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**Federal Railroad
Administration**

Evaluation of Concepts for Safe Speed Enforcement

National Maglev Initiative
Washington, DC 20590

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16. Abstract

This final report evaluates the suitability of existing and developmental safe speed enforcement concepts/systems for application to a high-speed maglev control system in the U.S. Requirments, functions and needs are identified and discussed for two major aspects of safe speed enforcement: 1) generation of safe speed commands, and 2) enforcement of safe speed limits as defined by those commands or otherwise imposed upon vehicles. The features, functions and general implementations of selected safe speed concepts utilized in maglev, high-speed rail and conventional rail transit systems, rubber-tired transit systems, and railroad systems are described. Emphasis in the descriptions is given to the general concept used to ensure safe speed and more specific aspects such as vehicle location detection, actual speed detection, safety related communications and implementation/configuration. An assessment is then made as to the suitability of the concepts in meeting the requirements and functions of safe speed enforcement in both long and short stator maglev applications. It is shown that while many of the non-maglev existing safe speed enforcement concepts are not directly applicable "as is" or with minimal modifications, they do incorporate various aspects and equipment which could fulfill the basic needs of a maglev system relative to safe speed enforcement.

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ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in.) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32) (5/9)] °F = y°C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (kn^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

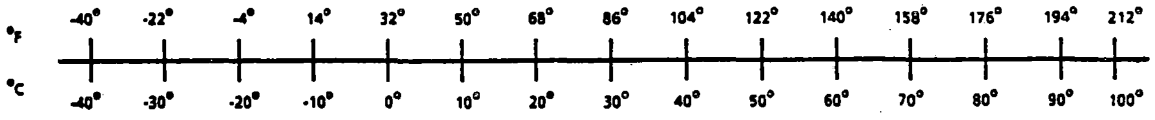
1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION



For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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1.0 INTRODUCTION

This is Battelle's Final Report on the program "Evaluation of Concepts for Safe Speed Enforcement," conducted under Contract No. DTFR53-91-C-00061 with the Federal Railroad Administration (FRA). The various sections of this report describe the nature of the work performed throughout this program as well as all associated results, conclusions, and recommendations. Major results of this program include functional requirements and constraints for a magnetic levitation (maglev) safe speed enforcement system, descriptions of candidate safe speed concepts and an assessment of the suitability of the concepts to a maglev application.

1.1 Background

The National Maglev Initiative (NMI) was organized by the Federal Government in 1989 to determine the extent to which maglev technology is technically and economically viable in this country. One of the first procurement activities of the Initiative was to issue a Broad Agency Announcement (BAA No. 90-1) in order to address specific areas of research which were deemed critical to the success of maglev. The FRA was given the responsibility of planning and implementing BAA activities.

One of the areas addressed by the BAA is that of control systems, which includes those elements of maglev that ensure a guideway system is safe for operation (route integrity) and that the vehicles and guideway are operated within authorized limits (safe speed and headway). The portion of a control system related to the enforcement of safe speed is the subject of this program—Evaluation of Concepts for Safe Speed Enforcement (BAA No. 138).

1.2 Objective/Scope

The main objective of this program was to evaluate the availability and suitability of existing means for the enforcement of safe speed limits for potential utilization by a U.S. maglev system. The overall goal was to determine where existing or developmental safe speed enforcement technologies/concepts are adequate "as is" and where additional research and/or development is needed.

2.0 PROGRAM ACTIVITIES

Work performed in this program was divided into four major tasks as directed by the Statement of Work. The nature of the work performed in each task is described below.

2.1 Task 1—Maglev Safe Speed Enforcement Functions and Needs

Task 1 involved the identification of the safe speed enforcement requirements, functions, and needs as they relate to maglev systems. Initial efforts were directed to identifying, gathering, and reviewing pertinent literature. Among the materials reviewed were articles and reports related to both maglev and high speed rail systems as well as FRA's Statement of Work for the Maglev System Concept Definition. Key information sources are listed in Appendix A.

