) - A block signal system under which train movements are authorized by block signals whose indications supersede the superiority of trains for both opposing and following movements on the same track.

Train-to-Wayside Communication System (TWC) - A non-vital, bi-directional, digital data communications system for communication, at fixed points, between the trains and wayside.

Transponder (Wayside) - A tuned wayside device, either active or passive, which, when electro-magnetically coupled to a receiving unit on a locomotive, conveys speed control, location or other information to the train. The locomotive-mounted unit, when active, is called an interrogator.

Within the signal industry considerable difference in interpretation or meaning of technical terms exists. These different interpretations and meanings which have developed in domestic and foreign technical literature have often caused confusion to U.S. railroad and transit signal engineers. Four terms which are important to an understanding of this report, but which have received varying interpretations, are the following: (1) Automatic Train Control, (2) Automatic Train Operation, (3) Automatic Train Protection, and (4) Automatic Train Supervision.

Although each of these technical system terms has already been defined herein, the interrelationship of these major signal/control systems and component subsystems is further illustrated in Figure 1-1, in order that the reader may identify the contemporary context of this report.

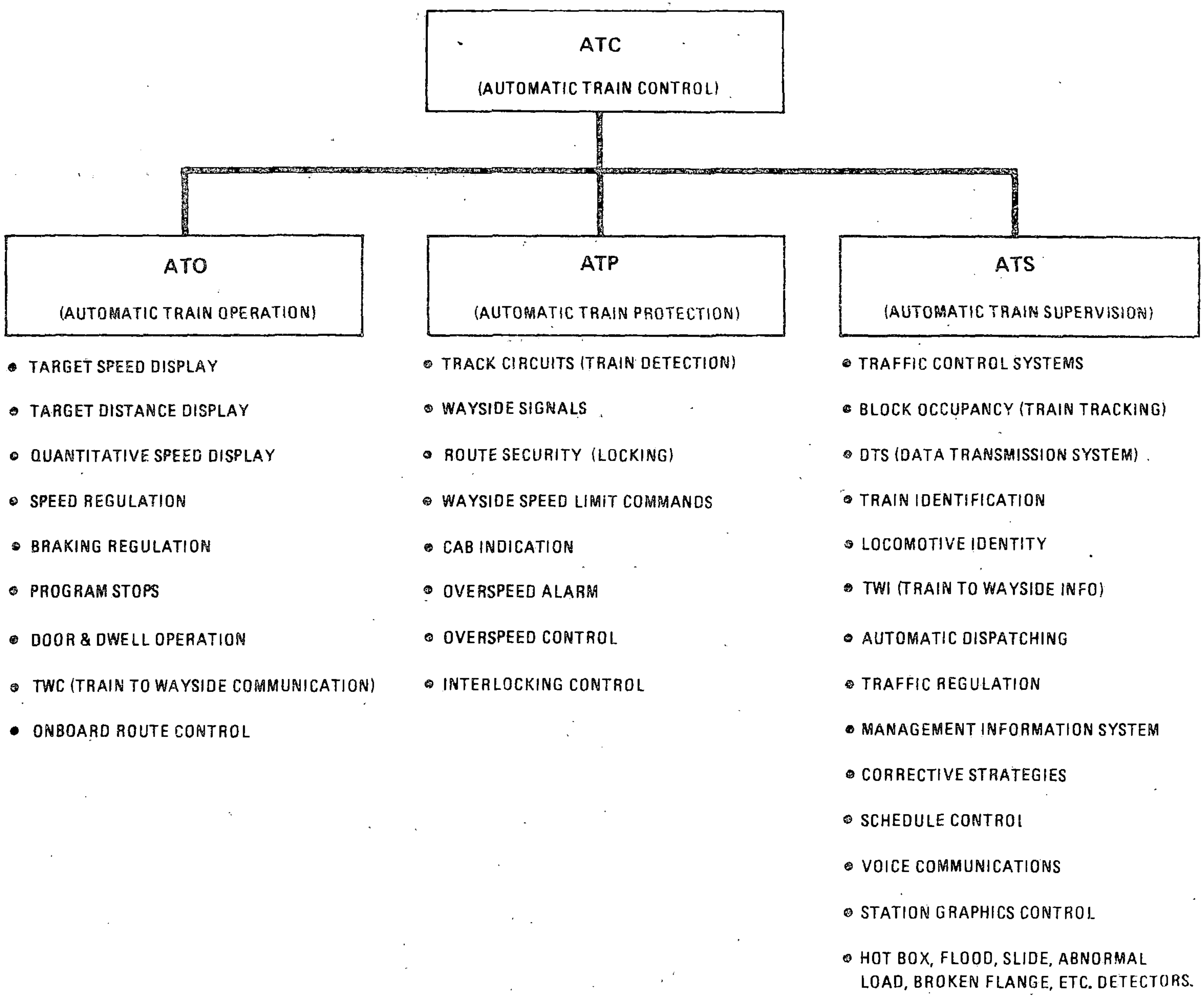

FIGURE 1-1. RELATIONSHIP OF MAJOR SIGNAL SYSTEMS AND AVAILABLE FUNCTIONAL SUBSYTEMS

1.5 Report Organization

This report has been prepared to show the capital requirements, effects on operating costs, and the benefits that can be expected with the installation of signal/control systems for high speed passenger train service.

Cost data are presented as cumulative costs expressed in dollars per track mile. It is recognized that a firm--or even average--cost of signal/control systems is difficult to accurately assess in a cost per track mile parameter because of the many variables that occur in signal system installation. Block lengths, signal spacing, signal type, number of sidings, interlockings, highway grade crossings, type of communication system, methods of installation and many other variables affect the final cost of any signal/control system installation. To provide the adjustment necessary to accommodate these variables all cost presentations and analyses will be made within a cost range that can be interpolated to the user's estimated level of complexity of system installations.

Additionally, many factors that influence overall system costs may be presented as specific costs in appropriate paragraphs discussing the function. For example, maintenance, safety, service improvements, standardization and training requirements all influence total costs. These specific costs are provided where information was available. These cost data may be based upon an average of data sources or from a single source. In each instance the source will be identified and the costs presented will be qualified in an effort to provide the reader with the best data assessment possible.

Sections 1.0 and 2.0 summarize the findings in Tasks 1, 2, and 3 final reports, document references No. 394, 395, and 403, respectively, as listed in Appendix A.

Section 1.0 provides the necessary background to demonstrate to the reader the relationship of this report to the others developed during the program.

Section 2.0 provides the technical evaluation and selection of the signal/control systems assessed in Tasks 1 and 2 to meet three levels or categories of implementation.

Various systems representing the state-of-the-art of signal/ control technologies have been identified and classes by categories for candidate system implementation.

Capital equipment costs for each candidate system are included in section 3.0 to the depth that data were available. These data are evaluated along with the operational costs developed in section 5.0 and system improvement effects identified and projected in section 7.0 to provide a base cost for development, installation, operation and maintenance of a proposed signal/control system to be utilized for high speed passenger trains.

A typical long distance Amtrak corridor has been selected to illustrate cost requirements for the installation and operation of an overlay system for high speed train control. Section 6.0 identifies the corridor, describes the signal/control systems that currently exist along the entire route and provides cost estimates for installation of each of the candidate overlay systems to this typical long distance corridor.

Section 7.0 describes the elements required for a complete cost/benefit analysis. It also considers several factors which cannot be measured on a profitability basis. Section 8.0 summarizes installation and maintenance costs. Recommendations are then made as to the direction of future effort in this program.

SECTION 2.0

SELECTED TECHNOLOGY

2.1 System Requirements

A signal/control system is required to provide the protection and control of high speed passenger train traffic on existing domestic railroads. The system is to be overlayed on existing signal/control systems for passenger trains intermixed with local commuter and freight train traffic.

The following significant requirements for an overlay signal/control system are considered necessary to provide the capability for safe, high speed passenger train operation intermixed with freight and commuter train traffic.

- Cab Signaling, in some form, is mandatory. Wayside signals, alone, are no longer adequate because the speed of operation does not provide sufficient viewing and reaction time by the engineman.

- A minimum of five signal (speed) aspects is considered necessary.

- Overspeed control is necessary to assure safe train operation at high speed because of headway and reaction time limitations.

- Compatibility with electrification is required to assure fail-safe operation in any track environment.

- Automatic Train Operation (ATO) may be desirable but is not mandatory. Its cost-effectiveness is a trade-off consideration.

The investigation and evaluation of current signal/control system technology and equipment are presented in tasks 1 and 2 final reports. Figure 2-1 provides a technical evaluation matrix which rates various signal/control system technologies with respect to system evaluation factors.

2.2 Candidate Systems

Several candidate signal/control and communication overlay systems have been identified and can be separated into three broad categories:

Category A. These requirements are 255 Km/h (160 MPH) operation of passenger trains intermixed with slower freight traffic in electrified territory.

Category B. In addition to fulfilling Category A requirements, these systems must also provide passenger train identification and tracking data to a central monitoring point.

Category C. The Category C requirements fulfill the Category A and B criteria and allow the central control point to exercise limited control of the passenger train speeds. Fulfillment of these requirements will allow the central control point to enforce timetable schedules and possibly to provide time of arrival data to passenger train stations.

2.2.1 Category A Candidate Systems

The minimum system which fulfills the basic Category A requirements is a 5-aspect cab signaling system with enforced overspeed control. The automatic train protection candidate systems capable of satisfying the Category A requirement are:

- 5-Aspect (100 Hz) NEC - This is a single carrier 100 Hz ac coded system as used in the United States. The fifth aspect could be provided via addition of either a 50 ppm

TECHNOLOGIES / EVAL. FACTORS	TRAIN DETECTION				CAB SIGNALING			ATS CONTROL		DISPLAY SYSTEM			COMMAND SYSTEM			COMMUNICATION SYSTEM				
	AC CODED	AUDIO FREQ.	HV IMPULSE	AXLE COUNTER	CODED AC	INTERMITTENT	CATC	RELAY LOGIC	COMPUTER LOGIC	HARDWIRE CUSTOM PANEL	HARDWIRE MODULAR PANEL	COLOR CRT	LINE OF LIGHT CONTROL	KEY BOARD CONTROL	LIGHT PEN CONTROL	TELEPHONE	V H F	U H F	MICROWAVE	
DEVELOPMENT RISK	4	3	2	3	4	3	3	5	4	4	5	4	4	4	3	4	4	3	4	1 HIGHEST RISK 5 LOWEST RISK
TECHNOLOGICAL GROWTH	4	3	3	4	3	3	4	1	4	1	3	4	1	3	4	4	1	3	4	
EXPANSION PROVISIONS	2	2	3	4	3	4	4	1	4	1	3	4	1	4	3	4	3	2	3	
PERFORMANCE GROWTH	2	3	3	4	3	2	4	1	4	1	2	4	1	3	4	3	2	3	4	
ELECTRIFICATION COMPATABILITY	3	4	1	4	3	5	5	4	4	5	5	5	5	5	5	2	4	5	5	
EMI/SURGE SUSCEPTABILITY	4	3	4	4	2	4	3	4	2	3	4	3	4	3	3	2	3	4	4	
FEDERAL REG. IMPACT	5	4	1	1	5	4	2	5	5	5	5	5	5	5	5	5	4	5	5	
	24	22	17	24	23	25	25	21	27	20	27	29	21	27	27	24	21	25	29	

FIGURE 2-1. TECHNICAL EVALUATION MATRIX

code rate (as used on the LIRR) or a 270 ppm code rate. Either of these code rates would require modifications to both existing on-board and wayside equipment.

- Intermittent - Intermittent cab signaling systems with either active or passive wayside transponders would meet the Category A requirements. This type of system could be derived from British Rail (BR), German Federal Railroad (DB), or Italian State Railways (FS) configurations. These configurations are discussed in detail in the tasks 1 and 2 reports.

- Continuous Inductive Loop - The continuous inductive loop system can be derived from the Continuous Automatic Train Control (CATC) in use by the German Federal Railroad (DB) consisting of a series of transposed inductive loops mounted on the track centerline between the rails. A train-borne antenna is positioned so as to pass continuously over the loop. A continuous data exchange between the train and control center provides for operation of all trains, train routing and station arrival schedules. A complete system description is provided in tasks 1 and 2 final reports.

- Dual Carrier AC Coded - The Italian State Railways (FS) has upgraded their Rome to Florence line to include two separate coded ac carriers. A 50 Hz coded track circuit provides continuous train control; a second or overlay 175 Hz coded track circuit is added to provide additional speed control for high speed passenger trains. The high speed trains are equipped to decode both carrier frequencies, while slower trains are limited to the 50 Hz carrier to obtain the applicable speed limits. Further system descriptions are available in task 1 and 2 final reports.

- Location - Indication Control (LIC) - The LIC system used by the British Columbia Railway is based on digital radio communication between the central controller and each main track train. Train location is provided by train interrogation of coded passive transponders that are located between the rails at fixed distances. Information from the wayside units provide train location, speed and identification data which are transmitted back to the central control point for processing and responsive train control. A detail description of the LIC system is provided in tasks 1 and 2 final reports.

2.2.2 Category B Candidate Systems

The system that satisfies Category B requirements can use any of the Category A candidate systems, but a data link must be developed between the passenger trains or the wayside portion of the cab signal system and a central monitoring point. This data link could be provided by the existing train-borne VHF radio. It could alternatively be comprised of separate telephone links to the existing Traffic Control System (TCS) centers or of telephone/microwave links to the overlaid cab signal systems.

2.2.3 Category C Candidate Systems

Category C systems can utilize any of the Category B systems. However, a data link must be added between the central control point and the overlayed Category B system to allow commands to be sent to the trains and stations for the control of schedule performance.

2.3 System Interface

From the requirements of the candidate signal/control systems discussed in the preceding paragraphs, the potential interfaces between the basic and overlay signal/control systems include:

- Individual signal blocks in existing ABS systems

- Train Control System (TCS) data centers
- Train to wayside VHF radio links
- Wayside to TCS control center telephone or microwave links.

The potential signal/control system candidates are assumed to be overlayed on at least an existing ABS system. This assumption simplifies design requirements for the overlay system and avoids overcomplicating the system.

Any one of the existing signal types could be installed wherever timetable and train order (TT&TO) is in effect, which is less than 6 percent of the total track miles over which Amtrak operates. Alternatively, if broken rail protection is not required, an axle counter system with wayside signals could be implemented.

2.3.1 Category A Interfaces

Figure 2-2 summarizes the track circuits presently in use as well as their compatibility with the potential Category A overlay system. Selected potential systems are discussed in the following paragraphs along with special considerations for implementation of these systems.

- 5-Aspect (100 Hz) NEC - This is a single carrier, 100 Hz, ac coded system currently used in the United States. The fifth aspect could be provided on existing four-aspect systems by the addition of a fifth code rate to the existing four code rates.

- British Rail (BR) Intermittent System - One of the simplest installations is the BR intermittent cab signal system, because there is no interface with the existing system. This system allows the engineman to interpret the existing wayside signal aspects in terms of his train's braking performance, while the cab signal system imposes the geographic restrictions on those speed limits.

EXISTING SYSTEM/ OVERLAY SYSTEM	STEADY DC	CODED DC
5 Aspect (100 Hz) NEC	Track Circuit	Track Circuit
Intermittent (BR)	None	None
Intermittent (DB)	Signal	Signal
Intermittent (FS)	Signal	Signal
Dual Carrier Continuous (FS)	Track Circuit	Track Circuit
Inductive Loop Continuous (DB)	Signal or Track Circuit	Signal or Track Circuit
Location-Indication-Control (BCR)	None	None

FIGURE 2-2.

STEADY AC	CODED AC	AUDIO	TT & TO
Track Circuit	Add to Existing Logic	Track Circuit	Total System Install
None	None	None	Not Useable
Signal	Signal	Signal	Add Axle Counters
Signal	Signal	Signal	Add Axle Counters
Track Circuit	Add to Existing Logic	Track Circuit	Total System Install
Signal or Track Circuit	Signal or Track Circuit	Signal or Track Circuit	Add Axle Counters
None	None	None	Total System Install

INTERFACE TYPES

- Italian State Railways (FS) and German Federal Railroad (DB) Intermittent Systems - The FS and DB intermittent cab signaling systems can be interfaced with any ABS system if additional aspects are not required. The wayside transponders are simply located in advance of the wayside signal they are to repeat and interface with the signal control circuitry. The transponder units do not draw power, so only a contact closure is required for each aspect to be designated.

- Italian State Railways (FS) Continuous System - The implementation of the FS continuous cab signaling system requires that the interface be located at the track relays. The most practical track circuits for interfacing with the FS continuous cab signaling are ac coded systems. These coded systems already contain the majority of the logic required, and only the additional aspects (or the second carrier) need be added.

- German Federal Railroad (DB) Continuous Inductive Loop System - The continuous inductive loop cab signaling system interfaces with the track circuit requiring a contact closure for each circuit denoting occupancy status. Loop sections must be installed between the rails. In the event that minimum headway operation is not necessary, the wiring interface to the existing system could be made at the wayside signals only, thus simplifying the interface. Vandalism would be a major problem with this system because of the exposed inductive loop wiring.

2.3.2 Special Considerations

Special considerations must be given to Category A systems for implementation in unique situations.

- Timetable and Train Order Considerations - On those portions of the Amtrak system which are currently operated by TT and TO, the interface requirements for the potential system will necessitate the installation of some basic track signal/control system for freight traffic. The installation of axle counters on DB and FS intermittent systems to define the blocks would allow the cab signal system to be installed and wayside signals could then be installed to interface the axle counters. This same technique is also valid for the installation of the inductive loop system. The use of the proposed NEC or FS continuous systems would require rework of the rail structure to provide insulated joints and installation of track circuits. In either case, if mixed traffic is to be considered with only passenger trains equipped with cab signals, wayside signals must be added, and a revision of the existing RS&I Rules would be required.

- Electrification Considerations - A similar situation is presented if there is electrification of any lines over which Amtrak now operates. The only significant electrified territory at present is the NEC which Amtrak already owns. The only existing domestic train detection circuits compatible with electrification at 60 Hz are ac track circuits using phase selective type track circuits. The overlay system can be used to replace existing incompatible systems.

- <u>Jointless Continuous Welded Rail Considerations</u> - In the event that it is desired to implement a system utilizing jointless continuous welded rail (CWR) with a minimum of insulated joints, the choice of systems becomes limited. The available train detection systems are either audio frequency circuits or axle counter systems. The latter have the disadvantage of not providing broken rail protection but are much simpler from both installation and maintenance standpoints. The choice of overlay systems is limited to the FS and DB intermittent and the DB continuous signaling systems since neither the NEC or FS coded track circuits are compatible with jointless CWR.

- <u>Highway Grade Crossing Considerations</u> - The questions concerned with operation of high speed trains over highway grade crossings is an investigative area which is not a part of this contract. However, in Task 6 of this study, recommendations are addressed which pertain to this and other related investigative areas.

2.3.3 <u>Category B and C Interfaces</u>.

The implementation of Category B and C systems presupposes that one of the Category A cab signaling systems exists or has been selected. Any of these systems can be expanded to achieve Category B and C requirements. The available interface for the data transmission to the central monitor point varies between systems as well as the types of data which can be transmitted. The types of data desired at the control monitor points are:

- Train Position
- Train Speed
- Train Identity
- Train Status

The implementation of a Category C system requires the addition of a data link from central control point to the train, which is merely making the data links described in Category B two-way links.

In all Category B and C implementations the central monitor and control computers would interface color CRT's for display. For data entry, a standard teletype keyboard can be used and hard copy data provided via line printer.

- Intermittent Systems - Expansion of the intermittent systems to achieve Category B and C requirements is limited in that the achievable minimum headway is greater than that of the continuous systems. With the BR intermittent system the wayside transponders can be location-coded, so that position data are available to the train at every checkpoint. The most desirable data interface then would be the existing train VHF or UHF radio. There are data packages available for interfacing these radio media to allow "burst" data to be transmitted to the central receiving point. The train-borne transponder can be expanded to add the logic and memory to store train identity, speed and status information for input to the VHF radio data module. The FS and DB intermittent systems are limited to about 8 bits of data in the wayside transponder's coding, so for very large systems it might be necessary to use a repetitive location code. Otherwise the installation would be the same as the BR system.

- Continuous Systems - With the FS continuous coded ac system location data are not easily transmitted to the train, so the most logical data interface is in the relay units at the wayside. These data interfaces connect microprocessors and modem units by either telephone lines or microwave links communicating with the central monitor point. This interface provides train position data, but train speed and identity must be directly computed at the central monitor point. Train identity can be manually entered in the central computer as the train enters the system. Train status data are directly available only when a VHF data link is installed on the train.

- Inductive Loop Systems - The inductive loop system provides the most interface options, since two-way communication already exists between the train and the loop controllers. Also, train identity, location, speed, and status data are present at both locations, so that the choice of interfaces is largely a matter of convenience and cost.

Category B and C interfaces would be compatible for tie-in to modern computer dispatching systems currently under development and installation on some U.S. railroads. Such systems, with varying degrees of management information subsystems, are already operational on such carriers as the Chessie, Southern Pacific and Louisville and Nashville.

SECTION 3.0

CAPITAL COSTS

The development of capital costs for any selected wayside overlay or on-board signal/control system involves a multitude of factors as to type and degree of sophistication. Substantial cost variance is caused by such factors as traffic density, speeds, headways, tonnages, number and size of interlockings, number of highway crossing protection devices, and the inherent problems involved in retrofitting a variety of different types of locomotives with the selected train control equipment.

In Section 2 of this report, the selected types of candidate overlay systems were summarized, as well as their compatibility with track circuits presently in use. In this section estimated cost ranges are presented for the procurement and installation of each of the candidate overlay systems.

In the development of these cost ranges, all estimated costs were based on 1978 prices for labor and material, with all installation and interfacing labor to be provided by railroad personnel. Certain candidate system technologies will be tested and evaluated during Phase II, followed with a demonstration system overlayed on an existing railroad in Phase III.

3.1 Category A Candidate System Costs

The cost data presented in this section were developed in the Task 2 report and are repeated here for the convenience of the reader.

Figure 3-1 summarizes the estimated cost ranges developed for procurement and installation of each of the Category A candidate

CATEGORY "A"

ESTIMATED COST RANGES - (PER MILE) - WAYSIDE SYSTEMS
(IN THOUSANDS)

EXISTING OVERLAY	STEADY DC	CODED DC	STEADY AC	CODED AC	AUDIO	TT&TO
5-Aspect (100 Hz) NEC:						
. ROW Cost/Mile	28/30	28/30	28/30	28/30	28/30	49/52
(+) . Per Track Mile	11/12	7/9	11/12	4/7	11/14	NA
(+) . Per Locomotive	45/58	45/58	45/58	45/58	45/58	45/58
Intermittent (BR):						
. ROW Cost/Mile	0	0	0	0	0	54/55
(+) . Per Track Mile	8/9	8/9	8/9	8/9	8/9	NA
(+) . Per Locomotive	27/30	27/30	27/30	27/30	27/30	27/30
Intermittent (DB):						
. ROW Cost/Mile	0	0	0	0	0	53/55
(+) . Per Track Mile	7/8	7/8	7/8	7/8	7/8	NA
(+) . Per Locomotive	22/23	22/23	22/23	22/23	22/23	22/23
Intermittent (FS):						
. ROW Cost/Mile	0	0	0	0	0	55/57
(+) . Per Track Mile	8/9	8/9	8/9	8/9	8/9	NA
(+) . Per Locomotive	30/31	30/31	30/31	30/31	30/31	30/31
Dual Carrier Continuous (FS):						
. ROW Cost/Mile	28/30	28/30	28/30	28/30	28/30	49/52
(+) . Per Track Mile	15/20	11/14	15/20	7/13	19/22	NA
(+) . Per Locomotive	67/72	67/72	67/72	67/72	67/72	67/72
Inductive Loop Continuous:						
. ROW Cost/Mile	28/30	28/30	28/30	28/30	28/30	47/62
(+) . Per Track Mile	49/64	47/62	49/64	47/62	51/66	NA
(+) . Per Locomotive	113/125	113/125	113/125	113/125	113/125	113/125

To find total cost per road mile, add right-of-way (ROW) cost and cost per track mile for total number of tracks signaled.

FIGURE 3-1

overlay systems. These cost ranges include the required material, labor and testing costs to install the wayside equipment for each of the candidate systems. Cost range estimating sheets showing detailed costs for each summary figure given in Figure 3-1 are presented in Appendix B.

To determine the wayside cost for any particular segment of railroad from the data given in Figure 3-1, the right-of-way cost per mile must be added to the cost per track-mile for the total number of tracks signaled within the segment. Signal/control equipment to be installed in the locomotives for wayside compatibility is shown as a per locomotive cost for each of the candidate wayside overlay systems.

The cost ranges for each Category A candidate system were based on the following criteria:

- All timetable and train order territory is single track.

- No costs are assumed to add bi-directional wayside signaling where it does not now exist. The train control systems costed are for overlaying on the existing type of wayside signal systems, whether single-direction or bi-direction.

- An average spacing of 4,500 to 7,500 feet for existing automatic block signals was assumed for cost estimating purposes.

- Approximately 65% of the signaled road miles is double track.

- One highway grade crossing equipped with an automatic warning system exists an average of every 10 miles. Of these automatically protected highway grade crossings, five percent are located on a track that is capable of high speed operation. A cost range of $25,000 to $30,000 for signal modifications to each double track crossing has been used.

- An equal number of cut sections as wayside block signals is assumed in calculation of track circuit costs.

- An average spacing of 10 miles for existing locations of interlockings was used for cost estimating purposes.

- In addition to wayside signal system interface, three civil speed restrictions per five-mile segment (for high speed operation) are assumed for such factors as track curvature, urban congestion, local ordinances, and stations.

- The total Amtrak locomotive fleet to be equipped is estimated at 500 units of various types. This figure includes the necessary spare units for optimum levels of service estimated between 1980 and the turn of the century.

3.2 Category B Candidate System Costs

Figure 3-2 summarizes the estimated additional costs for procurement and installation of train-to-central information systems. These additional costs (above base Category A costs) are projected upon a road-mile cost for additional wayside equipment and a per unit basis for additional locomotive equipment for each of the candidate systems. Cost range estimating sheets showing detailed cost figures for each summary figure given in Figure 3-2 are presented in Appendix B of this report.

CATEGORY "B"

ESTIMATED CAPITAL COSTS - TRAIN TO CENTRAL INFORMATION SYSTEMS

(PER ROAD MILE)

CATEGORY "A" WAYSIDE SYSTEM	ADDITIONAL COSTS FOR TRAIN-TO-CENTRAL	
	WAYSIDE/ROAD MILE	LOCOMOTIVE/EACH
5-Aspect (100 Hz) NEC Type	$ 17,000.00	$ NONE
Intermittent (BR)	9,500.00	3,000.00
Intermittent (DB)	9,500.00	3,000.00
Intermittent (FS)	9,500.00	3,000.00
Dual Carrier Continuous (FS)	17,000.00	NONE
Inductive Loop Continuous (DB)	9,500.00	3,000.00

Notes:

1. Above costs do not include any recurrent changes for leased commercial telephone or data circuits between railroad central offices and Amtrak national display center.

2. Above costs must be added to Category "A" base costs to obtain total including Category "B" for selected candidate wayside system and locomotive costs.

FIGURE 3-2

The cost estimates for the Category B overlay candidate systems are based on the following criteria:

- The Category B costs are additional to those already derived for the Category A implementation.

- The locomotives to be equipped include an existing VHF radio as standard equipment. Therefore, only the cost of the data encoder is shown.

- For the wayside central monitoring equipment the central monitor facility is assumed to be independent of the existing TCS centers. The interface points between the central monitor facility and the wayside track relays are assumed to be at the interlocking plants.

- The data to be transmitted to central for the ac coded track circuit systems are assumed to be picked up at the track relay locations. The data encoder costs are for the equipment to store the block occupancy data and transmit the data in serial form via telephone lines.

- The computer and peripheral equipment costs assume a Modcomp IV computer with 64K core storage, off-line disk storage unit, card punch, reader and line printer. The CRT cost includes a keyboard as an integral part of the unit.

- The software costs include the train tracking and identification programs (manual entry of train ID), a program to provide line printer and CRT readout of train progress relative to realtime schedule, and data reduction to provide daily train summaries.

3.3 Category C Candidate System Costs

Figure 3-3 summarizes the estimated additional costs for procurement and installation of central-to-train information systems. These additional costs (above the sum of Category A and B costs) are based upon a road-mile cost for additional wayside equipment and a per-unit basis for additional locomotive equipment for each of the candidate systems. Supporting data in the form of cost estimating sheets are given in Appendix B.

The cost range presented for implementing a Category C system is additive to the Category A and B costs so that each successive category must be summed to obtain the total cost of each candidate system at the desired implementation level. The qualifying assumptions for implementation of a Category C signal/control system include:

- The computer, including memory and peripheral equipment, costed in Category B is adequate to accommodate the additional software to implement the Category C system.

- The Category B single color CRT and keyboard will be utilized for data entry and tabular data display.

- The added color CRT will be utilized for train location and status display purposes.

- The data link from central control to the locomotive will be via VHF radio in all cases. It is assumed (as in Category B) that the VHF train radio already exists, and only the on-board decoder must be added.

- The additional software effort quoted is to provide the capability for transmitting schedule status data from central to each train to provide the engineer with better control of train performance to schedule.

CATEGORY "C"

ESTIMATED CAPITAL COSTS - CENTRAL TO TRAIN INFORMATION SYSTEMS

(PER ROAD MILE)

	ADDITIONAL COSTS FOR CENTRAL-TO-TRAIN	
CATEGORY "A" WAYSIDE SYSTEM	WAYSIDE/ROAD MILE	LOCOMOTIVE/EACH
5-Aspect (100 Hz) NEC Type	$ 2,700.00	$13,000.00
Intermittent (BR)	2,600.00	NONE
Intermittent (DB)	2,600.00	NONE
Intermittent (FS)	2,600.00	NONE
Dual Carrier Continuous (FS)	2,700.00	13,000.00
Inductive Loop Continuous (DB)	2,600.00	NONE

FIGURE 3-3

3.4 Combined Costs

Figure 3-4 summarizes the total costs for all three categories. These costs are summations of Category A, B, and C costs on a per-mile basis for each category presented in Figure 2-2. This summation, therefore, equates to the cost range for implementation of the Category C signal/control system.

COMBINED CATEGORIES "A", "B" & "C"

ESTIMATED COST RANGES - (PER MILE) - WAYSIDE SYSTEMS (IN THOUSANDS)

EXISTING OVERLAY	STEADY DC	CODED DC	STEADY AC	CODED AC	AUDIO	TT&TO
5-Aspect (100 Hz) NEC:						
. ROW Cost/Mile	48/50	48/50	48/50	48/50	48/50	69/72
(+) . Per Track Mile	11/12	7/9	11/12	4/7	11/14	NA
(+) . Per Locomotive	61/74	61/74	61/74	61/74	61/74	61/74
Intermittent (BR):						
. ROW Cost/Mile	12	12	12	12	12	66/67
(+) . Per Track Mile	8/9	8/9	8/9	8/9	8/9	NA
(+) . Per Locomotive	30/33	30/33	30/33	30/33	30/33	30/33
Intermittent (DB):						
. ROW Cost/Mile	12	12	12	12	12	65/67
(+) . Per Track Mile	7/8	7/8	7/8	7/8	7/8	NA
(+) . Per Locomotive	25/26	25/26	25/26	25/26	25/26	25/26
Intermittent (FS):						
. ROW Cost/Mile	40/42	40/42	40/42	40/42	40/42	61/64
(+) . Per Track Mile	8/9	8/9	8/9	8/9	8/9	NA
(+) . Per Locomotive	33/34	33/34	33/34	33/34	33/34	33/34
Dual Carrier Continuous (FS):						
. ROW Cost/Mile	48/50	48/50	48/50	48/50	48/50	69/72
(+) . Per Track Mile	15/20	11/14	15/20	7/13	19/22	NA
(+) . Per Locomotive	80/85	80/85	80/85	80/85	80/85	80/85
Inductive Loop Continuous						
. ROW Cost/Mile	40/42	40/42	40/42	40/42	40/42	59/73
(+) . Per Track Mile	49/64	47/62	49/64	47/62	51/66	NA
(+) . Per Locomotive	116/128	116/128	116/128	116/128	116/128	116/128
Location Identification Control (BCR)						
. ROW Cost/Mile	NA	NA	NA	NA	NA	19/25
(+) . Per Locomotive	NA	NA	NA	NA	NA	15/20

To find total cost per road-mile, add right-of-way (ROW) cost and cost per track-mile for total number of tracks signaled.

FIGURE 3-4

SECTION 4.0

OPERATIONAL CONSIDERATIONS

The signaling system for high-speed trains must be effective in governing train movements. However, if the system requires a high level of technical training to operate and maintain or is unreliable and subject to damage by vandalism, it will not be cost effective. Even though firm facts and figures are not available for most of the systems under consideration, some of the inherent qualities of these systems will be briefly examined.

4.1 Life Cycle Analysis

The economic life of railroad signaling equipment is evidenced by the fact that some devices are still in service after fifty years. Some of those devices may have been repaired or adjusted many times, but they remain serviceable equipment. Some mechanical interlockings are still functioning after more than eighty years. They have passed the point of economic obsolescence and are maintained by "custom fit and cannibalization" with parts that are no longer manufactured.

Overlay systems for high-speed passenger trains must be at least as capable of longevity of service as those systems now in use. There is reason to believe that the overlay systems could very well exceed existing systems in service life and prove to be more reliable with less required maintenance. If state-of-the-art electronic devices of proven reliability are used in redundant elements, there is little reason to doubt that a long life can be expected. The increasing usage and dependability of solid-state devices is becoming more evident with applications such as communication, television, telephone, microwave and microprocessors for industrial controls. These solid-state devices have experienced a continuous decrease in cost for the last twenty years. They have also become more reliable in operation. After "infant mortality" failures are cleared up they tend to have an extremely long, trouble-free life. For the calculations in this report a thirty year useful economic life will be assumed for any candidate system.

4.2 Reliability/Maintainability Analysis

The high-speed passenger train signaling systems that are evaluated here will increase the maintenance cost because of the added equipment. These additional costs are unavoidable because the overlay system will operate as though independent of the existing system. Therefore, the new overlay system will require maintenance in addition to the existing system. For this reason it is imperative that the added system be as maintenance free as possible and the required maintenance tasks easily identified and simple to execute. This requirement will be an important factor in the final selection of an overlay system.

Unfortunately most of the candidate system technologies are new entries in the field and even though all are currently in use, none has been in service long enough to have established significant in-use reliability trends. Some data may be forthcoming but are not available for this report. The subject certainly deserves to be thoroughly investigated, since maintenance costs are recurring and will affect overall signal system operating costs.

4.2.1 Reliability/Maintainability of Prevailing Signaling Systems

A source has not been found at the time of this report for determining the reliability of railroad signaling equipment in the usual terms of mean time between failures (MTBF). Some data are available from signal failure reports that domestic railroads are required to submit to FRA. These reports are for "false proceed" failures only and do not constitute a complete failure record. However, they are representative of potentially dangerous failures and are of value because they show trends. The data presented in

Figure 4-1, sheets 1 through 3, cover false proceed failures for a period of thirteen years from 1966 to 1978. The failures were categorized into eight general causes of failure:

- Open circuits (including crosses, grounds and foreign currents)
- Broken apparatus (including defective equipment or equipment out of adjustment)
- Human related (incorrect wire connections, parts incorrectly assembled, or parts improperly secured)
- Vandalism
- Failure due to environmental factors (rain, snow, sleet, ice, animals, brush, trees, etc.)
- Failure of relays or similar devices
- Foreign material on rails (sand, snow, rust, grease, etc.)
- Failures of undetermined cause

Part of the data was taken from the January-February 1979 issue of the Signalman's Journal, which used as its source the FRA reports from 1972 through 1978. These data are shown in Figure 4-2. The other data were taken from failure data available from the FRA Rail Safety Office and cover the period from 1966 to 1971. The FRA Rail Safety data are included as Appendix C.

The plots of each category of signal failure shown in Figure 4-1, sheets 1 through 3, show trend lines superimposed on data plots. These trend lines are a median of the plotted curves and

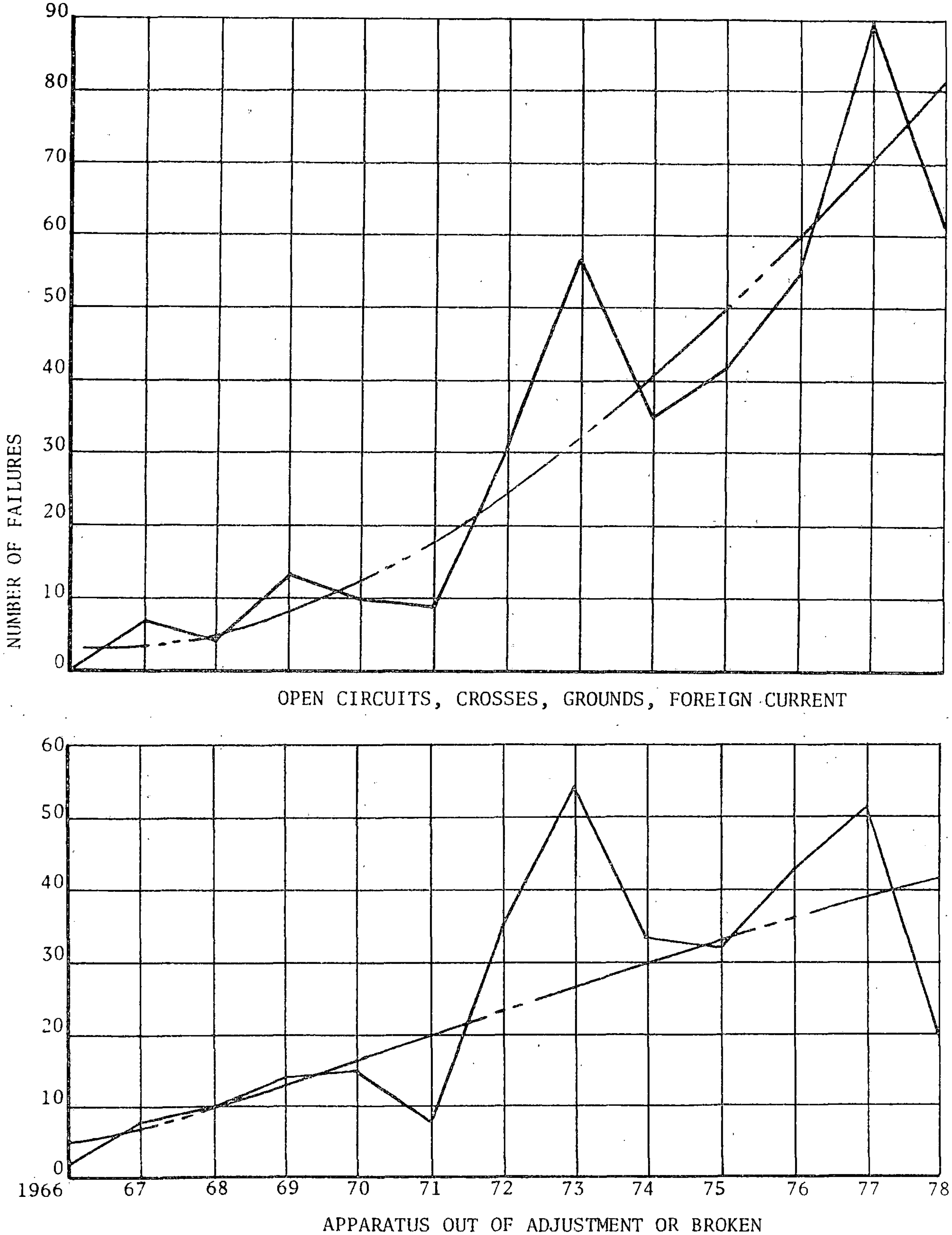

FIGURE 4-1. FALSE PROCEED FAILURES 1972-1978 (Sheet 1 of 3)