A primary purpose of the literature review was to gain an understanding of the anticipated maglev configurations and the related functional/operational characteristics (e.g., propulsion/brake system interface, vehicle-central interface, and communications) which may be encountered in maglev systems. Following this review, lists of the key functional/operational characteristics of several subsystems were generated for three major maglev systems (presently under testing and development) which are capable of operation at very high speeds (i.e., above 198 km/h or 125 mph) or super speeds (i.e., above 317 km/h or 200 mph). These were the German Transrapid system (TR-07), the Japanese HSST system (HSST-05), and the Japanese Linear Express (MLU-002). These characteristics, provided in Section 3.0 of this report, were utilized as one basis for identifying requirements as related to safe speed enforcement.

Another activity in this task was to identify operating conditions under which safe speed would have to be enforced. Then, functional requirements and constraints were identified and related to each of the operating conditions. During the conduct of Task 1, it was determined that the enforcement of safe speed actually consists of two major functions: 1) the generation of safe speed commands based on operating conditions and strategy, and 2) the enforcement of safe speed limits as defined by these commands or otherwise imposed on trains. Accordingly, functional requirements and constraints were generated separately for each of these functions.

This task culminated in the Task 1 Interim Report, submitted October 2, 1991.

2.2 Task 2—Available Speed Enforcement Systems

Task 2 involved the identification and characterization of the features, functions, and implementations of existing and/or developmental safe speed enforcement concepts/systems. Initial efforts in Task 2 were directed to identifying, gathering, and reviewing information on existing and/or developmental train control system concepts, particularly those in the automatic train protection (ATP) area relating to safe speed enforcement. This information pertained to maglev systems, high-speed rail and conventional rail transit systems, other transit systems (e.g., people-movers) and the Advanced Train Control System (ATCS) being developed by U.S. and Canadian railroads.

From this initial review, a number of system concepts were selected for further study. The intent of this selection process was twofold: 1) to select a representative sample of the different safe speed enforcement concepts currently available or under development, and 2) to select as many safe speed enforcement system concepts as possible that could be described within time and budget constraints.

Subsequently, additional information was obtained on the systems selected. Sources of information included numerous reports, technical articles, product information, and direct contact with a number of individuals. Appendix A identifies the major sources of information (i.e., literature and individuals) utilized/accessed in this task.

The final effort in this task was to describe the various safe speed enforcement concepts selected. These concepts were described in the context of the application in which they are being used or, in some instances, for which they are intended.

This work culminated in the Task 2 Interim Report, submitted December 11, 1991.

2.3 Task 3—Applicability of Available Controls

Task 3 involved assessing the capability of the system concepts identified in Task 2 in meeting the requirements and functions identified in Task 1. Each of the system concepts described in Task 2 was assessed separately in tabular format against the specific functional requirements of Task 1. Each assessment first addressed the manner in which the system concept performed the functions identified in Task 1. Then, each assessment addressed the applicability of the specific concept in meeting the needs of a maglev system relative to each functional requirement.

After the results of the assessments were summarized, conclusions and recommendations were generated. Recommendations were directed to the areas of safe speed enforcement in which additional research and/or development were considered necessary.

2.4 Task 4—Project Report and Symposia

This task involved the documentation of all results in draft and final reports. It also included participation in two symposia. One was held in Cambridge, Massachusetts, on September 26-27, 1991. The other is planned for Chicago, Illinois, on April 7-9, 1992.

3.0 TASK 1—MAGLEV SAFE SPEED ENFORCEMENT FUNCTIONS AND NEEDS

The following sections provide: 1) a description of general maglev characteristics, 2) a discussion on safe speed enforcement considerations, and 3) a description of maglev functional requirements and constraints.

3.1 Maglev System Characteristics

Maglev systems generally fall into two categories based on the type of levitation technology employed—electromagnetic suspension (EMS) and electrodynamic suspension (EDS). In EMS systems, the vehicles are levitated by means of an attractive force between on-board iron core electromagnets and ferromagnetic rails in the guideway. The German Transrapid and Japanese HSST systems are based on this technology. In EDS systems, the vehicles are levitated by means of a repulsive force generated between on-board superconductive magnets and induced electric currents (eddy currents) in guideway conductors. The Japanese Linear Express system (MLU-002) is based on this technology.

Maglev systems can be further categorized by the type of propulsion utilized: long stator or short stator. In long stator systems, the primary winding (armature) of a linear synchronous motor is installed in the guideway, and the other component of the motor is carried by the vehicle. The vehicle is propelled by the force between the on-board magnets and the traveling wave produced by the long stator windings. Vehicles generally travel with the same velocity as the traveling wave beneath them. Long stator propulsion is used in both EMS (e.g., Transrapid) and EDS (e.g., Linear Express) systems.