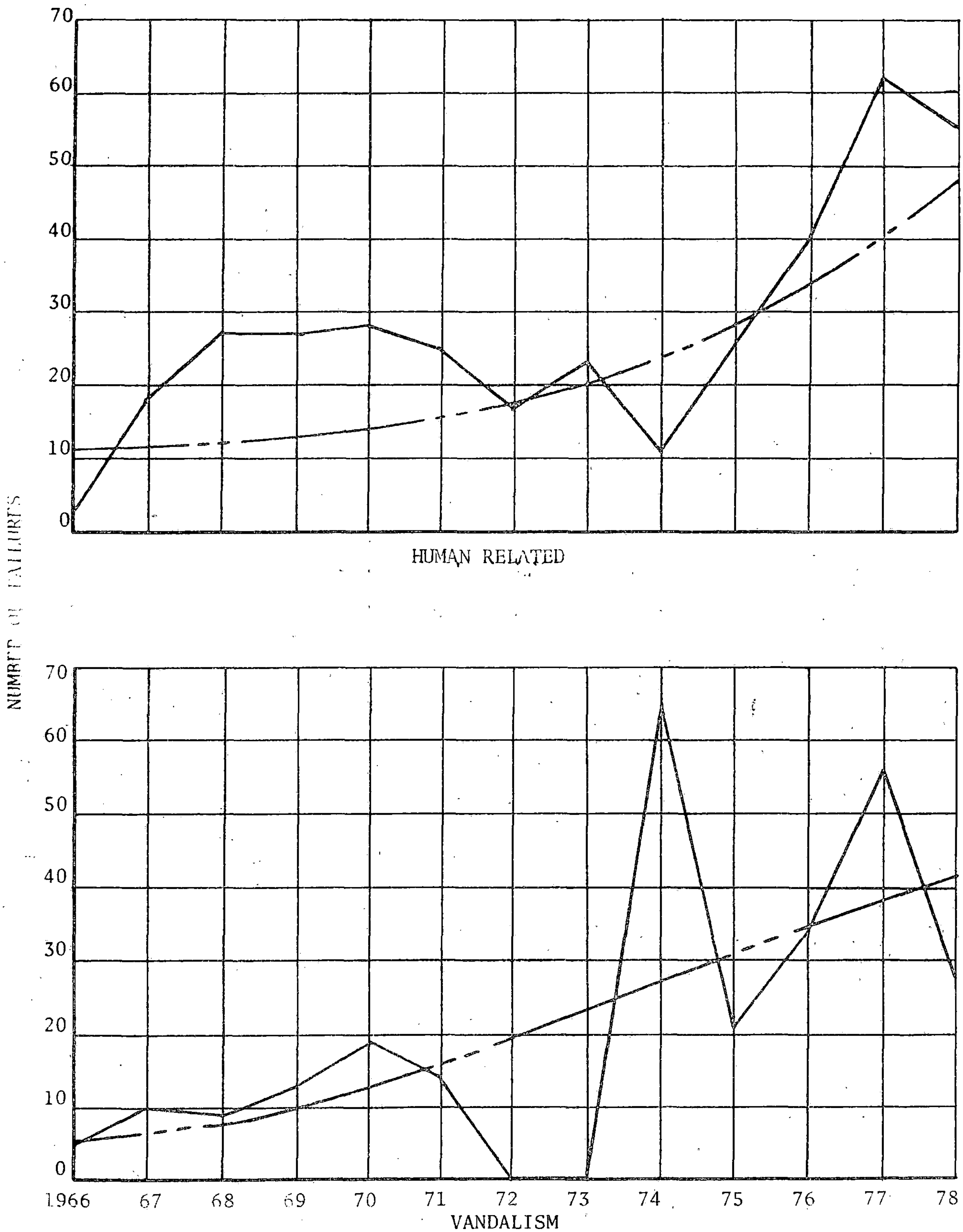

FIGURE 4-1. FALSE PROCEED FAILURES 1972-1978 (Sheet 2 of 3)

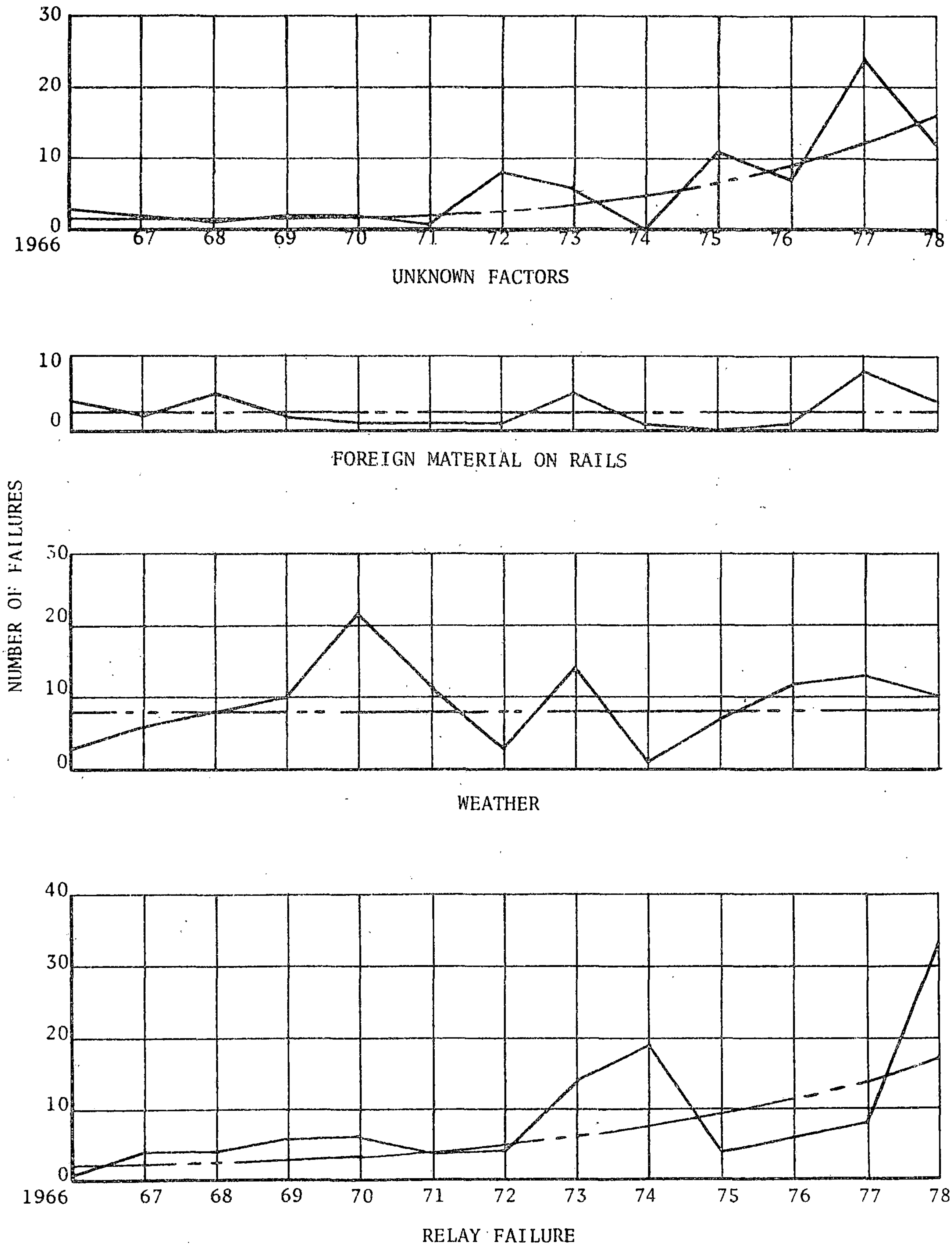

FIGURE 4-1. FALSE PROCEED FAILURES 1972-1978 (Sheet 3 of 3)

RAILROAD	1972	1973	1974	1975	1976	1977	1978
Amtrak (Northeast Corridor) (118i, 1522 miles)	-	-	-	-	1R	5C,4D,7E 2U,1V	3C,4F,4R,1U 1V
Atlanta & West Point (178 mi)	-	1C,1U,1F	-	-	1D	2V	-
Baltimore & Ohio (374i,3728 mi)	1D,1S	4C,1D,1F,1R,1S	3V	-	2D	1E,2V	1D
Bangor & Aroostook (3i,53 mi)	-	-	-	-	-	1C,1F	-
Boston & Maine (119i,814 mi)	1C	1C,2D,1E	1C,3V	1C,1R	2D,1F	3C,1D,2E,1V	1C,1F,1S
Burlington Northern (1275i, 10258 mi)	4C,5D,2R	1C,2D,1E,3F 1S,2U	4C,9D,3R,1S 5V	4C,2D,1E,4F 1R,1U,3V	1C,3D,6E,1F 3U,6V	6C,4D,7E 4U,5V	5C,4E,1F,4R 2S,3V
Chesapeake & Ohio (648i,3013 mi)	1U	2C,1D,1E	1V	-	1C,1E,1S,1V	2D,2E,2V	1D,5F,2R, 1S,1V
Chicago & North Western (151i, 1981 mi)	3C,3D,2U	7C,5D,1E,1R	8C,6D,1R,6V	5C,2D,2E	8C,3D,1E,1R 1U,2V	10C,2D,2R,1U 2V	3C,4D,3R
Chicago & Western Indiana (10i,52 mi)	-	1C,2F	1V	-	-	2C,1D	-
Chicago, South Shore & South Bend (84 mi)	-	-	-	-	1V	1V	2C
ConRail (1519i, 15640 mi)	4C,6D,3E,3F 1R,2U	3C,7D,3E,1F 2R	2C,2D,1R 17V	4C,5D,2E,3U 11V	7C,10D,9E,3F 2R,2U,12V	10C,11D,11E,4F 3R,5U,11V	3C,16F,1R, 9V
Delaware & Hudson (84i, 590 mi)	-	1C	1V	-	-	-	1F
Denver & Rio Grande Western (300i, 1077 mi)	-	-	1D	-	-	1C,1S	-
Elgin, Joliet & Eastern (26i, 189 mi)	-	1D	1V	-	1D	3D,1E,6V	1F,1R
Florida East Coast (59i, 442 mi)	-	1C,1D	2C	-	1V	-	2E,1V
Fort Worth & Denver (27i,446 mi)	-	1E	-	-	1E	1C,2D	1D
Frisco (St. Louis-San Francisco) (361i,1884 mi)	2C,1E	2C,3D,2E 1S,1U	2C,2D,2E,2V	2C,2D	1C,2D,1V	2E,2F,3V	2C,1D,1E
Grand Trunk Western (53i,666 mi)	-	1C,1D	1C,1D	1C	1C	-	-
Houston, Belt & Terminal (14i, 35 mi)	-	1D	-	-	-	2V	-
Illinois Central Gulf (301i,3770 mi)	4C,3D,1R	4C,7D,1R	2C,3R,3V	7C,1D,2E,1V	6C,2D	18C,1D,1E,2F, 3U,2V	15C,1D,3E,2F 5R,2U,3V
Indiana Harbor Belt	-	-	-	-	1E		1E
Kansas City Southern (99i,650 mi)	-	1D	1D	1C,2D,1V	-	1C,1E,2U,1V	1C,1U
Kansas City Terminal (11i,23 mi)	1D	1S	1C	-	1V	-	-
Katy (Missouri-Kansas-Texas) (43i,866 mi)	-	2C,2D	1C,1D,1R,1V	1D	3C,1F	3D,2E,1V	2C,1R

FIGURE 4-2. NUMBER AND CAUSES OF FALSE-PROCEED FAILURES 1972-1978 (Sheet 1 of 2)

RAILROAD	1972	1973	1974	1975	1976	1977	1978
Long Island (34i, 339 mi)	1D,2E	1C,1D,1E,1R	1V	1C,2D,2F	1C,1D,1R	1C	2R
Louisville & Nashville (645i,3553 mi)	2C,3D,1F,1U	1C,2D	1C,1D	1D,2E,1F,1U	1C,3D,3E,1U 1V	5C,1D,7E,2F 1S,1U,2V	2C,3E,3R,1V
Milwauke Road (Chicago Milwaukee (St. Paul & Pacific) (315i,3364 mi)	1C,1U	1C,1D,2F 2R,1S	2R,3V	1F	2D,2E,2V	2C,1D,1E,1V	2C,1E,1U
Missouri Pacific (642i,5584 mi)	1D,1U	1C,2D,1E,1R	1C,4D,1R,3V	2C,2D,1R	1C,2D,1E,1F	1C,1D,1E,1R 2U,3V	1C,1E,1F,2U 1V
Norfolk & Western (1091i, 5584 mi)	4C,3D	2C,5D,2E,1F,2R	2C,5D,3R,5V	3D,1F	3C,2D,2E,1R 1V	2C,4D,4E,1F 2R,2S,2U,6V	1D,3E,1F,2R
Path (Port Authority Trans-Hudson) (10i,30 mi)	1E	2C,1E,1F,1R	-	-	-	-	-
Rock Island (Chicago Rock Island & Pacific) (233i,3112mi)	2C,1D	5C,3D,1E	1V	6C,4D,4E,1F 1V	5C,1D,1E,1V	5C,1D,1F,1V	2C,1D,1E,2F 2R,1U,1V
Santa Fe (Atchison, Topeka & Santa Fe) (924i,7029 mi)	1C,3D,3E	2C,3D,3E,1F	1C,2E,4V	1C,4D,7E,2U 2V	4C,2D,4E,2F, 4V	2C,1D,3E,3S 1V	7D,2E,2R 4V
Seaboard Coast Line (945i,3957 mi)	2D,2E	5C,1D,2E,1R	2C,2E,1R	3C,1D,2U	2C,2D,1F	4C,1D,5E	1C,2E,1V
SOO Line (112i, 376 mi)	2C,1D	1C	3C,2E,1V	1C,1E,1V	-	1V	-
Southern (468i, 4492 mi)	1C,1D,1E	4C,1D,1R,1U	1R,1V	2C,1E,1U,1V	6C,1D,4E,2F	6C,4D,1V	3C,3U,1V
Southern Pacific (1106i,7379 mi)	2E	1C,2E,1F	1C,2E,1F,2R 2V	1C,1R,1V	3C,1D	4C,2D,2E,1S	6C,1D,3E,1F, 1R,2V
Union (7i,30 mi)	-	-	-	-	1E	1D	1C
Union Pacific (734i,5326 mi)	-	-	1E	-	1C,2E	1E,1V	1C,2E
Western Pacific (213i,947 mi)	1E	1U	-	-	1E	1E	-
TOTALS	99	173	165	142	198	312	222
13089 i 99058 mi	31C,35D,17E 3F,4R,1S,8U	57C,54D,23E 14F,14R,5S,6U	35C,33D,11E 1F,19R,1S,65V	42C,32D,25E 7F,4R,11U 21V	55C,43D,40E 12F,6R,1S 7U,34V	90C,51D,62E, 13F,8R,8S 24U,56V	61C,19D,55E, 10F,33R,4S. 12U,28V

Legend:
C = Circuits open, crossed or grounded. Foreign current, etc.
D = Apparatus broken, defective or out of adjustment
E = Errors in making a connection or adjustments
F = Failure of apparatus due to ice, sleet, snow, wet track, weather or lightning
R = Failure of relays and similar devices
S = Sand, rust or other deposits on rails
U = Undetermined
V = Vandalism
i = interlockings and traffic control points
mi = track miles of automatic block signaling and traffic control

FIGURE 4-2. NUMBER AND CAUSES OF FALSE-PROCEED FAILURES 1972-1978 (Sheet 2 of 2) may be speculative to some extent. Any use of these graphs for future extrapolation must be made with some reservation. Nonetheless, the trends are of interest. The creditability of the trends is given further credence by the plot of environmental related failures and those caused by foreign material on the rails, shown on Figure 4-1, sheet 3. Both of these have a level trend as would be expected. However, the failures caused by circuit problems, Figure 4-1, show an unexpected upward trend. The upward trend of failures caused by broken apparatus, Figure 4-1, is not surprising after considering that some equipment now in service has already exceeded a reasonable service life and is subject to fatigue and other failures associated with age.

The failures caused by human related error, Figure 4-1, sheet 2, show an alarming upward trend. As of 1978 they appear to be unaffected by training programs instituted by the majority of railroads in the early to mid-1970's. Possibly these training programs will reverse the trend with time. Nonetheless, this upward trend is reason enough that training along with personnel motivation be actively pursued by domestic railroads as a method of increasing safety through the reduction of human error.

4.3 Vandalism Susceptibility

Figure 4-1, sheet 2, shows that the false proceed failures caused by vandalism appear to be increasing even though those for 1978 were less than 1977. Vandalism is a subject of concern for most American railroads. This was evident from the testimony presented at the Railroad Safety Hearing in February, 1979. It was suggested in this hearing that legislation be introduced to make the intentional destruction of railroad signaling and other wayside equipment a federal crime. Local convictions for such offenses are almost unheard of. This could be partially due to the lack of understanding by local law enforcement agencies of the importance of signaling in safe train operation. In the

Northeastern United States helicopter patrols have been effective in reducing vandalism in at least one instance. However, this remedy is not a general solution to the problem because of the cost of helicopter service operations. Patrols of any kind would be cost prohibitive because of the length of signal installations.

The most reasonable approach appears to be to expose as little equipment as possible. Signal cable and equipment enclosures should be buried when possible. Access panels to enclosures should be rugged to discourage tampering. Wayside signals should not include moving parts and should have impact-resistant plastic lenses. The mast of wayside signals should be designed to make climbing by intruders difficult. None of these concepts is foreign to railroads. Most are taking all measures that are available and adding others as their budgets will allow.

For the proposed overlay signal/control systems these criteria must be met. One European system employing wires between the tracks is particularly susceptible to vandalism and without some redesign would be unacceptable in the United States because of that vulnerability. However, most systems considered as candidates are cab signal systems which have minimal track mounted equipment, and where such equipment is required there is no reason to believe that they could not be adequately protected. Figure 4-3 provides a cost evaluation of the susceptability to vandalism, for each basic type of signal/control system and associated display and communication systems.

4.4 Training Requirements

Training must be provided for operations and maintenance personnel. Training requirements for operators are not expected to be as extensive as those required for maintenance people. During the public safety inquiry noted, above, Burlington Northern (BN) provided information relating to their training program.