In short stator systems, the primary windings of (usually) linear induction motors are installed on-board the vehicle, and the secondary windings are installed in the guideway. The vehicle is propelled by the field between the primary windings and the passive windings in the guideway. Propulsion power for this type of system is transferred to the vehicle via sliding contacts. Short stator linear induction motors have been used in EMS systems (e.g., HSST), but may also be applicable to systems employing EDS technology.

3.1.1 Maglev Subsystem Characteristics

At the time of this report, there were no definitive or comprehensive requirements or specifications for a U.S. maglev system. The Maglev System Concept Definition procurement was in process under the direction of the FRA. The resulting definitions are to include system level conceptual definitions and analysis efforts resulting in descriptions of the major subsystems and components of maglev transportation systems, including interfaces and performance requirements. However, results of these definition efforts were not available for utilization in this project.

For this reason, and in order to better determine requirements and constraints, it was necessary to determine the various characteristics which may be present in U.S. maglev systems. To aid this process, the key characteristics of the primary subsystems of the Transrapid system (TR-07), the HSST-05 system, and the Linear Express (MLU-002) system were identified. These characteristics are listed in Tables 1, 2, and 3 for the TR-07, HSST-05, and MLU-002 systems, respectively. These characteristics helped define the configurations, functions, and operational aspects which may be ultimately encountered in U.S. maglev systems. The subsystems addressed are as follows:

- Levitation/Suspension
- Guidance
- Propulsion
- Braking
- Power
- Automatic Train Control
- Communications.

TABLE 1. CHARACTERISTICS OF TRANSRAPID SYSTEM (TR-07)

Subsystem	Characteristics
Levitation/Suspension	● Levitation (primary suspension) produced by electromagnets (axial flux) on vehicle's undercarriage producing attractive force to laminated steel guideway rails. ● Electromagnets powered by DC storage batteries and linear generators (at speeds greater than ≈120 km/h. ● Air gap maintained at approximately 0.008 m (8 mm). ● Secondary suspension provided by pneumatic springs between coach body and levitation frame. ● Series of rods and roll stabilizing devices used to control lateral suspension and roll motion. ● Levitation considered to be safety critical because vehicle must stop only at safe stopping areas.
Guidance	● Guidance produced by separate electromagnets (transverse flux) on vehicle's undercarriage (facing guideway walls) producing lateral attractive force to ferromagnetic rails on sides of guideway structure. ● Electromagnets powered by DC storage batteries and linear generators (at speeds greater than ≈120 km/h). ● Guidance function considered to be safety critical.
Propulsion	● Long stator iron core linear synchronous motor. ● Laminated stators with three phase windings mounted under both sides of guideway beam. ● Field windings on vehicle act as the rotor; windings excited by DC storage batteries. ● Substations convert three phase utility power into variable voltage, variable frequency (VVVF) power.

Propulsion (Continued)	• Substations are dual redundant—each half having a transformer rectifier unit feeding a pair of three-phase inverters. • Inverter outputs fed to guideway via transformers. • AC current creates travelling magnetic wave that reacts with levitation magnets on vehicle and produces thrust. • Speed of vehicle controlled by adjusting voltage and frequency of three-phase current in long stator windings. • By changing polarity, long stator motor functions as contactless brake. • Long stator motor sections are energized as train approaches and de-energized as train leaves section. • Each section is fed from both ends, and each side is fed from functionally independent substations and inverters.
Braking	• Primary braking is accomplished by changing the frequency of the current in the long stator windings—controlled by central/decentralized equipment. • Electrical energy generated during dynamic braking dissipated in load resistors at substations. • Secondary braking is accomplished, if needed, via on-board eddy current brake system. • Two eddy current brake systems on each vehicle; each consists of longitudinal electromagnets (axial flux), powered by on-board DC storage batteries and chopper. • Electromagnets of eddy current system induce eddy currents in non-laminated guideway rails, thus producing noncontact braking.