TECHNOLOGIES / EVAL. FACTORS	TRAIN DETECTION: AC CODED	TRAIN DETECTION: AUDIO FREQ.	TRAIN DETECTION: HV IMPULSE	TRAIN DETECTION: AXLE COUNTER	CAB SIGNALING: CODED AC	CAB SIGNALING: INTERMITTENT	CAB SIGNALING: CATC	A T S CONTROL: RELAY LOGIC	A T S CONTROL: COMPUTER LOGIC	DISPLAY SYSTEM: HARDWIRE CUSTOM PANEL	DISPLAY SYSTEM: HARDWIRE MODULAR PANEL	DISPLAY SYSTEM: COLOR CRT	COMMAND SYSTEM: LINE OF LIGHT CONTROL	COMMAND SYSTEM: KEY BOARD CONTROL	COMMAND SYSTEM: LIGHT PEN CONTROL	COMMUNICATION SYSTEM: TELEPHONE	COMMUNICATION SYSTEM: V H F	COMMUNICATION SYSTEM: U H F	COMMUNICATION SYSTEM: MICROWAVE	
CAPITAL COST	3	2	4	5	2	5	1	2	4	2	3	4	4	2	2	1	3	2	4	1 HIGHEST RISK 5 LOWEST RISK
OPERATING & MAINT COST	3	1	2	5	3	4	2	2	4	2	3	4	4	4	5	1	3	2	4	
TRAINING REQ'TS	3	1	3	2	3	4	2	4	2	3	3	2	3	2	4	2	2	2	2	COST FACTOR
SKILL LEVEL REQ'TS	3	1	2	3	3	4	2	3	2	5	4	3	4	3	5	4	3	3	2	
VANDALISM SUSCEPTABILITY	3	3	3	2	3	2	1	3	3	4	4	3	3	4	2	1	4	4	5	
ENERGY CONSUMPTION	2	3	4	4	2	4	3	2	4	2	2	4	2	5	5	4	4	3	5	
	17	11	18	21	16	23	11	16	19	18	19	20	20	20	23	13	19	16	22	
	ATP							AT'S												

FIGURE 4-3. COST EVALUATION MATRIX

They have spent 2 million dollars to train 522 persons, which amounts an average cost of $3,831 per person.

4.4.1 Operator Training

Training must be provided to both train and wayside operators. All candidate signal/control systems use cab signaling equipment which should be relatively simple to operate. It is estimated that no more than two days training will be required for any system under consideration. Wayside operators may require more training--particularly for an intermittent system such as the one in use on the British Columbia Railroad which was described in Paragraph 3.6 of the Task 1 report. Such a system could well require several weeks of training for several categories of employees.

Figure 4-3 presents the level of training required to support each basic type of signal/control system and associated display and communications systems. A skill level for selection or qualification of signal maintenance personnel is included.

4.4.2 Maintenance Training

Maintenance training on most signal/control systems will require several weeks and will necessitate maintenance manuals and other training aids. These systems are somewhat different than existing systems and in some cases may require a somewhat different maintenance philosophy. Maintenance personnel must be indoctrinated in the techniques of locating problem areas and isolating to the replacement module. However, the sophistication of the system and the degree of maintenance complexity are factors which must influence the selection of an overlay system. An evaluation of operating and maintenance costs and the required skills level is provided in Figure 4-3.

4.5 Safety Enhancement

The raw number of railroad accidents has shown a steady increase over the past decade. These accidents are most often blamed on the railroads' deferment of maintenance and the increase of axle loading and length of trains. The former is attributed to the economic decline of the industry, while the latter demonstrate efforts to increase productivity.

Even though the number of train accidents grows each year, the accident rate can be considered to be declining when compared with the increase in the number of trains and the speed of operation--particularly of tonnage trains. Figure 4-4 is a table of Railroad Accident Fatalities for the Period 1966 to 1977 reproduced from an article, "Railroad Safety in Perspective", Document Reference 355, Appendix A. The steady decrease in fatalities illustrates an overall increase in safety of operations.

Safety is a feature that cannot be directly evaluated in terms of cost per mile or saving in damaged property because it also involves human life. No one can really assess the value of a human life. Injuries or fatalities usually require civil actions in our court system to establish some level of compensation, so the adage "what price safety?" remains unanswered. The intangible benefits reflected in the many safety related studies, research and testing programs remains unclear in relation to the costs involved. Benefits resulting from research or testing may be reflected in improved safety over years of time.

Safety more specifically directed toward railroad signal systems has shown a steady increase in the number of faults over the past decade, but when compared with the total rail system as shown in Figure 4-4 it indicates a very respectable safety record. Figure 4-5 summarizes the accidents, fatalities, injuries and property damage attributed to accidents resulting from signal failures. The data were provided by the FRA at the Public Inquiry for Rail Safety noted, above. The period 1975 through 1977 shows

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Passengers	23	12	11	6	8	16	47	6	7	8	5	2
Employees	159	166	146	178	155	118	127	158	140	110	100	104
Trespassers	678	646	628	627	593	551	537	578	565	524	458	485
Others*	1,824	1,659	1,574	1,488	1,469	1,325	1,234	1,174	1,196	918	1,121	960
Hwy.Grade Crossings**	1,780	1,632	1,546	1,490	1,440	1,356	1,260	1,185	1,220	978	1,099	948
Total	2,684	2,483	2,359	2,299	2,225	2,010	1,945	1,916	1,908	1,560	1,684	1,531

* The preponderance of these fatalities occurred in highway grade crossing accidents.

** Fatalities distributed in four previous categories and not duplicated in the total.

Sources: Fatality and injury statistics for years 1966 through 1976 from FRA Accident/Incident Bulletin: Summary and Analysis of Accidents on Railroads in the United States; for 1977, from Preliminary Report of Railroad Accidents/Incidents and Resulting Casualties, FRA.

FIGURE 4-4. RAILROAD ACCIDENT FATALITIES: 1966-1977

YEAR	NO. SIG. REL. ACCIDENTS	NUMBER FATALITIES	NUMBER INJURIES	PROPERTY DAMAGE	COST/TRACK MI (102,958 TRK MI)
1975	11	0	1	$300,000	$2.91/TRK MI
1976	11	0	0	400,000	$3.88/TRK MI
1977	12	0	2	100,000	0.97/TRK MI
		AVG. COST OF ACCIDENT			$2.59/TRK MI

Legend: Track - TRK
Mile - MI

FIGURE 4-5. ACCIDENTS RELATED TO SIGNAL FAILURE no fatalities related to signal failures, while the railroad industry averaged 1592 fatalities for the same period. Damages are interpreted as $2.59 per track mile for signal related accidents.

Costs involving human related accidents again demonstrate a small percentage when compared to rail industry averages. Figure 4-6 provides a comparison of the cost of property damage in signal accidents caused by human error with those of total rail accidents related to human error in a comparable period. Again, a ratio of $0.52 to $38.82 per track mile provides the signal system with a good comparative safety record.

The figures do not justify any accident. However, they do substantiate the "Fail-Safe" design principal required in signal/control systems. It is recognized that the goal of operating without accidents is not economically achievable, but it certainly provides a worthy goal.

Accidents Related to Human Error for
Class I Railroads

YEAR	NUMBER ACCIDENTS	NUMBER FATALITIES	NUMBER INJURIES	PROPERTY DAMAGE	COST/ TRK MI
1975	67	4	566	$8.5 million	$42.29/trk mi
1976	83	4	88	$5.9 million	$29.35/trk mi
		AVG COST PER ACCIDENT			$35.82/trk mi

Figures per AAR for 1977 False Proceed Failures
Classification of Signal Related Accidents

FAILURE CAUSE	PERCENT OF TOTAL	COST/ TRK MI
Human Error	20.2%	$.52/trk mi
Vandalism	14.9%	$.39/trk mi
Line Faults	14.4%	$.37/trk mi
Defective Relay or Signal Device	12.2%	$.32/trk mi
Undetermined	9%	$.23/trk mi
Misc.	29.3%	$.76/trk mi

FIGURE 4-6. ACCIDENTS RELATED TO HUMAN ERROR

SECTION 5.0

OPERATING/MAINTENANCE COSTS

In the previous sections of this report, capital costs and operational considerations were developed for each of the six selected candidate overlay signal/control systems. In this section cost estimates have been developed for the incremental increase in signal system operating costs for each of the six base, Category A systems and for optional expansion of these base overlay systems to Category B and Category C full data control and central monitoring systems.

5.1 Normalized Signal System Maintenance

Existing U.S. railroad signal systems have a relatively long life. Wayside equipment averages 35 to 40 years and pole and wire lines approximately 20-25 years. Because of this, signal material replacement can be deferred for several years with little impact on the integrity of the signal system. If deferral is continued for too long a period, the reliability of the system is seriously weakened and signal system failures will sharply increase. Eventually, major signal system operating expenditures become necessary to restore an efficient, safe and reliable operation.

Normalized signal system operating (maintenance) expense can be defined as the average annual cost over the long term to maintain the fixed plant in a condition adequate to support an efficient transportation service. In general, annual work functions and material replacement costs for normalized maintenance will be the cost to perform the work function or material replacement divided by the life of the work function or material in years.

The general pattern of signal system rebuilding (capitalizations) for Class I railroads has been similar: about twenty years from 1935 to 1955 of above normal installations centering around a World War II peak followed by 15 to 20 years of sub-normal installations due to reduced railroad incomes. Signal system maintenance expenditures have also followed the cyclical nature of the railroad economy.

5.2 Current Signal System Maintenance Costs

During the course of this study two data sources were selected to determine an average normalized maintenance cost for signal systems. The first was based upon the results of a comprehensive FRA study performed in connection with Section 505 of the 4 R Act. This study, completed in 1975 and covering 23 years of cost data, was entitled "Normalized and Deferred Maintenance Costs of Class I Railroads", performed by T. K. Dyer, Inc., for FRA. All costs within this study are correlated by the ICC Uniform System of Accounts for U.S. railroads. The second source was obtained from data presented by U.S. railroads during the 1979 FRA safety inquiry noted, above.

Figure 5-1, on the following page, demonstrates relevant findings on 14 representative railroads taken from the 1975 Normalized and Deferred Maintenance Study. The 23-year costs, shown in 1975 dollars, have been adjusted to 1978 constant dollars, using the AAR published "Indexes of Railroad Material Prices and Wage Rates for Class I Railroads". With this escalation the 23-year average signal maintenance cost, in 1978 dollars, calculates to $1,787 per track mile signaled.

During the FRA safety inquiry the MOPAC ascertained that their maintenance budget involving signals and interlockings for 1978 was $10 million, with $12.1 million budgeted for 1979. On the basis of MOPAC operating 5,578 miles (8,975 km) of signaled

ANNUAL SIGNAL MAINTENANCE COSTS

ICC AC 249

25 YEARS: 1953 THROUGH 1978

RAILROAD	RD. MILES SIGNALED	RD. MILES CAB SIGNALED	TK. MILES SIGNALED	COST PER RD. MILE*	COST PER TK. MILE*	1978 COST PER TK. MILE
RF&P	114	109	235	4,205	2,040	2,652
C&NW	1,650	619	2,009	1,895	1,556	2,022
B&M	611	33	900	2,159	1,466	1,906
Chessie	5,069	0	6,874	2,299	1,695	2,204
MKT	870	0	870	596	596	1,113
SOU	3,792	0	4,512	1,720	1,446	1,880
SCL	3,326	0	3,948	1,475	1,243	1,616
BN	9,028	36	10,231	2,736	2,414	3,066
UP	4,070	1,070	5,300	1,394	1,070	1,359
L&N	3,493	0	3,763	1,577	1,464	1,903
N&W	4,339	0	5,515	2,030	1,597	2,076
MEC	135	0	176	1,221	936	1,777
CRI&P	2,973	167	3,326	861	770	1,001
SP	6,702	0	7,448	1,397	1,257	1,596
				AVERAGE	1,396	1,787

*1975 DOLLARS

FIGURE 5-1

track, the following cost of maintenance per track mile can be calculated:

1978	$10,000,000/5,578 miles = $1,793/track mile
1979 (Budget)	$12,100,000/5,578 miles = $2,169/track mile

The Chessie System has allocated $15 million for maintenance of its 6,741 miles (10,846 km) of signaled track, equating to a budget of $2,225 per track mile. The 17% increase in the MOPAC maintenance budget supports the railroad industry's concern for efficient operation and safety.

Based upon the foregoing data, it appears that a normalized maintenance figure of about $1,790 per signaled track mile (in 1978 dollars) represents the national average to maintain existing U.S. railroad signal systems at their current level of normalization. As should be expected, individual railroads may vary from such an average, especially if a large amount of grade crossing protection exists in non-signaled territory in relation to the total mileage of signaled territory. Other factors, such as a heavy commuter rail operation, or a terminal retarder yard facility combined with a relatively short, signaled mainline, such as characterizes the RF&P, will also cause individual deviations. However, when such factors are taken into account the signal maintenance costs per track mile signaled are remarkably consistent for those railroads that can be considered to be maintaining their signal systems in a normalized condition. This is probably due, to a considerable degree, to the FRA R.S.&I. requirements.

5.3 Incremental Increase in Signal Maintenance Costs

With installation of any of the six selected candidate overlay systems, an incremental increase in signal operating costs will result. In each case locomotive maintenance costs will also increase due to maintenance of the additional on-board cab signal/control equipment required. Thus, the total incremental increase in signal operating expense must include the incremental increase to ICC Account 371 (Locomotive Repairs) as well as that attributable to ICC Account 249 (Maintenance of Way-Signals and Interlockers).

Of the six alternative candidate Category A overlay systems, systems two, three and four--intermittent types--are the least costly to maintain. System six--continuous inductive loop type--is the most expensive (approximately six times that of the intermittent group), while systems one and five fall between the other two groups (approximately one-and-one half times the intermittent group).

5.3.1 Category "A" Operating Costs

Cost estimates for the incremental increases in signal maintenance expense were developed for each of the candidate systems and may be found in Figures 5-2, 5-3 and 5-4.

Based upon a normalized signal maintenance cost of $1,790 per track mile the following incremental increases in signal maintenance expense were calculated:

Type of Overlay System	Increase in Signal Maintenance Cost Per Track Mile
5-Aspect (100 Hz) NEC Type	13%
Intermittent (BR)	10%
Intermittent (DB)	10%
Intermittent (FS)	10%
Dual Carrier Continuous (FS)	16%
Inductive Loop Continuous (DB)	63%

CATEGORY "A"

WAYSIDE SYSTEMS - INCREMENTAL INCREASE IN MAINTENANCE COST

(PER TRACK MILE)

OVERLAY WAYSIDE SYSTEM	ADDITIONAL COSTS FOR OVERLAY SYSTEMS WAYSIDE/TRACK MILE	LOCOMOTIVE/EACH
5-Aspect (100 Hz) NEC Type	$ 240.00	$ 980.00
Intermittent (BR)	180.00	600.00
Intermittent (DB)	180.00	460.00
Intermittent (FS)	180.00	620.00
Dual Carrier Continuous (FS)	290.00	1,400.00
Inductive Loop Continuous (DB)	1,120.00	2,300.00

Figure 5-2

CATEGORY "B"

MAINTENANCE COSTS - TRAIN TO CENTRAL INFORMATION SYSTEMS

INCREMENTAL INCREASE PER TRACK MILE

CATEGORY "A" WAYSIDE SYSTEM	ADDITIONAL COSTS FOR TRAIN-TO-CENTRAL	
	WAYSIDE/TRACK MILE	LOCOMOTIVE/EACH
5-Aspect (100 Hz) NEC Type	$340.00	$ 0.00
Intermittent (BR)	190.00	60.00
Intermittent (DB)	190.00	60.00
Intermittent (FS)	190.00	60.00
Dual Carrier Continuous (FS)	340.00	0.00
Inductive Loop Continuous (DB)	190.00	60.00

Notes:

1. Above costs do not include any recurrent changes for leased commercial telephone or data circuits between railroad central offices and Amtrak national display center.

2. Above costs must be added to Category "A" base costs to obtain total including Category "B" for selected candidate wayside system and locomotive costs.

Figure 5-3

CATEGORY "C"

MAINTENANCE COSTS - CENTRAL TO TRAIN INFORMATION SYSTEMS

INCREMENTAL INCREASE PER TRACK MILE

	ADDITIONAL COSTS FOR CENTRAL-TO-TRAIN	
CATEGORY "A" WAYSIDE SYSTEM	WAYSIDE/TRACK MILE	LOCOMOTIVE/EACH
5-Aspect (100 Hz) NEC Type	$80.00	$260.00
Intermittent (BR)	80.00	0.00
Intermittent (DB)	80.00	0.00
Intermittent (FS)	80.00	0.00
Dual Carrier Continuous (FS)	80.00	260.00
Inductive Loop Continuous (DB)	80.00	0.00

Figure 5-4

5.3.2 Category "B" Operating Costs

With Category "A" overlay system maintenance costs added to the base signal system maintenance costs, the following incremental increases in maintenance costs are calculated for maintaining the additional equipment required for Category "B":

Type of Overlay System	Additional Increase in Signal Maintenance Cost Per Track Mile
5-Aspect (100 Hz) NEC Type	17%
Intermittent (BR)	10%
Intermittent (DB)	10%
Intermittent (FS)	10%
Dual Carrier Continuous (FS)	16%
Inductive Loop Continuous (DB)	7%

5.3.3 Category "C" Operating Costs

With both Category "A" and Category "B" systems in service, the following incremental increases in signal maintenance costs are calculated for maintaining the additional equipment required for Category "C":

Type of Overlay System	Additional Increase in Signal Maintenance Cost Per Track Mile
5-Aspect (100 Hz) NEC Type	3%
Intermittent (BR)	4%
Intermittent (DB)	4%
Intermittent (FS)	4%
Dual Carrier Continuous (FS)	3%
Inductive Loop Continuous (DB)	3%

5.3.4 Cumulative Increase for All Systems

If the optional additions of both Category "B" and Category "C" data systems were to be added to the base overlay Category "A" candidate overlay systems, the following average incremental increases in wayside signal system maintenance (Account 249) are estimated:

Type of Overlay System	Signal Maintenance Costs Per Track Mile (1978 $)		
	Existing	Existing Plus A+ B+ C	Increase
5-Aspect (100 Hz) NEC Type	$1,790	$2,450	37%
Intermittent (BR)	1,790	2,240	25%
Intermittent (DB)	1,790	2,240	25%
Intermittent (FS)	1,790	2,240	25%
Dual Carrier Continuous (FS)	1,790	2,500	40%
Inductive Loop Continuous (DB)	1,790	3,180	78%

Incremental increases in locomotive maintenance costs may be found in the tables on the following pages of this section.

SECTION 6.0

CORRIDOR SELECTION

A viable corridor of Amtrak service has been selected to serve as the basis for cost/benefit analysis for the candidate overlay signal/control systems. A corridor outside of the Northeast Corridor has been selected for several reasons:

- The NECIP is in various stages of implementation which makes a fair assessment of current and future status difficult.
- The NECIP includes an overlay cab signaling system for improved headway between trains. This system is in the development stage and may be a candidate signal/control system.
- The NEC generates the highest ridership on the least track miles of the Amtrak system and would not represent the average or norm for a total Amtrak system cost analysis of an overlay signal/control system.
- Even though electrification compatibility is a system design requirement, a small percentage of Amtrak route is electrified, and the electrified tracks are located within the NEC. Again, an improved electrified system is being installed and will not provide a good base for evaluation until completed.

The selected corridor includes several representative signal/ control systems including a computer controlled audio frequency system. An additional consideration in selecting a passenger service corridor for evaluation was one that was representative of a corridor that had sufficient ridership to survive the proposed restructuring of routes by Amtrak. Figure 6-1 provides the Amtrak route structure that currently exists. The Department of Transportation has submitted to Congress a proposed route restructuring plan that deletes 43% of the route miles while continuing to serve 91% of the current ridership. The recommended restructuring of the Amtrak route system was published in Document Reference No. 413, Appendix A.

6.1 Selected Corridor

The corridor selected for the cost/benefit analysis is based on the Amtrak route from New Orleans to Los Angeles over the Southern Pacific railroad. The selected corridor ties the Gulf Coast to California including most of the "Sun Belt" states. Document Reference No. 409, Appendix A, ranks the Los Angeles-New Orleans Corridor as eighth in density of use (passenger mile per train mile) while indicating ranking of 23rd by profit (loss) per passenger mile.