Braking (Continued)	• Eddy current system loses effectiveness at speeds below about 150 km/h. • Tertiary brake system provides "final" emergency braking; levitation magnets on-board vehicle are de-energized, causing vehicle to land on skids.
Power	• Power source for long stator motor and other central/decentralized equipment is commercial power from local utilities. • Each vehicle section contains four electrically isolated battery buffered 440 volt DC supplies. • Battery supplies recharged by on-board inductive pick-up linear generators as vehicle moves; linear generator windings react with flux from long stator motor windings. • Battery systems used to power vehicle communication systems, eddy current brakes, levitation and guidance magnets and other on-board functions (e.g., environmental conditioning equipment). • At speeds below 120 km/h, linear generators supplement batteries. • At speeds above 120 km/h, linear generators provide almost all vehicle power and recharge batteries.

Automatic Train Control	● Central control automatically controls train operations during normal conditions and most emergencies. ● Vehicle equipment functions include detection of vehicle position, travel direction, speed, acceleration and deceleration; transmission of data; voice information; processing of status/error messages; and monitoring of on-board equipment operation. ● Decentralized and central control functions include route control, vehicle control, station supervision and control, and communications. ● Safety critical functions preformed by central, decentralized, and on-board systems. ● Vital on-board functions include guidance, levitation, and braking (emergency via eddy current and/or skids), vehicle position detection, travel direction, speed, acceleration, and deceleration. ● Vital functions performed by decentralized equipment include route control and coordination of vehicle propulsion and braking via long stator motor windings. ● Vehicle location determined at two levels: raw position via passive loops (tags) in guideway and active on-board sensors, and fine position by counting stator pack grooves; redundancy used via two readers on each side of vehicle and tags on both sides of guideway. ● Vehicle location information transmitted to central.

Automatic Train Control (Continued)	● Safe speed enforcement accomplished via central, decentralized, and on-board equipment. - Command speeds selected/generated at central. - Decentralized equipment coordinates vehicle propulsion and braking via long stator motor. - On-board equipment can stop vehicle via eddy current system and skids independent of central/decentralized control; on-board equipment gets adequate information via data link to stop at safe stopping area. ● Route integrity ensured by decentralized equipment. - Determines if route requested by central is safe. - Checks switch positions and guideway occupancy conditions before issuing route clear indication. ● Vehicle must be able to bring itself to a safe stopping area independent of central control (i.e., in case of loss of communications).
Communications	● Vehicle communicates with wayside receivers via 40 GHz radio link. ● Wayside receivers communicate with central via fiber-optic links. ● Two receivers in range at any one time. ● Two transmitters/receivers on vehicle.

TABLE 2. CHARACTERISTICS OF HSST SYSTEM (HSST-05)

Subsystem	Characteristics
Levitation/Suspension	• Levitation (primary suspension) produced by electromagnets on vehicle's undercarriage producing attractive force to iron rails. • Electromagnet power source is on-board DC voltage modulated at 2 KHz rate. • Air gap maintained at approximately 10 mm. • Electromagnets mounted on modules (8 per car). • Secondary suspension provided by pneumatic springs (4 per module)—support vehicle in vertical and lateral directions. • Auxiliary roller unit used to move car in case of levitation failure or maintenance; units extended hydraulically when needed.
Guidance	• Lateral guidance provided by same electromagnets as those used for levitation (magnets are laterally offset).
Propulsion	• Short stator iron core linear induction motor (LIM). • Armature located on the vehicle. • Passive rotor, consisting of aluminum strip conductors, is located in the guideway. • DC propulsion power fed to vehicle via sliding contacts. • DC power converted into VVVF power for control of propulsion.

Braking	● Primary braking system is via linear induction motor in regenerating and phase reversing modes at speeds greater than approximately 6 km/h. ● Mechanical braking system consists of hydraulic brake system and brake shoes which squeeze the rail. ● Mechanical brake used 1) at speeds below 6 km/h, 2) as a parking brake, and 3) as an emergency brake in case of LIM failure. ● Vehicles also can land on skids if levitation is removed and roller unit not utilized.
Power	● Power fed to vehicle via sliding contacts (usually DC) from substations. ● On-board storage batteries supply DC power to maintain levitation if substation loses power. ● On-board inverter produces VVVF power.