These rankings indicate an available ridership but a poor profit picture. The inclusion of an overlay signal/control system to provide both faster train service and closer headway while sharing trackage with freight trains would provide a better schedule and stimulate increased ridership.

The entire 2,041-mile route is predominantly ABS and TCS utilizing coded dc track circuits. However, a state-of-the-art, computer-controlled signal/control system using an audio frequency overlay on a dc track circuit has been installed on a substantial segment of the line. The current signal/control systems are steady dc or coded dc track circuits which would not be compatible with electrification. However, these existing systems would readily accept any of the candidate overlay signal/controls systems.

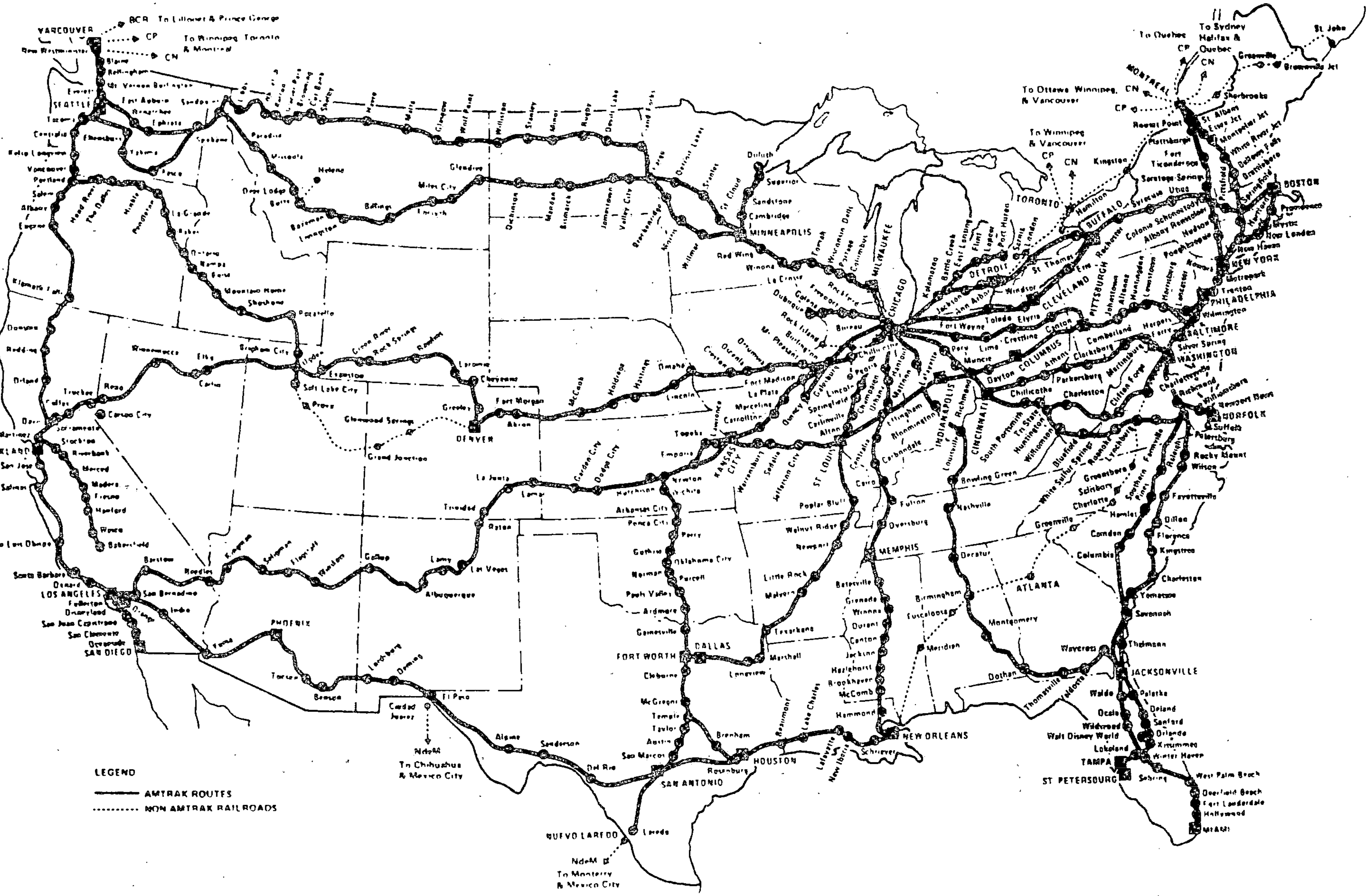

FIGURE 6-1. 1977 AMTRAK SYSTEM

The likelihood of this corridor being electrified within the next decade is slim due to economic considerations. It is a requirement that any proposed overlay system be compatible with electrification. The cost of providing a basic electrification system is not included in this analysis, but it is assumed the overlay system can be installed in an electrified territory without a problem. The cost differences between the basic or currently installed system will be evaluated by system compatibility and therefore do not reflect the cost of the current or basic signal/control system but only the cost of the overlay signal/control system and the required interface with the existing system.

6.2 Corridor Definition

The route, signal boundaries, and interlockings defining each segment by system types are provided in Figure 6-2. The signal/control systems are defined generally with specific system descriptions available in task 1 and 2 reports, Document References Nos. 394 and 395, Appendix A. A graphic representation of the corridor route delineating the specific signal/control systems is shown on Figure 6-3.

The segment from New Orleans to Houston, excluding interlockings, is a coded dc track circuit with communications and control provided by pole line. The segment from Houston to Rosenberg is shared track where Southern Pacific (SP) has trackage rights. The signal/control system for this segment is a TCS. SP tracks begin again in Rosenberg and continue to Flatonia with an ABS utilizing a coded dc signal/control system. An interlocking is located at Eagle Lake.

The TCS consists of an underlying dc track circuit with an overlay pulse code modulated (PCM) 10 kHz carrier for signal and train control that begins at Flatonia and continues to Belen near El Paso with an interlocking at San Antonio. The central control

DESTINATION FROM	TO	DISTANCE IN MILES	SYSTEM TYPE	SYSTEM DESCRIPTION	COMMUNICATION CONTROL INTERFACE
NEW ORLEANS					
NEW ORLEANS	W. BRIDGE JCT	10	INTERLOCKING		
W. BRIDGE JCT	AVONDALE	1			
AVONDALE	MP 271	260	ABS	CODED DC TRACK CKT (WABCO 514)	POLE LINE
BEAUMONT					
MP 271	MP 282.1	11	INTERLOCKING		
MP 282.1	FAUNA	69	ABS	CODED DC TRACK CKT (WABCO 514)	POLE LINE
HOUSTON					
FAUNA	ENGLEWOOD-TWR68				
ENGLEWOOD-TWR68	EUREKA JCT	24	INTERLOCKING		
EUREKA JCT	WEST JCT				
WEST JCT	ROSENBERG	24	TCS	TRACK RIGHTS (ONLY)	
ROSENBERG (INTLK AT EAGLE LAKE)	FLATONIA	84	ABS	CODED DC TRACK CKT (WABCO 514)	POLE LINE
FLATONIA	SAN ANTONIO	81	TCS	DC TRACK CKT/WITH AUDIO FREQ CODED OVERLAY (4 ASPECT) MIMIC BOARD DISPLAY	POLE LINE (POWER) MICROWAVE (COMM/CONTR)
SAN ANTONIO					
SAN ANTONIO (EAST WYE, TOWERS 112 & 121)	WITHERS	12	INTERLOCKING		
WITHERS	SANDERSON	295	TCS	DC TRACK CKT/WITH AUDIO FREQ CODED OVERLAY (4 ASPECT) MIMIC BOARD DISPLAY	POLE LINE (POWER) MICROWAVE (COMM/CONTR)
SANDERSON	SIERRA BLANCA	222	TCS	DC TRACK CKT AUDIO FREQ CODED OVERLAY (4 ASPECT) COLOR CRT DISPLAY	POLE LINE
SIERRA BLANCA	BELEN	79	TCS	DC TRACK CKT/WITH AUDIO FREQ CODED OVERLAY (4 ASPECT) COLOR CRT DISPLAY	POLE LINE
EL PASO					
BELEN (TOWERS 47 & 119)	ANAPRA	19	DOUBLE TRK & INTERLOCKING		
ANAPRA	MESCAL	265	TCS	CODED DC TRK CKT	POLE LINE
MESCAL	STOCKAM (TUSCON)	41	DOUBLE TRK & ABS	CODED DC TRK CKT	POLE LINE
STOCKAM (TUSCON)	YUMA (INTLK IN YUMA)	293 (VIA PHOENIX)	TCS	CODED DC TRK CKT	POLE LINE
YUMA	COLTON	191	TCS	CODED DC TRK CKT	POLE LINE
COLTON YARD		—	INTERLOCKING		
COLTON	LOS ANGELES	60	TCS	CODED DC TRK CKT	POLE LINE
		2041			

FIGURE 6-2. AMTRAK ROUTE NEW ORLEANS-LOS ANGELES

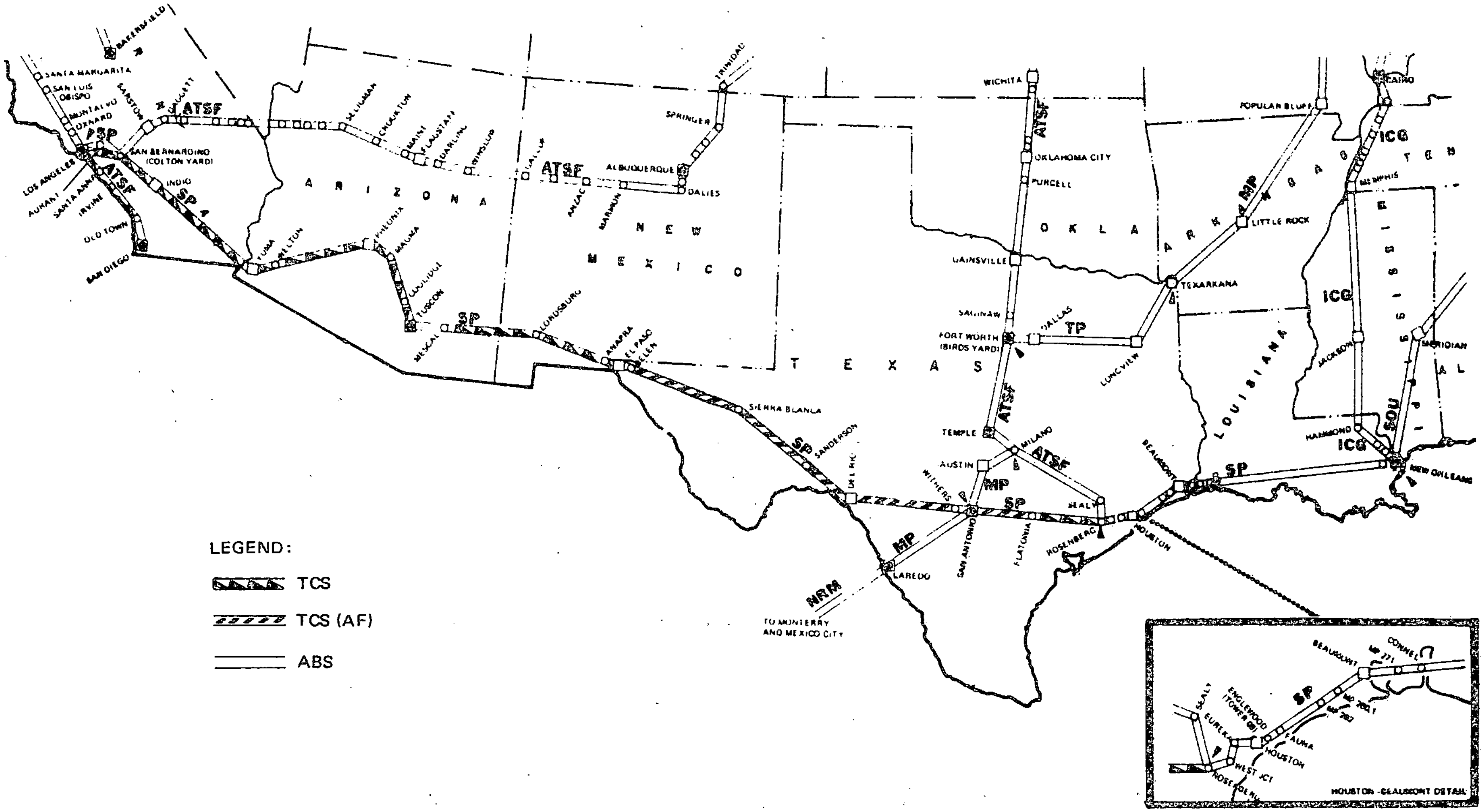

FIGURE 6-3. NEW ORLEANS-LOS ANGELES CORRIDOR
SIGNAL CONTROL SYSTEM

point is located at Houston and includes a 16-bit (Modcomp III) computer processing unit driving both mimic board and color cathode ray tube (CRT) displays. A mimic board display is utilized for the track segment from Flatonia to Sanderson excluding the interlocking from San Antonio to Withers. Color CRT displays are used for dispatcher control between Sanderson and Sierra Blanca and a single color CRT from Sierra Blanca to Belen. An interlocking spans El Paso between Belen and Anapra. The audio frequency TCS utilizes a microwave system to provide communications and control between the control center located in Houston and wayside. A system description of the SP audio frequency signal/control system is included in Paragraph 5.3 of the Task 1 Final Report.

The remaining trackage from Anapra to Los Angeles, is a dc coded TCS except the 41 mile (66 kilometer) segment between Mescal and Tuscon which is double track employing coded dc ABS.

The El Paso to Los Angeles segment includes an interlocking at the Colton yard near Los Angeles.

The Southern Pacific uses a four-aspect signal system on the New Orleans-Los Angeles route with established block lengths on continuously welded rail (CWR). The CWR is cut and insulated at each block boundary point. Block lengths were 17,000 feet (5,182 meters) but are being reduced to 8,000 feet (2,438 meters) to improve track signal levels.

6.3 Corridor Overlay Systems Installation Costs

All six candidate overlay systems were considered for the New Orleans to Los Angeles corridor. The installation cost data developed in the Task 2 report (and summarized in Section 3.0 of this report) have been applied to the existing signal system(s) between New Orleans and Los Angeles for application of each of the candidate overlay signal/control systems.

In addition, Category "B" and Category "C" costs have been shown and identified as the additional costs required to arrive at System "B" or system "C" levels.

6.3.1 Category "A"

- Category "A" System Description

  To simplify the tables and graphs dealing with corridor systems installation costs, the various systems have been coded as systems 1 through 6. The systems have been described in Tasks 1 and 2 but are repeated here for convenience of the reader.

  System 1

  System 1 (NEC) is a 5-aspect code-rated frequency track circuit which incorporates cab signaling.

  System 2

  System 2 (BR) is an intermittent cab signaling system employing passive wayside transponders. The transponder creates a binary coded message based on its permanent coding and repetitively transmits that message as a modulated 73.5 kHz carrier as long as the receiver is energized by the onboard transmitter.

  System 3

  System 3 (DB) is also an intermittent cab signaling system except that the wayside transponders are active and provide signaling information from track circuits.

  System 4

  System 4 (FS) is an intermittent cab signaling system, but the wayside transponders are passive and only transmit signaling information from track circuits.

System 5

System 5 (FS) is a continuous cab signaling system using dual carrier ac coded track circuits.

System 6

System 6 (DB) is a continuous cab signaling system having wayside communications elements of transposed inductive loops of cables mounted between the tracks.

- Category "A" Corridor Installation Costs

  Installation costs for the Category "A" systems are shown in Figure 6-4. The source for these cost estimates is Reference Document No. 395, the Task 2 report of this study series. These costs are derived from the cost ranges in Figure 3-1, using the higher figures to present the worst case costs for analysis purposes.

- Category "B" Corridor Installation Costs

  Category "B" corridor installation costs are shown in Figure 6-5. These costs are derived from costs in Figure 3-2.

- Category "C" Corridor Installation Costs

  Category "C" corridor installation costs are shown in Figure 6-6. These costs are derived from Figure 3-3.

FIGURE 6-4. CATEGORY "A" CORRIDOR INSTALLATION COSTS

CORRIDOR TRACK MILES SIGNALED	TRACK DATA		SYSTEM INSTALLATION COSTS											
			1		2		3		4		5		6	
	SYSTEM TYPE	SYSTEM DESCRIPTION	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST
1263	ABS	CODED DC	39	49257	9	11367	7	8841	9	11367	44	55572	60	75780
24	TCS	--	52	1248	55	1320	55	1320	57	1368	52	1248	55	1320
677	TCS	AUDIO	44	29788	9	6093	7	4739	9	6093	52	35204	62	41974
1964	SUBTOTAL		X	80293	X	18780	X	14900	X	18828	X	92024	X	119074
LOCOMOTIVE COSTS			PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL
			58	580	30	300	23	230	31	310	72	720	125	1250
TOTAL INSTALLATION COSTS			80873		19080		15130		19138		92744		120324	
TOTAL COST PER MILE (FOR 2041 MILES OF TRACK)			39.6		9.3		7.4		9.4		45.4		58.9	

FIGURE 6-5. CATEGORY "B" CORRIDOR INSTALLATION COSTS

CORRIDOR TRACK MILES SIGNALED	TRACK DATA		SYSTEM INSTALLATION COSTS											
			1		2		3		4		5		6	
	SYSTEM TYPE	SYSTEM DESCRIPTION	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST
1263	ABS	CODED DC	56	70728	19	23997	17	21471	19	23997	61	77043	69	87147
24	TCS	--	69	1656	10	240	10	240	10	240	69	1656	64	1536
677	TCS	AUDIO	61	41297	19	12863	17	11509	19	12863	69	46713	71	48067
1964	SUBTOTAL		X	113681	X	37100	X	33220	X	37100	X	125412	X	136750
LOCOMOTIVE COSTS (10 EA)			PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL
			58	580	33	330	26	260	34	340	72	720	128	1280
TOTAL INSTALLATION COSTS			114261		38430		33480		37440		126132		138030	
TOTAL COST PER MILE (FOR 2041 MILES OF TRACK)			56.0		18.3		16.4		18.3		61.8		67.6	

FIGURE 6-6. CATEGORY "C" CORRIDOR INSTALLATION COSTS

CORRIDOR TRACK MILES SIGNALED	TRACK DATA		SYSTEM INSTALLATION COSTS											
			1		2		3		4		5		6	
	SYSTEM TYPE	SYSTEM DESCRIPTION	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST	COST PER MILE	TOTAL COST
1263	ABS	CODED DC	59	74517	21	26523	21	26523	51	64413	64	80832	72	90936
24	TCS	--	72	1728	67	1608	67	1608	64	1536	72	1728	66	1584
677	TCS	AUDIO	64	43328	21	14217	19	12863	51	34527	72	48744	74	50098
1964	SUBTOTAL		X	119573	X	42348	X	40994	X	100476	X	131304	X	142618
LOCOMOTIVE COSTS (15 EA)			PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL	PER LOCOMOTIVE	TOTAL
			74	1110	33	495	26	390	34	510	85	1275	128	1920
TOTAL INSTALLATION COSTS			120683		42843		41384		100986		132579		144538	
TOTAL COST PER MILE (FOR 2041 MILES OF TRACK)			59.1		21.0		20.3		49.5		64.9		70.8	

SECTION 7.0

COST/BENEFIT ANALYSIS

Improvements to railroad passenger operations resulting from the installation of any of the signal/control systems considered in these studies could lead to increased speed and density. Added safety is a further benefit of enforced speed control. A Category "B" System may provide improved service by the train identification and tracking provided by that system. A Category "C" System will improve the schedules even further through the feature which allows a dispatcher or supervisor to continuously control passenger train speed and enforce schedules. It will also provide the passenger convenience of updating arrival and departure data in the train station.

7.1 Economic Service Improvement

In order to fully develop and analyze revenue-cost relationships that would result from the increased passenger train speeds permitted by an overlay signal/control system, considerable data beyond the scope of this study would be required. For example, such factors as the incremental increase in costs for track and right-of-way maintenance to permit high speed operation, the costs and problems concerned with highway grade crossing elimination (or full barrier protection), and numerous other areas would require investigation and documentation.

Additionally, DOT Order 5000.1 (1972) is quite specific in the methodology that cost/benefit studies are to be conducted for multi-year programs, viz, placing them on a discounted cash flow basis. The information developed within this technical research study is not sufficient at this stage to meet such DOT requirements. During Phase II, and subsequent Phase III applications to actual operation, overlay of advanced signal/control systems may be found to be fully justified on a present value basis when all benefits--both to freight and passenger service--are included.

In fact, perhaps one of the more important system improvement effects will be in areas other than the profitability of passenger service. Increased speeds with increased safety will also provide the means for higher freight speeds and the resulting benefits to both the public and private sectors. Once a federally-funded high speed overlay system were developed and installed for high-speed passenger service, on-board package installation for freight locomotives would become a relatively simple task. The economic and safety benefits to the railroads in the freight service area could, by themselves, justify the installation for passenger service.

The price increases in gasoline have already had an effect on Amtrak ridership, but at the time of this report the future effects are not specifically known, nor can they be predicted from the available data.

It is difficult to assess the profitability of passenger service in general and the improvements recommended by Amtrak studies. In the public process by which Congress intends to decide Amtrak's future, one of the recurring issues raised by the public is whether Amtrak should be viewed solely as a profit-making corporation or as an instrument to provide an energy efficient public service which otherwise would not be available. If profitability is deferred to some future date when ridership reaches a profitable level, then a signal/control system for high speed passenger service will contribute to that goal. Intercity business travel demands the least time lost in travel with predictable schedules. An advantage of intercity train service is the downtown-to-downtown departure and arrival; therefore, schedules competitive to air travel can deduct time to and from airports to their advantage.

7.2 Standardization

A standard of signal aspects, titles and indications was proposed in the Task 3 Final Report, Document Reference No. 403, Appendix A. The standardization requirement would, in essence, require the replacement of all wayside signal indicator heads except color position and color light heads capable of displaying two colors simultaneously. Cost data are not available, nor is the quantity of signal masts that would be affected. However, the quantity would be great. Burlington Northern (BN) has had a program of replacing semaphore signal units with color lights since 1976. BN reported at the FRA February 1979 Safety Inquiry, that they had spent $2,630,000 for signal conversion between 1976 and 1978 and had budgeted $943,100 to continue the program through 1979. The number of replacements made or the number of track miles converted was not reported. BN operates 22,988 miles of track or approximately 11 percent of the domestic Class I railroad trackage. Projecting their signal replacement costs over a four-year period represents a capital investment of $32,482,727 for signal change of the U.S. railroad system, or a projected cost of $8,120,691 per year. How many years this would have to continue is not predicted in this report.

Another major element of cost consideration in installation of a standard system of signal aspects, titles, and indications is the retraining of operating personnel. The only cost figures available for training are presented in section 4.0 of this report, and they deal with signal maintenance. Any assessment of the cost of retraining signalmen and operating crews for resignaling is an approximation at best. Assuming that one third of the 494,003 Class I railroad employees will require an average of twelve hours of retraining at the average wage of $7.09 per hour, the total retraining cost will equal an approximate cost of $14,009,925 exclusive of material and facility costs. This cost would be amortized over the time required for conversion of the existing signal devices. The $14 million cost equates to an assumed 136 dollars per track mile cost when amortized over the 102,958 miles (165,660 km) of signaled track reported in 1977.

7.3 Environmental Benefits

The environmental benefits which will result from greater utilization of both passenger and freight high speed service include increased energy efficiency, reduction in air pollution, improved transportation safety, better land use, and reduction in ecological damages.

The importance of total environmental evaluation will increase with the population growth. Better means of measuring environmental impacts will be developed as the importance of the impact grows.

The environmental benefits of increased use of rail service in the future would appear to markedly increase the merits of electrification. Each of the six candidate overlay signal/control systems selected and discussed in this study is compatible with railroad electrification.

SECTION 8.0

CONCLUSIONS AND RECOMMENDATIONS

The tables shown in Section 3.0 (Capital Costs) and Section 5.0 (Operating/Maintenance Costs) summarize the data developed in this Task concerning costs and economics. Application in Section 6.0 of these cost data to an actual corridor, together with the cost/benefit discussion in Section 7.0, serve to tie together all previous task reports of the overall study by determining the costs and relative benefits of the alternative candidate overlay systems.

The principal findings and conclusions of this Report are as follows:

1. The capital cost expenditures for the wayside portion of the candidate overlay systems vary from approximately $7,500 per track mile (intermittent systems) to $90,000 per track mile (inductive loop continuous system).

   Between these two groups lie the continuous in-rail types, falling in the range of $50,000 per track mile where continuous cab signaling does not now exist.

2. The wayside costs for the addition of Category "B", Train-to-Central Information, were determined to range from approximately $9,500 per track mile for the intermittent and/or continuous loop systems to $17,000 per track mile for this addition to the in-rail continuous type overlay systems.

3. The wayside costs for the addition of Category "C", Central-to-Train Control, were determined to be approximately $2,600 - $2,700 per track mile for any of the candidate overlay systems.

4. The incremental increase in wayside signal maintenance costs was determined to be 10% for the intermittent overlay signal/control systems; 13% for the 5-aspect 100 Hz continuous type; 16% for the dual carrier continuous type; and 63% for maintaining the additional equipment occasioned by an overlay installation of the continuous inductive loop system.

5. Installation costs of on-board locomotive equipment required for the candidate (basic) overlay signal/control systems were determined to be approximately $25,000 per locomotive for the intermittent types; $50,000 for the 5-aspect 100 Hz continuous type; $70,000 for the dual channel continuous type; and $115,000 per locomotive for the inductive loop continuous type.

6. With the addition of Category "B", Train-to-Central Information, approximately $3,000 per locomotive would be required for either the intermittent types or the continuous inductive loop overlay systems. No additional locomotive costs would be required for the addition of Category "B" to the in-rail continuous types.

7. For the additional option of Central-to-Train Information, Category "C", a $13,000 locomotive installation cost was determined for the in-rail continuous types, while no additional costs for this option would be incurred if either the intermittent or inductive loop continuous systems were applied to form the base overlay.

8. Construction costs of grade crossing separation or full barrier protection have not been included in the investment costs estimated in this Report. Grade crossing separation benefits are generally assumed to accrue principally to the highway user and thus are not considered a proper charge against high-speed passenger service.

9. Neither the costs for increased track maintenance for high-speed passenger service nor the resulting benefits to freight service (higher speeds, increased safety, crew cost reductions, improved competitive performance, etc.) have been included since these areas are beyond the scope of this technical study. However, it is felt that the benefits to freight service resulting from any federally-funded capitalization for higher speeds could be substantial.

The following recommendations are offered based upon the study findings:

1. The continuous inductive loop system alternative should, at this time, be dropped as a candidate system. This recommendation is based upon: 1) the extremely high capital cost; 2) the high maintenance cost and exposure to vandalism; and 3) the dichotomy in U.S. and German signal system philosophies which would result in retention of the existing wayside system thereby necessitating the operation and maintenance of two signal systems.

2. The functional specification to be prepared in Task 6 should allow for development of either the intermittent or the continuous in-rail type candidate systems.

3. FRA should consider a revision of the RS&I rules in order to eliminate the requirement that all locomotives must be cab signal equipped if cab signaling/train control exists anywhere within a specific territory.

4. It is recommended that additional cost evaluation and analysis be projected in the Phase II, Test and Evaluation, and Phase III, Demonstration System. Cost data should become more definitive with each successive phase of the study program. Phase II, will provide more realistic signal/control system costs, installation costs, maintainability and the basics of system operability and reliability. Each of these cost parameters will be further substantiated and refined after a signal/control demonstration system is subjected to testing in a revenue operating environment, Phase III.

APPENDIX A

DOCUMENT REFERENCE LIST

This report has referenced a number of sources for data, including technical papers, periodicals, books, and government reports. The sources have been both domestic and foreign. Where extensive material was extracted for the report the appropriate acknowledgement was made in the text. However, the report could not have been completed without the general background information which was obtained from the documents in this appendix. The authors acknowledge these sources by including them here. The numbers in the left column of the appendix listing are document numbers assigned for filing purposes. The numbers are not sequential, since only those documents applicable to Task 5 report have been included here. It may be noted that some documents were requested for this study task and were not received. However, they are listed here for their topical value and the fact that they may be received after the report is published.

Appendix A

DOCUMENT REFERENCE LIST

	Title	Source	Date
3	SHORT-TRAIN RAILROAD	PRO. R.R.	AUG 76
11	CONRAIL HELPS PUMP NEW LIFE INTO THE C&S MARKET	RY. AGE	FEB 77
22	C&S PROJECTS CONTINUING IN 1975	RSC	JUN 75
28	BULLET TRAINS REVISITED (KALMBACH PUB. CO.)	TRAINS	OCT 73
53	AN ECONOMIC ANALYSIS OF TRAIN CONTROL	UMTA	MAY 74
70	052726 USE OF ELECTRONIC COMPONENTS IN SIGNAL-LING. CATALOGUE OF FAILURES OF ELECTRONIC COMPONENTS STANDARDS	UIC	OCT 72
71	052727 USE OF ELECTRONIC COMPONENTS IN SIGNAL-LING. FAULTS AND SAFETY IN RAILWAY SAFETY SYSTEMS	UIC	OCT 72
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168	152679 RELIABILITY ENGINEERING: ITS IMPACT ON TRANSPORTATION CONTROL SYSTEMS (NOT RECEIVED)	GEN. RW. SIG. CO.	MAY 74
191	THE POCKET LIST OF RAILROAD OFFICIALS (BOOK) (QUARTERLY)	NAT. RR. PUB. CO.	2nd. QTR. 1979
192	A PRACTICAL MANUAL ON THE APPRAISAL OF CAPITAL EXPENDITURE	SOCIETY OF MGT ACCTS OF CANADA	1971
197	ELECTRIFICATION GETS CHEAPER ALL THE TIME	RGI	MAY 74
223	ROLE OF THE SIGNAL ENGINEER	BY ENGR. (TKD)	JAN 77
272	THE FIRE IS UNDER CONTROL, BUT		
277	AN EVALUATION OF RAILROAD SAFETY	OTA	MAY 78
278	OPERATING COSTS OF RAIL RAPID TRANSIT (UMTA-NY-11-0009-74-2)	UMTA	MAY 74
279	CAPITAL STOCK MEASURES FOR TRANSPORTATION, VOL. 3, (DOT-OS-10195) PROJECTIONS FOR INVESTMENT NEEDS	DOT	FEB 73
290	VANDALISM SUPPRESSION BY HELICOPTER	FRA	JAN 73
299	SUMMARY REPORT ON VANDALISM AND PASSENGER SECURITY IN THE TRANSIT INDUSTRY (TRANSPORTATION RESEARCH RECORD NO. 487, 1974)	ATA	1974
300	SCOPE OF CRIME AND VANDALISM ON URBAN TRANSIT SYSTEMS (TRANSPORTATION RESEARCH NO. 487, 1974)	ATA	1974
309	TREATMENT OF INFLATION IN ENGINEERING ECONOMICS ANALYSIS	IEEE	MAY 76

DOCUMENT REFERENCE LIST - Continued

	Title	Source	Date
167	152678 FAILURE MODE AND EFFECT ANALYSIS FOR SYSTEM SAFETY ASSURANCE OF ELECTRONIC CONTROLS (NOT RECEIVED)	GEN. RW. SIG. CO.	APR 76
168	152679 RELIABILITY ENGINEERING: ITS IMPACT ON TRANSPORTATION CONTROL SYSTEMS (NOT RECEIVED)	GEN. RW. SIG. CO.	MAY 74
191	THE POCKET LIST OF RAILROAD OFFICIALS (BOOK) (QUARTERLY)	NAT. RR. PUB. CO.	2nd. QTR. 1979
192	A PRACTICAL MANUAL ON THE APPRAISAL OF CAPITAL EXPENDITURE	SOCIETY OF MGT ACCTS OF CANADA	1971
197	ELECTRIFICATION GETS CHEAPER ALL THE TIME	RGI	MAY 74
223	ROLE OF THE SIGNAL ENGINEER	BY ENGR. (TKD)	JAN 77
272	THE FIRE IS UNDER CONTROL, BUT		
277	AN EVALUATION OF RAILROAD SAFETY	OTA	MAY 78
278	OPERATING COSTS OF RAIL RAPID TRANSIT (UMTA-NY-11-0009-74-2)	UMTA	MAY 74
279	CAPITAL STOCK MEASURES FOR TRANSPORTATION, VOL. 3, (DOT-OS-10195) PROJECTIONS FOR INVESTMENT NEEDS	DOT	FEB 73
290	VANDALISM SUPPRESSION BY HELICOPTER	FRA	JAN 73
299	SUMMARY REPORT ON VANDALISM AND PASSENGER SECURITY IN THE TRANSIT INDUSTRY (TRANSPORTATION RESEARCH RECORD NO. 487, 1974)	ATA	1974
300	SCOPE OF CRIME AND VANDALISM ON URBAN TRANSIT SYSTEMS (TRANSPORTATION RESEARCH NO. 487, 1974)	ATA	1974
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	Title	Source	Date
310	L&D PREVENTION IS WORKING	PROG. RR	OCT 78
311	1.29 AND COUNTING (L&D)	PROG. RR	OCT 78
326	LATEST SIGNAL TECHNIQUES LET RAILROADS DECREASE JOINT USAGE	RSC	JUL 72
333	ELECTRIFYING COULD SAVE MONEY	RSC	MAY 73
335	RELIABILITY ENGINEERING: IMPACT ON TRANSPORTATION CONTROL SYSTEMS	RSC	JLY/AUG 74
343	PROCEDURES FOR ANALYZING THE ECONOMIC COSTS OF RAILROAD ROADWAY FOR PRICING PURPOSES - VOLUME I - PROCEDURES	FRA	JAN 76
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345	REPORT ON THE VISIT TO THE U.S.S.R. BY THE U.S. ELECTRIFICATION DELEGATION (1975)	FRA	1975
355	RAILROAD SAFETY IN PERSPECTIVE	PROG. RR	MAY 78
359	RAILROAD ACCOUNTING	DOT	MAY 77
361	NORTHEAST CORRIDOR - TASK 18 SUPPORT SERVICES: ENGINEERING, ECONOMICS AND COST ESTIMATING	FRA	JUL 76
364	A NEW WAY TO MEASURE PERFORMANCE	RY. AGE	NOV 78
375	THE PRICE OF SAFETY	IME	JAN 77
376	AN OPTIMAL DECISION RULE FOR REPAIR VS REPLACEMENT	IEEE	AUG 77
377	IMPROVED PASSENGER SERVICE FOR THREE CORRIDORS	FRA	APR 73
378	ECONOMETRIC ANALYSIS AND FORECASTS OF INTERCITY RAIL PASSENGER DEMAND ON SELECTED AMTRAK CORRIDORS: A CASE STUDY	DOT	DEC 78
386	A PROSPECTUS FOR CHANGE IN THE FREIGHT RAILROAD INDUSTRY	DOT	OCT 78

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	Title	Source	Date
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395	EVALUATION OF SIGNAL/CONTROL SYSTEM EQUIPMENT AND TECHNOLOGY. TASK 2 - STATUS OF PRESENT SIGNAL/CONTROL EQUIPMENT	FRA	JAN 79
398	VANDALS CREATE "COMBAT ZONE" FOR RAILROADERS, A FEDERAL CRIME?	MOD. RR	MAR 79
400	AN ANALYSIS OF AMTRAK'S FIVE YEAR PLAN	GAO	MAR 78
402	TRANSCRIBED PROCEEDINGS FRA GENERAL SAFETY INQUIRY PUBLIC HEARING ON SIGNAL AND TRAIN CONTROL REGUATIONS AND ORDERS, DOCKET NO. RSSI-78-5 NOTICE 6	FRA	APR 79
403	EVALUATION OF SIGNAL/CONTROL SYSTEM EQUIPMENT AND TECHNOLOGY, TASK 3, STANDARDIZATION, SIGNAL TYPES, TITLES (DRAFT FINAL REPORT)	FRA	APR 79
407	AMTRAK - FIVE YEAR CORPORATE PLAN FISCAL YEARS 1978 - 1982	NRPC	OCT 77
408	A REEXAMINATION OF THE AMTRAK ROUTE STRUCTURE	U.S. DEPT. OF TRANS.	MAY 78
409	EVALUATION REPORT OF THE SECRETARY OF TRANSPORTATION'S PRELIMINARY RECOMMENDATIONS OF AMTRAKS ROUTE STRUCTURE	INTERSTATE COMMERCE COMMISSION	SEP 78
413	WE WANT THE JOB DONE RIGHT (A "PARED DOWN" AMTRAK)	PR	MAR 79

APPENDIX B

CAPITAL COSTS

The information included in this Appendix was taken from Task 2 of this study series and includes elemental costs for the installation of each of six candidate signal/control systems considered in this report.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: STEADY DC
OVERLAY SYSTEM: 5 ASPECT 100 HZ NEC
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Factory Wired Interface Cases	38	228,000.	247,000.
3.	Miscellaneous Equipment	1	39,000.	45,000.
4.	Stores Overhead		18,000.	21,000.
5.	Engineering		8,000.	10,000.
6.	Supervision/Testing		12,000.	14,000.
7.	Labor Installing		116,000.	135,000.
8.	Labor Overhead		74,000.	86,000.
		Total II	$525,000.	$611,000.
		Per Track Mile	$ 11,000.	$ 12,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$ 22,000.	$ 28,000.
2.	Miscellaneous Equipment	1	3,000.	4,000.
3.	Stores Overhead		2,000.	3,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,000.	1,000.
6.	Labor Installing		10,000.	13,000.
7.	Labor Overhead		6,000.	8,000.
		Total III	$ 45,000.	$ 58,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: CODED DC
OVERLAY SYSTEM: 5 ASPECT 100 HZ NEC
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Factory Wired Interface Cases	38	152,000.	171,000.
3.	Miscellaneous Equipment	1	27,000.	34,000.
4.	Stores Overhead		13,000.	15,000.
5.	Engineering		6,000.	7,000.
6.	Supervision/Testing		9,000.	11,000.
7.	Labor Installing		81,000.	101,000.
8.	Labor Overhead		52,000.	64,000.
		Total II	$370,000.	$456,000.
		Per Track Mile	$ 7,000.	$ 9,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$22,000.	$28,000.
2.	Miscellaneous Equipment	1	3,000.	4,000.
3.	Stores Overhead		2,000.	3,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,000.	1,000.
6.	Labor Installing		10,000.	13,000.
7.	Labor Overhead		6,000.	8,000.
		Total III	$45,000.	$58,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: STEADY AC
OVERLAY SYSTEM: 5 ASPECT 100 HZ NEC
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Factory Wired Interface Cases	38	228,000.	247,000.
3.	Miscellaneous Equipment	1	39,000.	45,000.
4.	Stores Overhead		18,000.	21,000.
5.	Engineering		8,000.	10,000.
6.	Supervision/Testing		12,000.	14,000.
7.	Labor Installing		116,000.	135,000.
8.	Labor Overhead		74,000.	86,000.
		Total II	$525,000.	$611,000.
		Per Track Mile	$ 11,000.	$ 12,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$22,000.	$28,000.
2.	Miscellaneous Equipment	1	3,000.	4,000.
3.	Stores Overhead		2,000.	3,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,000.	1,000.
6.	Labor Installing		10,000.	13,000.
7.	Labor Overhead		6,000.	8,000.
		Total III	$45,000.	$58,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: CODED AC
OVERLAY SYSTEM: 5 ASPECT 100 HZ NEC
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Factory Wired Interface Cases	38	72,000.	114,000.
3.	Miscellaneous Equipment	1	15,000.	25,000.
4.	Stores Overhead		7,000.	12,000.
5.	Engineering		3,000.	5,000.
6.	Supervision/Testing		5,000.	8,000.
7.	Labor Installing		46,000.	75,000.
8.	Labor Overhead		29,000.	48,000.
		Total II	$207,000.	$340,000.
		Per Track Mile	$ 4,000.	$ 7,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$22,000.	$28,000.
2.	Miscellaneous Equipment	1	3,000.	4,000.
3.	Stores Overhead		2,000.	3,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,000.	1,000.
6.	Labor Installing		10,000.	13,000.
7.	Labor Overhead		6,000.	8,000.
		Total III	$45,000.	$58,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: AUDIO
OVERLAY SYSTEM: 5 ASPECT 100 HZ NEC
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Factory Wired Interface Cases	38	247,000.	285,000.
3.	Miscellaneous Equipment	1	42,000.	51,000.
4.	Stores Overhead		19,000.	23,000.
5.	Engineering		9,000.	11,000.
6.	Supervision/Testing		13,000.	16,000.
7.	Labor Installing		124,000.	152,000.
8.	Labor Overhead		79,000.	96,000.
		Total II	$563,000.	$687,000.
		Per Track Mile	$ 11,000.	$ 14,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$22,000.	$28,000.
2.	Miscellaneous Equipment	1	3,000.	4,000.
3.	Stores Overhead		2,000.	3,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,000.	1,000.
6.	Labor Installing		10,000.	13,000.
7.	Labor Overhead		6,000.	8,000.
		Total III	$45,000.	$58,000.