TABLE 3. CHARACTERISTICS OF LINEAR EXPRESS SYSTEM (MLU-002)

Subsystem	**Characteristics**
Levitation/Suspension	● Levitation based on powerful on-board DC superconductive electromagnets (~ 700 k A-turn per magnet) maintained in cryogenic environment (liquid helium). ● Superconductive coils provide magnetic field that reacts with passive guideway coils or aluminum strips producing currents in guideway conductors as vehicle moves—produces repulsive force. ● Levitation force is speed dependent; forward speed of 40-80 km/h required for levitation; rubber tired wheels used at lower speeds. ● Air gap achievable up to approximately 100 mm. ● Secondary suspension provided via pneumatic springs.
Guidance	● Cross coupled conducting coils (which also serve as armature of linear synchronous motor) mounted on sides of guideway. ● Coil arrangement produces "null flux" guidance; lateral vehicle displacement at levitation speed produces repulsive force and attractive force on opposite sides for guidance (due to reaction of cross coupled coils and on-board superconducting magnets). ● At low speeds, vehicle guided by laterally mounted wheels that bear on guideway sidewalls.

Propulsion	● Air core long stator linear synchronous motor. ● Armature windings (same cross coupled coils used for guidance) located on sides of guideway. ● Three phase current in armature produces traveling magnetic wave that reacts with on-board superconducting magnets, producing propulsion. ● Speed of vehicle controlled by varying armature input frequency. ● Successive guideway blocks powered-up and then shut down as vehicle leaves block.
Braking	● Primary braking provided by guideway mounted linear synchronous motor acting as regenerative brake. ● Electric brake, based on sliding shoes, and an aerodynamic brake (fins on car body) also used as emergency brakes.
Power	● Power for long stator motor provided commercially via utility company. ● Cycloconverter changes frequency and current into required values for motor. ● Linear generator produces on-board power for charging batteries; electromagnetic pick-up from guideway; batteries provide power up to approximately 40 km/h; exclusive use of linear generator at speeds above 115 km/h.
Automatic Train Control	● Vehicle location determined via cross induction wires located on guideway sidewalls.
Communications	● Vehicle to central communication provided via leakage coaxial cables.

3.2 Safe Speed Enforcement Considerations

As utilized in this project, the term "safe speed enforcement" is considered to encompass both the functions of 1) generating safe speed commands and 2) enforcing safe speed limits as defined by these commands or otherwise imposed upon trains. These two functions are commonly carried out separately with the second being the overriding consideration. In order to facilitate the discussions which follow, the term "safe speed assurance" is utilized to denote the overall process and "speed enforcement" refers to only the enforcement portion thereof.

Safe speed assurance is a vital process whereby the speeds of the individual trains within a system are controlled such that train movements (i.e., speeds, positions) safely conform to designated operating specifications. This process involves assuring conformance to all conditions and requirements affecting the safe movement of all trains at all times.

Each speed command must represent a (usually, maximum) safe speed for the associated train at any given time. The generation of this command is based upon the existing status of the train taken in the context of all factors (design, operational, etc.) that impact/restrict the determination of its allowable speed. Since high-speed maglev systems can be expected to require continuously updated speed commands, the resulting commands will probably take the form of continuous profiles that define the set of instantaneous commands generated over time.

In addition to the generation of safe speed commands appropriate for each train, it must be ensured that violations of such commands are protected against. Should a violation occur, appropriate action must be taken to correct the situation or otherwise cause the affected train(s) to assume a condition known to be safe. Basic enforcement of commanded speeds commonly takes the form of overspeed protection. Here, command speed is compared to actual speed and, if found to be greater by more than a predetermined margin, appropriate remedial action is taken. Such action may include removal of the speed command and the initiation of an irrevocable brake application. Other situations, usually involving a failure condition, may also call for slowing or stopping a train even if an actual command speed violation does not exist. However, such actions must be provided for in the overall context of safe speed enforcement.

3.2.1 Operating Considerations

Safe speed assurance must be carried out in the context of existing system operations and conditions which include all possible normal, abnormal, and emergency situations. Both safe speed generation and safe speed enforcement functions must recognize and correctly respond to these situations. Following is an overview of those operating considerations which directly impact the safe speed assurance process. Both main line and yard/shop train operations are addressed—the latter two topic areas address yard/shop operations.