CATEGORY "A"
EXISTING SYSTEM: TT&TO
OVERLAY SYSTEM: 5-ASPECT 100 Hz CONTINUOUS (or) DUAL CHANNEL CARRIER (FS)
(BASED ON 50 MILE SEGMENT)

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Wired Instrument Case	38	$ 247,000.	$ 285,000.
2.	Line Poles	2,000	260,000.	260,000.
3.	Pole Line Hardware	1	12,000.	12,000.
4.	Messenger 336. MCM-Aluminum	227,200	83,000.	83,000.
5.	2 Cond. #6-3000V Cable	277,200	554,000.	554,000.
6.	Lashing Wire	227,200	11,000.	11,000.
7.	Insulated Joints	76	12,000.	12,000.
8.	Transformer Locations	38	30,000.	53,000.
9.	Miscellaneous Equipment		181,000.	191,000.
10.	Stores Overhead/Taxes		83,000.	88,000.
11.	Engineering		38,000.	40,000.
12.	Supervision/Testing		57,000.	60,000.
13.	Labor Installing		542,000.	570,000.
14.	Labor Overhead		344,000.	362,000.
		Total Cost	$2,454,000.	$2,581,000.
		Cost Per Mile	$ 49,000.	$ 52,000.

CATEGORY "A"
CAPITAL COSTS
INTERMITTENT WAYSIDE OVERLAY SYSTEMS
(BASED ON 50 MILE SEGMENTS)

II. (BR) TRACK MILE WAYSIDE COSTS

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Additional Signal Heads	38	$ 26,000.	$ 26,000.
2.	Additional Signal Control Equipment	38	152,000.	171,000.
3.	Transponders	80	28,000.	28,000.
4.	Miscellaneous Equipment		31,000.	34,000.
5.	Stores Overhead		14,000.	16,000.
6.	Engineering		7,000.	7,000.
7.	Supervision/Testing		10,000.	11,000.
8.	Labor Installing		93,000.	101,000.
9.	Labor Overhead		59,000.	64,000.
	Total II (BR)		$420,000.	$458,000.
	Per Track MIle		$ 8,000.	$ 9,000.

(DB) TRACK MILE WAYSIDE COSTS

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Underground Cable	36,000	$ 47,000.	$ 47,000.
2.	Transponders	120	24,000.	24,000.
3.	Wired Interface Cases	38	76,000.	95,000.
4.	Miscellaneous Equipment		22,000.	25,000.
5.	Stores Overhead		10,000.	11,000.
6.	Engineering		7,000.	7,000.
7.	Supervision/Testing		10,000.	12,000.
8.	Labor Installing		93,000.	108,000.
9.	Labor Overhead		60,000.	68,000.
	Total II (DB)		$ 349,000.	$ 397,000.
	Per Track Mile		$ 7,000.	$ 8,000.

(FS) TRACK MILE WAYSIDE COSTS

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Underground Cable	36,000	$ 47,000.	$ 47,000.
2.	Transponders	120	66,000.	66,000.
3.	Wired Interface Cases	38	76,000.	95,000.
4.	Miscellaneous Equipment		28,000.	31,000.
5.	Stores Overhead		13,000.	14,000.
6.	Engineering		6,000.	7,000.
7.	Supervision/Testing		9,000.	10,000.
8.	Labor Installing		85,000.	93,000.
9.	Labor Overhead		54,000.	59,000.
	Total II (FS)		$384,000.	$422,000.
	Per Track Mile		$ 8,000.	$ 9,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: TT&TO
OVERLAY SYSTEM: INTERMITTENT (BR)
(BASED ON 50 MILE SEGMENT)

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Wired Wayside Cases	38	$ 38,000.	$ 57,000.
2.	Line Poles	2,000	260,000.	260,000.
3.	Pole Line Hardware	1	12,000.	12,000.
4.	Messenger 336 MCM-Alum.	554,400 LF	166,000.	166,000.
5.	2 Cond.-#6, 3000V Cable	277,200 LF	554,000.	554,000.
6.	Communication Cable	277,200 LF	180,000.	180,000.
7.	Lashing Wire	600,000 LF	30,000.	30,000.
8.	Transformer Locations	38	30,000.	53,000.
9.	Mini Computer	2	8,000.	8,000.
10.	Axle Counters (Incl. Wayside Logic)	76	13,000.	13,000.
11.	Transponders	80	28,000.	28,000.
12.	Miscellaneous Equipment		198,000.	204,000.
13.	Stores Overhead/Taxes		91,000.	94,000.
14.	Engineering		42,000.	43,000.
15.	Supervision/Testing		63,000.	65,000.
16.	Labor Installing		592,000.	610,000.
17.	Labor Overhead		376,000.	388,000.
		Total	$2,681,000.	$2,765,000.
		Cost Per Mile	$ 54,000.	$ 55,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: TT&TO
OVERLAY SYSTEM: INTERMITTENT (DB)
(BASED ON 50 MILE SEGMENT)

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Wired Wayside Cases	38	$ 38,000.	$ 57,000.
2.	Line Poles	2,000	260,000.	260,000.
3.	Pole Line Hardware	1	12,000.	12,000.
4.	Messenger 336 MCM-Alum.	554,400 LF	166,000.	166,000.
5.	2 Cond.-#6, 3000V Cable	277,200 LF	554,000.	554,000.
6.	Communication Cable	277,200 LF	180,000.	180,000.
7.	Lashing Wire	600,000 LF	30,000.	30,000.
8.	Transformer Locations	38	30,000.	53,000.
9.	Mini Computer	2	8,000.	8,000.
10.	Axle Counters (Incl. Wayside Logic)	76	13,000.	13,000.
11.	Transponders	120	24,000.	24,000.
12.	Miscellaneous Equipment		197,000.	204,000.
13.	Stores Overhead/Taxes		91,000.	94,000.
14.	Engineering		42,000.	43,000.
15.	Supervision/Testing		62,000.	64,000.
16.	Labor Installing		586,000.	609,000.
17.	Labor Overhead		372,000.	387,000.
		Total	$2,665,000.	$2,758,000.
		Cost Per Mile	$ 53,000.	$ 55,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: TT&TO
OVERLAY SYSTEM: INTERMITTENT (FS)
(BASED ON 50 MILE SEGMENT)

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Wired Wayside Cases	38	$ 38,000.	$ 57,000.
2.	Line Poles	2,000	260,000.	260,000.
3.	Pole Line Hardware	1	12,000.	12,000.
4.	Messenger 336 MCM-Alum.	554,400 LF	166,000.	166,000.
5.	2 Cond.-#6, 3000V Cable	277,200 LF	554,000.	554,000.
6.	Communication Cable	277,200 LF	180,000.	180,000.
7.	Lashing Wire	600,000 LF	30,000.	30,000.
8.	Transformer Locations	38	30,000.	53,000.
9.	Mini Computer	2	8,000.	8,000.
10.	Axle Counters (Incl. Wayside Logic)	76	13,000.	13,000.
11.	Transponders	120	66,000.	66,000.
12.	Miscellaneous Equipment		204,000.	210,000.
13.	Stores Overhead/Taxes		94,000.	97,000.
14.	Engineering		43,000.	44,000.
15.	Supervision/Testing		64,000.	67,000.
16.	Labor Installing		609,000.	628,000.
17.	Labor Overhead		387,000.	399,000.
		Total	$2,758,000.	$2,844,000.
		Cost Per Mile	$ 55,000.	$ 57,000.

CATEGORY "A"
CAPITAL COSTS
TRAIN-BORNE EQUIPMENT
INTERMITTENT TC SYSTEMS

- PER LOCOMOTIVE -

III. TRAIN-BORNE EQUIPMENT (BR)

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Package	1	$12,000.	$12,000.
2.	Miscellaneous Equipment		3,000.	5,000.
3.	Stores Overhead		900.	1,000.
4.	Engineering		400.	500.
5.	Supervision/Testing		600.	700.
6.	Labor Installing		6,000.	7,000.
7.	Labor Overhead		4,000.	4,000.
		Total II (BR)	$27,000.	$30,000.

TRAIN-BORNE EQUIPMENT (DB)

	ITEM	QUANT.	COST RANGE LOW	COST RANGE high
1.	Train-Borne Package	1	$10,000.	$10,000.
2.	Miscellaneous Equipment		2,000.	3,000.
3.	Stores Overhead		1,000.	1,000.
4.	Engineering		300.	400.
5.	Supervision/Testing		500.	600.
6.	Labor Installing		5,000.	5,000.
7.	Labor Overhead		3,000.	3,000.
		Total II (DB)	$22,000.	$23,000.

TRAIN-BORNE EQUIPMENT (FS)

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Package	1	$14,000.	$14,000.
2.	Miscellaneous Equipment		3,000.	4,000.
3.	Stores Overhead		1,000.	1,000.
4.	Engineering		500.	500.
5.	Supervision/Testing		700.	700.
6.	Labor Installing		7,000.	7,000.
7.	Labor Overhead		4,000.	4,000.
		Total II (FS)	$30,000.	$31,000.

* ALL ABOVE COSTS TO NEAREST THOUSAND

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: STEADY DC
OVERLAY SYSTEM: DUAL CXR CONT. (FS)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Wired Interface Cases	38	342,000.	432,000.
3.	Miscellaneous Equipment		56,000.	73,000.
4.	Stores Overhead		26,000.	34,000.
5.	Engineering		12,000.	15,000.
6.	Supervision/Testing		18,000.	23,000.
7.	Labor Installing		167,000.	218,000.
8.	Labor Overhead		106,000.	138,000.
		Total II	$757,000.	$986,000.
		Per Road Mile	$ 15,000.	$ 20,000.

III. TRAIN-BORNE EQUIPMENT

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Package	1	$32,000.	$32,000.
2.	Miscellaneous Equipment	1	6,000.	9,000.
3.	Stores Overhead		2,000.	2,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,600.	1,700.
6.	Labor Installing		15,000.	16,000.
7.	Labor Overhead		9,000.	10,000.
		Total III (Per Loco.)	$66,600.	$71,700.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: CODED DC
OVERLAY SYSTEM: DUAL CXR CONT. (FS)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST — COST RANGE

	ITEM	QUANT.	LOW	HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE SIGNAL EQUIPMENT COST — COST RANGE

	ITEM	QUANT.	LOW	HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Wired Instrument Cases	38	228,000.	299,000.
3.	Miscellaneous Equipment	1	39,000.	53,000.
4.	Stores Overhead		18,000.	24,000.
5.	Engineering		8,000.	11,000.
6.	Supervision/Testing		12,000.	17,000.
7.	Labor Installing		116,000.	158,000.
8.	Labor Overhead		74,000.	100,000.
		Total II	$525,000.	$715,000.
		Per Track Mile	$ 11,000.	$ 14,000.

III. TRAIN-BORNE EQUIPMENT — COST RANGE

	ITEM	QUANT.	LOW	HIGH
1.	Train-Borne Package	1	$32,000.	$32,000.
2.	Miscellaneous Equipment	1	6,000.	9,000.
3.	Stores Overhead		2,000.	2,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,600.	1,700.
6.	Labor Installing		15,000.	16,000.
7.	Labor Overhead		9,000.	10,000.
		Total III (Per Loco.)	$66,600.	$71,700.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: STEADY AC
OVERLAY SYSTEM: DUAL CXR CONT. (FS)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Wired Interface Cases	38	342,000.	432,000.
3.	Miscellaneous Equipment	-	56,000.	73,000.
4.	Stores Overhead		26,000.	34,000.
5.	Engineering		12,000.	15,000.
6.	Supervision/Testing		18,000.	23,000.
7.	Labor Installing		167,000.	218,000.
8.	Labor Overhead		106,000.	138,000.
		Total II	$757,000.	$986,000.
		Per Track Mile	$ 15,000.	$ 20,000.

III. TRAIN-BORNE EQUIPMENT

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Package	1	$32,000.	$32,000.
2.	Miscellaneous Equipment	1	6,000.	9,000.
3.	Stores Overhead		2,000.	2,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,600.	1,700.
6.	Labor Installing		15,000.	16,000.
7.	Labor Overhead		9,000.	10,000.
		Total III (Per Loco.)	$66,600.	$71,700.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: CODED AC
OVERLAY SYSTEM: DUAL CXR CONT. (FS)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Wired Instrument Cases	38	152,000.	200,000.
3.	Miscellaneous Equipment	1	27,000.	38,000.
4.	Stores Overhead		13,000.	17,000.
5.	Engineering		6,000.	12,000.
6.	Supervision/Testing		9,000.	19,000.
7.	Labor Installing		82,000.	175,000.
8.	Labor Overhead		52,000.	111,000.
		Total II	$371,000.	$625,000.
		Per Track Mile	$ 7,000.	$ 13,000.

III. TRAIN-BORNE EQUIPMENT

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Package	1	$32,000.	$32,000.
2.	Miscellaneous Equipment	1	6,000.	9,000.
3.	Stores Overhead		2,000.	2,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,600.	1,700.
6.	Labor Installing		15,000.	16,000.
7.	Labor Overhead		9,000.	10,000.
		Total III (Per Loco.)	$66,600.	$71,700.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: AUDIO
OVERLAY SYSTEM: DUAL CXR CONT. (FS)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Transformer Locations	38	$ 30,000.	$ 53,000.
2.	Wired Instrument Cases	38	432,000.	499,000.
3.	Miscellaneous Equipment		69,000.	83,000.
4.	Stores Overhead		32,000.	38,000.
5.	Engineering		15,000.	18,000.
6.	Supervision/Testing		22,000.	26,000.
7.	Labor Installing		207,000.	248,000.
8.	Labor Overhead		132,000.	157,000.
		Total II	$939,000.	$1,122,000.
		Per Track Mile	$ 19,000.	$ 22,000.

III. TRAIN-BORNE EQUIPMENT

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Package	1	$32,000.	$32,000.
2.	Miscellaneous Equipment	1	6,000.	9,000.
3.	Stores Overhead		2,000.	2,000.
4.	Engineering		1,000.	1,000.
5.	Supervision/Testing		1,600.	1,700.
6.	Labor Installing		15,000.	16,000.
7.	Labor Overhead		9,000.	10,000.
		Total III (Per Loco.)	$66,600.	$71,700.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: STEADY DC
OVERLAY SYSTEM: INDUCTIVE LOOP CONTINUOUS (DB)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Loop Wire	580,800	$ 261,000.	$ 261,000.
2.	Hardware	1	13,000.	13,000.
3.	Factory Wired Interface Houses	5	400,000.	490,000.
4.	Miscellaneous Equipment	1	101,000.	115,000.
5.	Stores Overhead		47,000.	53,000.
6.	Engineering		21,000.	24,000.
7.	Supervision/Testing		32,000.	36,000.
8.	Labor Installing		302,000.	343,000.
9.	Labor Overhead		192,000.	218,000.
		Total II	$1,369,000.	$1,553,000.
		Per Track Mile	$ 27,000.	$ 31,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$ 55,000.	$ 55,000.
2.	Miscellaneous Equipment	1	5,000.	8,000.
3.	Stores Overhead		8,000.	20,000.
4.	Engineering		2,000.	2,000.
5.	Supervision/Testing		3,000.	3,000.
6.	Labor Installing		25,000.	25,000.
7.	Labor Overhead		16,000.	16,000.
		Total III (Per Loco.)	$114,000.	$129,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: CODED DC
OVERLAY SYSTEM: INDUCTIVE LOOP CONTINUOUS (DB)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Loop Wire	580,800	$ 261,000.	$ 261,000.
2.	Hardware	1	13,000.	13,000.
3.	Factory Wired Interface Houses	5	375,000.	465,000.
4.	Miscellaneous Equipment	1	97,000.	111,000.
5.	Stores Overhead		45,000.	51,000.
6.	Engineering		21,000.	23,000.
7.	Supervision/Testing		31,000.	35,000.
8.	Labor Installing		291,000.	332,000.
9.	Labor Overhead		185,000.	211,000.
		Total II	$1,319,000.	$1,502,000.
		Per Track Mile	$ 26,000.	$ 30,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$ 55,000.	$ 55,000.
2.	Miscellaneous Equipment	1	5,000.	8,000.
3.	Stores Overhead		8,000.	20,000.
4.	Engineering		2,000.	2,000.
5.	Supervision/Testing		3,000.	3,000.
6.	Labor Installing		25,000.	25,000.
7.	Labor Overhead		16,000.	16,000.
		Total III (Per Loco.)	$114,000.	$129.000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: STEADY AC
OVERLAY SYSTEM: INDUCTIVE LOOP CONTINUOUS (DB)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Loop Wire	580,800	$ 261,000.	$ 261,000.
2.	Hardware	1	13,000.	13,000.
3.	Factory Wired Interface Houses	5	390,000.	480,000.
4.	Miscellaneous Equipment	1	100,000.	113,000.
5.	Stores Overhead		46,000.	52,000.
6.	Engineering		21,000.	24,000.
7.	Supervision/Testing		32,000.	36,000.
8.	Labor Installing		299,000.	338,000.
9.	Labor Overhead		189,000.	215,000.
		Total II	$1,351,000.	$1,532,000.
		Per Track Mile	$ 27,000.	$ 31,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$ 55,000.	$ 55,000.
2.	Miscellaneous Equipment	1	5,000.	8,000.
3.	Stores Overhead		8,000.	20,000.
4.	Engineering		2,000.	2,000.
5.	Supervision/Testing		3,000.	3,000.
6.	Labor Installing		25,000.	25,000.
7.	Labor Overhead		16,000.	16,000.
		Total III (Per Loco.)	$114,000.	$128,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: CODED AC
OVERLAY SYSTEM: INDUCTIVE LOOP CONTINUOUS (DB)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Loop Wire	580,800	$ 261,000.	$ 261,000.
2.	Hardware	1	13,000.	13,000.
3.	Factory Wired Interface Houses	5	360,000.	440,000.
4.	Miscellaneous Equipment	1	95,000.	107,000.
5.	Stores Overhead		44,000.	49,000.
6.	Engineering		20,000.	23,000.
7.	Supervision/Testing		30,000.	34,000.
8.	Labor Installing		284,000.	320,000.
9.	Labor Overhead		181,000.	203,000.
		Total II	$1,288,000.	$1,450,000.
		Per Track Mile	$ 26,000.	$ 29,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$ 55,000.	$ 55,000.
2.	Miscellaneous Equipment	1	5,000.	8,000.
3.	Stores Overhead		8,000.	20,000.
4.	Engineering		2,000.	2,000.
5.	Supervision/Testing		3,000.	3,000.
6.	Labor Installing		25,000.	25,000.
7.	Labor Overhead		16,000.	16,000.
		Total III (Per Loco.)	$114,000.	$129,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: AUDIO
OVERLAY SYSTEM: INDUCTIVE LOOP CONTINUOUS (DB)
(BASED ON 50 MILE SEGMENT)

I. ROAD MILE SIGNAL COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Pole Line Hardware	1	$ 6,000.	$ 6,000.
2.	Messenger 336. MCM-AL	277,200 LF	83,000.	83,000.
3.	2C#6 - 3000V Cable	277,200 LF	554,000.	554,000.
4.	100 Hz Substation	2	50,000.	70,000.
5.	Miscellaneous Equipment	1	104,000.	107,000.
6.	Stores Overhead		48,000.	49,000.
7.	Engineering		22,000.	23,000.
8.	Supervision/Testing		33,000.	34,000.
9.	Labor Installing		311,000.	320,000.
10.	Labor Overhead		197,000.	203,000.
		Total I	$1,408,000.	$1,449,000.
		Per Road Mile	$ 28,000.	$ 30,000.