3.2.1.1 Civil Speed Restriction. This relates to speed limits inherent in the system design which restrict the maximum allowable speed for all portions of the guideway. Limits can be expected to differ for tangent and curved portions, for traversing switches, and for other types of guideway sections. These limits are system specific and relate to both the train and guideway designs and their interface/interaction. These restrictions provide an upper bound on the allowable maximum safe speed command. Under normal conditions, the normally applicable civil speed limits may be further restricted. This may be done on a system-wide basis or for selected portions of the guideway only. For example, maintenance work in progress may necessitate issuing a "slow order" for the affected portion(s) of the guideway. Also, adverse environmental conditions may necessitate reducing all civil speed limits to, say, 75 percent of their normal values for limited periods of time.

3.2.1.2 Headway Control. This relates to the need to maintain sufficient braking distance between adjacent trains and between trains and those portions of the guideway/route for which authority to enter has yet to be granted. Basic headway speed restrictions commonly relate to distance-to-go and the speed of the subject train; rate of closure may also be a consideration here.

3.2.1.3 Route Integrity. This relates to the need to assure that a train is not granted route authority until the integrity of the route has been confirmed. Factors to be considered here include switch alignment and locking, presence of obstacles fouling the operational envelope, guideway integrity (e.g., vertical and horizontal alignment), and intrusion/security violation detection. It must be recognized that, once granted, it may become necessary to revoke route authority if there is an unexpected change in conditions. For example, sensors may detect a sudden loss of guideway integrity. This could necessitate emergency braking of the train.

3.2.1.4 Schedule Control. This relates to determining the speeds necessary for train(s) to operate in accordance with established schedules or frequency of service requirements. To do so may require that the normal train speeds be increased or decreased as necessary to reestablish on-time service or to adjust the relative positions of two or more trains. While it can be expected that any given train can be issued a slower than normal speed command, other restricting considerations may preclude issuing one which is greater.

3.2.1.5 Station Stopping. This relates to special speed control routines which are commonly initiated at a specific target distance from a station, and so designed as to bring trains to smooth, accurate stops at station platforms. If the stations are off-line, rather than on-line, there will be associated route integrity considerations in that it will be necessary to traverse a switch when departing the main line for the station siding.

3.2.1.6 Station Departing. This relates to a normal starting routine designed to bring the train up to allowable line speed in a controlled manner. If the station is off-line, it will be necessary to first set and lock the exit switch. This can only be done if there is no conflict with oncoming traffic which may have already been granted a route authority that includes that switch.

3.2.1.7 Siding Utilization. This includes similar considerations as for station stopping and departing except that stopping accuracy may be less critical. However, trains must stop so that neither end fouls the main line guideway envelope. Sidings may be utilized for emergency stopping locations, or to permit normal passing of opposing trains on bidirectional sections of guideway.

3.2.1.8 Manual Train Operation. This relates to the role of the human train operator in driving the train to the extent that such operation is permitted. It can be expected that there will be an on-board "attendant" seated in the train head-end "operating position". At the least, these operators can be expected to be able to initiate an emergency stop if they detect an emergency situation not yet recognized by the automatic controls. Examples here are on-board smoke and fire and, possibly, an obstacle on the guideway. Should the operator be permitted to drive the train, it will probably be necessary to impose severe speed limits which are in keeping with human factors considerations for this activity.

3.2.1.9 Failure/Fault Conditions. This relates to those failures which do not necessarily directly impact (i.e., restrict) the generation of the speed command via route integrity or other considerations, but which nevertheless require that a train reduce its speed or be brought to a full stop. Included here are such conditions as loss of the train-central communications link, failure of the guidance system, and impending loss of levitation. In many of these instances, it is possible that either or both detection and responsive action will be an on-board train function, even in those systems where central control normally initiates all commands related to train speed reduction and braking.

3.2.1.10 Manual Train Control—Yards and Shops. While yard and shop-related guideways can be automated to some extent, the need to manually drive trains will continue to exist. Therefore, it will be necessary to restrict and/or govern human actions so that trains will be safely under control at all times. In large part, this can be accomplished by limiting the speed at which the trains can be driven and employing comprehensive safety rules and procedures for train operations.

3.2.1.11 Other Considerations—Yards and Shops. These relate to considerations associated with train movement in a yard or shop environment. While not applicable to the extent that they are for fully automated main line operations, aspects of headway control, route integrity, and failure/fault conditions response are applicable here as well.