II. TRACK MILE WAYSIDE SIGNAL EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Loop Wire	580,800	$ 261,000.	$ 261,000.
2.	Hardware	1	13,000.	13,000.
3.	Factory Wired Interface Houses	5	425,000.	525,000.
4.	Miscellaneous Equipment	1	105,000.	120,000.
5.	Stores Overhead		48,000.	55,000.
6.	Engineering		22,000.	25,000.
7.	Supervision/Testing		33,000.	38,000.
8.	Labor Installing		314,000.	358,000.
9.	Labor Overhead		199,000.	277,000.
		Total II	$1,420,000.	$1,622,000.
		Per Track Mile	$ 28,000.	$ 32,000.

III. TRAIN-BORNE EQUIPMENT COST

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Train-Borne Equipment	1	$ 55,000.	$ 55,000.
2.	Miscellaneous Equipment	1	5,000.	8,000.
3.	Stores Overhead		8,000.	20,000.
4.	Engineering		2,000.	2,000.
5.	Supervision/Testing		3,000.	3,000.
6.	Labor Installing		25,000.	25,000.
7.	Labor Overhead		16,000.	16,000.
		Total III (Per Loco.)	$114,000.	$129,000.

CATEGORY "A"
CAPITAL COSTS
EXISTING SYSTEM: TT&TO
OVERLAY SYSTEM: INDUCTIVE LOOP CONTINUOUS
(BASED ON 50 MILE SEGMENT)

	ITEM	QUANT.	COST RANGE LOW	COST RANGE HIGH
1.	Line Poles	2,000	$ 260,000.	$ 260,000.
2.	Pole Line Hardware	1	12,000.	12,000.
3.	Messenger 336 MCM, Alum.	277,200 LF	68,000.	68,000.
4.	Communication Cable	277,200 LF	180,000	180,000.
5.	Lashing Wire	600,000 LF	30,000.	30,000.
6.	Axle Counters (Incl. Wayside Logic)	76	13,000.	13,000.
7.	Loop Wire	580,000 LF	261,000.	261,000.
8.	Mtg. Hardware	1	13,000.	13,000.
9.	Factory Wired Logic Houses	5	490,000.	490,000.
10.	Miscellaneous Equipment		166,000.	332,000.
11.	Stores Overhead/Taxes		89,000.	100,000.
12.	Engineering		39,000.	43,000.
13.	Supervision/Testing		58,000.	65,000.
14.	Labor Installing		549,000.	610,000.
15.	Labor Overhead		349,000.	388,000.
		Total I	$2,577,000.	$2,865,000.
		Cost Per Mile	$ 51,000.	$ 57,000.

CATEGORY "B"
CAPITAL COSTS
TRAIN-TO-CENTRAL INFORMATION
for
5-ASPECT 100 Hz (NEC) or DUAL CHANNEL CARRIER (FS) SYSTEMS
(BASED ON 50 MILE SEGMENT)

	ITEM	QUANT.	UNIT COST	TOTAL
1.	2-Pair Tel. Cable	277,200 ft.	0.28 LF	$ 77,616
2.	Messenger 336.4 MCM	277,200 ft.	0.30 LF	68,160
3.	Lashing Wire	277,200 ft.	0.05 LF	11,360
4.	Pole Line Hardware		LS	6,000
5.	Data Encoder	1	45,000	45,000
6.	CRT (Single Color)	1	5,000	5,000
7.	Computer & Peripherals	1	140,000	140,000
8.	Miscellaneous Material			52,970
9.	Stores Overhead/Taxes			24,375
10.	Engineering			11,200
11.	Supervision/Testing			16,800
12.	Labor Installing (Incl. Software)			258,400
13.	Labor Overhead			154,600
			Total	$871,481

Total Per Road Mile/$17,500

Above costs do not include any recurrent charges for leased commercial telephone circuits between railroad central offices and Amtrak national display center.

CATEGORY "B"
CAPITAL COSTS
TRAIN-TO-CENTRAL INFORMATION
for
INTERMITTENT OR INDUCTIVE LOOP CONTINUOUS LOOP SYSTEMS
(BASED ON 50 MILE SEGMENT)

I. WAYSIDE COSTS

	ITEM	QUANT.	UNIT COST	TOTAL
1.	Base Station	1	12,000	$ 12,000
2.	Computer & Peripherals	1	140,000	140,000
3.	CRT (Single Color)	1	5,000	5,000
4.	Miscellaneous Material			23,500
5.	Stores Overhead/Taxes			10,800
6.	Engineering			4,900
7.	Supervision/Testing			7,500
8.	Labor Installing (Incl. Software)			170,400
9.	Labor Overhead			98,700
			Total	$478,800

Total Per Road Mile/$9,500

II. PER LOCOMOTIVE COSTS

	ITEM	QUANT.	UNIT COST	TOTAL
1.	Locomotive Radio Modules	1	1,500	$ 1,500
2.	Miscellaneous Material		LS	225
3.	Stores Overhead/Taxes			105
4.	Engineering			50
5.	Supervision/Testing			75
6.	Labor Installing			675
7.	Labor Overhead			430
		Total Per Locomotive		$ 3,000

CATEGORY "C"
CAPITAL COSTS
CENTRAL TO TRAIN INFORMATION
for
5-ASPECT 100 Hz (NEC) or DUAL CHANNEL CARRIER (FS) SYSTEMS
(BASED ON 50 MILE SEGMENT)

I. WAYSIDE COSTS

	ITEM	QUANT.	UNIT COST	TOTAL
1.	Base Station (Add'l)	1	3,000	$ 3,000
2.	CRT (Full Color)	1	25,000	25,000
3.	Miscellaneous Material			4,200
4.	Stores Overhead/Taxes			1,900
5.	Engineering			900
6.	Supervision/Testing			1,400
7.	Labor Installing			62,500
8.	Labor Overhead			34,900
			Total	$133,800

Total Per Road Mile/$2,700

II. PER LOCOMOTIVE COSTS

	ITEM	QUANT.	UNIT COST	TOTAL
1.	Train-Borne Radio	1	1,500	$ 1,500
2.	Decoder	1	5,000	5,000
3.	Miscellaneous Material		LS	975
4.	Stores Overhead/Taxes			450
5.	Engineering			200
6.	Supervision/Testing			310
7.	Labor Installing			2,925
8.	Labor Overhead			1,850
		Total Per Locomotive		$ 13,000

CATEGORY "C"
CAPITAL COSTS
CENTRAL-TO-TRAIN INFORMATION
for
INTERMITTENT OR INDUCTIVE CONTINUOUS LOOP SYSTEMS
(BASED ON 50 MILE SEGMENT)

	ITEM	QUANT.	UNIT COST	TOTAL
1.	CRT (Full Color)	1	25,000	$ 25,000
2.	Miscellaneous Material		LS	3,750
3.	Stores Overhead/Taxes			1,725
4.	Engineering			800
5.	Supervision/Testing			1,125
6.	Labor Installing (Incl. Software)			61,200
7.	Labor Overhead			34,100
			Total	$127,700
		Total Per Road Mile		$ 2,600

APPENDIX C

SUMMARY OF FALSE PROCEED REPORTS

The information included in this appendix was provided by the Federal Railroad Administration Office of Safety and represents the false-proceed signal failures for domestic railroads for the period between 7/1/76 through 9/30/78.

CAUSES OF FALSE PROCEED FAILURES REPORTED BY CARRIERS FOR TRANSITION PERIOD 7/1/76 - 9/30/76* AND FISCAL YEAR 1977

Railroads	Sand, rust or other deposits on rails		Failure of relays and similar devices		Circuits open crossed or grounded. Foreign current, etc.		Apparatus broken, defective or out of adjustment,		Failure of apparatus due to ice, sleet, snow wet track weather or lightning		Vandalism		Errors in making a connection or adjust-ments		Unde-termined		TOTAL	
Atchison, Topeka & Santa Fe. . .	(3)	-	-	-	-	2	-	1	-	-	(1)	-	-	3	-	-	(4)	6
Atlanta & West Point	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2
Baltimore & Ohio	-	-	-	-	-	-	-	-	-	-	(1)	-	(1)	-	-	-	(2)	-
Bangor & Aroostook	-	-	-	-	-	1	-	-	-	(1)	-	-	-	-	-	-	-	2
Boston & Maine Corp.	-	-	-	-	(1)	2	-	1	-	-	-	1	-	2	-	-	(1)	6
Burlington Northern, Inc.. . . .	-	-	-	-	(1)	5	(1)	3	-	-	(3)	2	-	7	-	4	(5)	21
Chesapeake & Ohio	-	-	-	-	-	-	-	2	-	-	-	2	-	2	-	-	-	6
Chicago & Eastern Illinois . . .	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(1)	-	(1)	-
Chicago & Illinois Midland . . .	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	(1)	-
Chicago & North Western.	-	-	-	2	(2)	8	-	2	-	-	-	2	-	-	-	1	(2)	15
Chicago, Milwaukee, St. Paul and Pacific	-	-	-	-	(1)	1	-	1	-	-	-	1	-	1	-	-	(1)	4
Chicago, Rock Island & Pacific.	-	-	-	-	-	5	(1)	-	-	1	-	1	-	-	-	-	(1)	7
Chicago South Shore & South Bend	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Chicago & Western Indiana. . . .	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	3
Conemangh & Black Lick	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Consolidated Rail Corporation. .	-	-	(1)	2	(3)	7	(3)	8	-	4	(2)	9	(1)	10	(2)	3	(12)	43
Denver & Rio Grande Western. . .	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2
Elgin, Joliet & Eastern.	-	-	-	-	-	-	-	3	-	-	(1)	5	-	1	-	-	(1)	9
Fort Worth & Denver.	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	3
Houston Belt & Terminal.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
Illinois Central Gulf.	-	-	-	-	-	18	-	1	-	2	(1)	1	(1)	-	(1)	2	3	25
Kansas City Southern	-	-	-	-	-	1	-	-	-	-	-	1	(1)	-	(1)	1	2	3
Long Island.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Louisville & Nashville	-	1	-	-	-	5	-	1	-	2	(2)	-	-	7	-	1	(2)	17
Missouri-Kansas-Texas.	-	-	-	-	-	-	(3)	-	-	-	-	1	(1)	1	-	-	(4)	2
Missouri Pacific	-	-	-	1	-	1	-	-	-	-	-	3	-	1	-	1	-	7
Norfolk & Western.	-	2	(1)	1	(1)	1	(2)	2	-	1	(2)	4	(1)	3	-	2	(7)	16
Northeast Corridor (Amtrak). . .	-	-	-	-	-	5	(2)	2	-	-	-	1	(3)	4	(2)	-	(7)	12
St. Louis-San Francisco.	-	-	-	-	-	-	-	-	-	2	(2)	1	-	2	-	-	(2)	5
St. Louis Municipal Bridge . . .	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Seaboard Coast Line.	-	-	-	-	(2)	2	(1)	-	-	-	-	-	(2)	3	-	-	(5)	5
Soo Line	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Southern Pacific Transportation	(1)	-	-	-	-	4	(2)	-	-	-	-	-	(2)	-	-	-	(5)	4
Southern	-	-	-	-	(1)	5	(1)	3	-	-	-	1	-	-	-	-	(2)	9
Texas & Pacific.	-	-	-	-	-	-	(1)	-	-	-	-	-	-	-	-	-	(1)	-
Union Pacific.	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2
Union Railroad	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Western Pacific.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Transition Period 7/1/76 - 9/30/76	(4)	-	(2)	-	(12)	-	(17)	-	ø	-	(15)	-	(14)	-	(7)	-	(71)	-
Fiscal Year 1977 10/1/76-9/30/77	-	5	-	8	-	79	-	34	-	13	-	41	-	45	-	17	-	246
38 Carriers																TOTAL		327

*Indicated by Figures in Parentheses

CAUSES OF FALSE PROCEED FAILURES REPORTED BY CARRIERS FOR FISCAL YEAR 1978 (10-1-77 - 9-30-78)

Railroads	Sand, rust or other deposits on rails	Failure of relays and similar devices.	Circuits open crossed or grounded. Foreign current, etc.	Apparatus broken, defective or out of adjustment.	Failure of apparatus due to ice, sleet, snow wet track weather or lightning	Vandalism	Errors in making a connection or adjust-ments	unde-termined	TOTAL
Atchison, Topeka & Santa Fe.....	-	2	-	7	-	4	2	-	15
Baltimore & Ohio...............	-	-	-	1	-	-	-	-	1
Boston & Maine Corp............	1	-	1	-	-	-	1	-	3
Burlington Northern, Inc........	2	4	5	-	1	3	4	-	19
Chesapeake & Ohio..............	1	2	-	1	-	1	5	0	10
Chicago & North Western.........	-	3	3	4	-	-	-	-	10
Chicago, Milwaukee, St. Paul and Pacific....................	-	-	2	-	-	-	1	1	4
Chicago, Rock Island & Pacific..	-	2	2	1	2	1	1	1	10
Chicago South Shore and South Bend	-	-	2	-	-	-	-	-	2
Consolidated Rail Corporation...	-	1	8	-	-	9	16	-	34
Denver & Hudson................	-	-	-	-	1	-	-	-	1
Elgin, Joliet & Eastern.........	-	1	-	-	1	-	-	-	2
Fort Worth & Denver............	-	-	-	1	-	-	-	-	1
Florida East Coast............	-	-	-	-	-	1	2	-	3
Illinois Central Gulf.........	-	5	15	1	2	3	3	2	31
Indiana Harbor Belt...........	-	-	-	-	-	-	1	-	1
Kansas City Southern..........	-	-	1	-	-	-	-	1	2
Long Island...................	-	2	-	-	-	-	-	-	2
Louisville & Nashville.........	-	3	2	-	-	1	3	-	9
Missouri-Kansas-Texas.........	-	1	2	-	-	-	-	-	3
Missouri Pacific..............	-	-	1	-	1	1	1	2	6
Norfolk & Western.............	-	2	-	1	1	-	3	-	7
Northeast Corridor (Amtrak)	-	4	3	-	-	1	4	1	13
Seaboard Coast Line...........	-	-	1	-	-	-	2	1	4
Southern......................	-	-	3	-	-	1	-	2	6
Southern Pacific Transportation	-	1	6	1	1	2	3	-	14
Southern Railway of Alabama....	-	-	-	-	-	-	-	1	1
St. Louis-San Francisco.......	-	-	2	1	-	-	1	-	4
Terminal Railroad Association of St. Louis................	-	-	-	-	-	1	-	-	1
Union Railroad................	-	-	1	-	-	-	-	-	1
Union Pacific.................	-	-	1	-	-	-	2	-	3
Fiscal Year 1978 10/1/77-9/30/78	4	33	62	18	10	29	55	12	223
31 Carriers									

CAUSES OF FALSE PROCEED FAILURES REPORTED BY CARRIERS FOR
FISCAL YEAR 1978 (10-1-77 - 9-30-78)

Railroads	Sand, rust or other deposits on rails	Failure of relays and similar devices.	Circuits open crossed or grounded. Foreign current, etc.	Apparatus broken, defective or out of adjustment.	Failure of apparatus due to ice, sleet, snow wet track weather or lightning	vandalism	Errors in making a connection or adjustments	undetermined	TOTAL
Atchison, Topeka & Santa Fe.....	-	2	-	7	-	4	2	-	15
Baltimore & Ohio................	-	-	-	1	-	-	-	-	1
Boston & Maine Corp.............	1	-	1	-	-	-	1	-	3
Burlington Northern, Inc........	2	4	5	-	1	3	4	-	19
Chesapeake & Ohio...............	1	2	-	1	-	1	5	0	10
Chicago & North Western.........	-	3	3	4	-	-	-	-	10
Chicago, Milwaukee, St. Paul and Pacific....................	-	-	2	-	-	-	1	1	4
Chicago, Rock Island & Pacific..	-	2	2	1	2	1	1	1	10
Chicago South Shore and South Bend	-	-	2	-	-	-	-	-	2
Consolidated Rail Corporation...	-	1	8	-	-	9	16	-	34
Denver & Hudson.................	-	-	-	-	1	-	-	-	1
Elgin, Joliet & Eastern.........	-	1	-	-	1	-	-	-	2
Fort Worth & Denver.............	-	-	-	1	-	-	-	-	1
Florida East Coast............	-	-	-	-	-	1	2	-	3
Illinois Central Gulf.........	-	5	15	1	2	3	3	2	31
Indiana Harbor Belt...........	-	-	-	-	-	-	1	-	1
Kansas City Southern..........	-	-	1	-	-	-	-	1	2
Long Island...................	-	2	-	-	-	-	-	-	2
Louisville & Nashville........	-	3	2	-	-	1	3	-	9
Missouri-Kansas-Texas.........	-	1	2	-	-	-	-	-	3
Missouri Pacific..............	-	-	1	-	1	1	1	2	6
Norfolk & Western.............	-	2	-	1	1	-	3	-	7
Northeast Corridor (Amtrak)	-	4	3	-	-	1	4	1	13
Seaboard Coast Line...........	-	-	1	-	-	-	2	1	4
Southern......................	-	-	3	-	-	1	-	2	6
Southern Pacific Transportation	-	1	6	1	1	2	3	-	14
Southern Railway of Alabama....	-	-	-	-	-	-	-	1	1
St. Louis-San Francisco.......	-	-	2	1	-	-	1	-	4
Terminal Railroad Association of St. Louis...............	-	-	-	-	-	1	-	-	1
Union Railroad................	-	-	1	-	-	-	-	-	1
Union Pacific.................	-	-	1	-	-	-	2	-	3
Fiscal Year 1978 10/1/77-9/30/78	4	33	62	18	10	29	55	12	223
31 Carriers									

Evaluation of Signal/Control Systems Equipment and Techniques, Task 5: Economic Studies, US DOT, FRA, 1980 -06-Signals, Control & Communications