3.3 Functional Requirements and Constraints

There are numerous functional requirements and related constraints associated with the speed assurance process. These differ for the safe speed generation and safe speed enforcement functions and are, therefore, addressed separately below. The former relates, in large part, to the previously discussed operating conditions, while the latter relates to both the resulting speed commands and selected failure/fault conditions.

As utilized here, functional requirements are activities or actions which are to be carried out in the act of performing the speed assurance process. The manner in which these requirements are met can be expected to vary from one maglev system to another. Constraints are conditions which limit, or impose restrictions upon, the execution of the safe speed assurance process. In large part, these are the consequence of needing to generate and enforce speed commands in a fail-safe manner.

The determination of the functional requirements and constraints discussed below are based upon a variety of factors. Foremost among these are the traditional practices associated with the rail transit industry (especially as they exist at the more highly automated systems). Also considered were current practices associated with high-speed rail systems (e.g., TGV, ICE), the characteristics of maglev systems as described in Section 3.1 of this report, and the general criteria and minimum requirements in FRA's Statement of Work for their Maglev System Concept Definition.

3.3.1 Safe Speed Command Generation

The initial step in the speed command generation activity entails the fail-safe determination and production of a command speed based upon a definitive set of inputs which reflect existing operating conditions. Following this, the resulting command is encoded and transmitted to the train propulsion/braking controls which may be located on the wayside and/or train depending upon the specific system design. When received, the command is decoded and validated to ensure that it is a legitimate speed command. The initial step (i.e., speed command determination/production) is the most complex of the three because of the number and nature of the input factors involved. The other two can be satisfactorily accomplished utilizing appropriate design and implementation practices.

It is essential that speed command generation be treated as a vital process. Both the process itself and the sources of those inputs (e.g., train location/guideway occupancy, train speed) which serve as the basis for determining the resulting commands must be implemented in a fail-safe (or equivalent) manner. This permits the resulting commands to be considered as valid. It can be expected that it will be necessary to transmit speed commands from their point of origin (i.e., generation circuitry) to the point where they are utilized by propulsion/braking controls. Commonly, the transmission path is from central or wayside control to the trains, but for maglev systems will involve the guideway mounted propulsion units as well. To prevent the acceptance and utilization of speed commands that are incorrect due to corruption in the transmission process, the commands need to be suitably encoded so that corruption of these coded commands will result in an invalid speed code. These can then be rejected by the receiving control circuitry which must be designed to respond in a fail-safe manner when an invalid code is received.

The functional requirements and constraints relating to safe speed generation are discussed in the following sections. These are related to operating considerations previously discussed in Section 3.2.

3.3.1.1 Civil Speed Restriction. The determination of civil restrictions requires that the position of the train along the guideway be known and, based upon that position, the appropriate speed restriction (i.e., limit) be extracted from a preestablished and stored set of values. This requires that position be known with sufficient accuracy, and that it be assured. the stored values are accurate and extracted without an error denoting a speed limit less restrictive than required. Because of the noncontact nature of maglev operations, the determination of train location cannot be based upon traditional means (i.e., the shunting of track circuits by train wheels/axles). Reliable and fail-safe alternative means will be required. To accommodate slow orders pertaining to specific guideway sections, it must be possible to revise the stored values on a selective basis. Further, to accommodate temporary needs to restrict maximum operating speeds on a system-wide basis, it must be possible to reduce all speed limits as stored or prior to their use following extraction.

3.3.1.2 Headway Control. The determination of headway related speed restrictions requires, at a minimum, that the speed of the subject train be known along with the distance between it and the preceding train, as well as its limit of route authority. It may also be necessary to know the speed and position of preceding trains. This information, along with predetermined braking capabilities, serves as the basis of determining allowable speed as a function of existing headway. This determination may also be based upon allowable rate-of-closure and the closure policy under which the system operates. Constraints here relate to the accurate determination of train speed and distance-to-go. The latter requires accurate knowledge of train position(s).

3.3.1.3 Route Integrity. The speed command generation process and/or the issuance of the actual commands require input relative to route integrity. Basically, this input provides permission, or not, for a train to proceed along its assigned route at whatever safe speed is otherwise determined. Depending upon the system configuration and operations, this permission (i.e., route authority) may be provided on a limited basis (e.g., permission to proceed up to Mile Point 10.5) which is extended as restricting route conditions clear ahead of the subject train. The generation of the route integrity input is accomplished external to the speed command generation process. However, any associated limitations must be accurately related to existing train position and headway considerations.

3.3.1.4 Schedule Control. The requirements upon train speeds resulting from schedule or frequency-of-service considerations are usually subservient to all other requirements/restrictions. Therefore, the speed command generation process can merely incorporate such requirements into the overall process of issuing a speed command. Since this command must represent the most restricted speed called for by all considerations which constitute its determination, schedule considerations must not dictate train speeds which are greater than otherwise permitted.

3.3.1.5 Station Stopping. Stopping accuracy requirements, as well as considerations related to passenger comfort, necessitate the use of well-defined and controlled station stopping routines. Given that such routines are available, they must be properly executed. To do so requires the sensing of the location where the routine is to be initiated and may require constant monitoring of train speed and distance-to-go throughout the stopping process. If the system is so operated that all trains do not always stop at all stations, it will be necessary for the system controls to initiate (or inhibit) the station stopping process as required. This will require relating specific trains to specific stations and responding accordingly when the normal station stopping routine initiation points are reached. The need for a high level of accuracy relative to train speed and location is critical here and can be expected to be greater than that required for other main line operations. This may necessitate the utilization of improved sensing devices.

3.3.1.6 Station Departing. The process of generating speed commands, and their execution, associated with departing a station may not be different from that associated with starting-up from full stop elsewhere in the system. However, actual issuance of the departure command may be contingent upon receiving a train release signal from the schedule controller, and its execution will require determination that the train is ready to depart (e.g., all doors are closed and locked). Final release may be initiated by the train operator, but will automatically be subjected to oversight and inhibition relative to the above-cited considerations. Premature release of a train must not be permitted under any circumstances. System operational practices may impose additional considerations. For example, the TR-07 system requires checking train speed shortly after station departure to ensure that propulsion capabilities are normal. If determined to be abnormal, the train is directed to stop before leaving the station area or at the next safe stopping location.

3.3.1.7 Siding Utilization. The same basic speed generation considerations discussed under station stopping and departing apply here. Once the train has entered a siding and stopped, it is critical that it not depart until it receives authority to do so. Holding of the train is commonly accomplished by issuing a zero speed command. When authority to proceed is granted (based on route integrity, schedule, location of trains, and other applicable considerations), the brakes will be commanded off and a start-up speed profile initiated. The critical consideration here is the holding of the train in the siding until it is safe for it to depart.

3.3.1.8 Manual Train Operation. The speed at which a maglev train can be driven under manual control must be subjected to all considerations and restrictions associated with fully automatic operation plus a further restriction on the maximum allowable speed based on human factors considerations. In effect, a speed limiting governor must be provided when a train is being driven manually. This could take several forms including imposition of an absolute limit or overspeed detection and response/enforcement. However, whatever approach is employed must be of a fail-safe nature.

3.3.1.9 Failure/Fault Conditions. The requirements here relate to responding to abnormal conditions (i.e., failures/faults) which necessitate reducing a train's speed below that permitted under the otherwise normal operating conditions. Such abnormal conditions may include propulsion motor power loss and control system malfunction. Their occurrence may or may not directly affect the normal speed command generation process depending upon their nature and the generation circuitry design. However, given that a basis (e.g., sensors, diagnostics) exists for detecting or predicting such conditions, it is necessary to take appropriate action(s) when they arise. Where such failures do directly impact the speed generation process, common responses include removal of the existing speed command (i.e., commanded speed is set to zero) and initiation of irrevocable emergency stopping. Those failure/fault conditions which impose speed restrictions, but do not impact the command speed directly, are discussed later in Section 3.3.2.2.

3.3.1.10 Yard Operations. The speed command related requirements pertaining to yard and shop operations are a subset of those discussed above for main line operations. Essentially they are concerned with manual control, route integrity, maximum allowable speeds, and responding to failures/faults.

3.3.2 Safe Speed Enforcement

It is the fundamental purpose of the safe speed enforcement function to ensure that trains never operate at speeds in excess of those denoted by their speed commands, or as further restricted by existing definitive failure/fault conditions. Although speed commands must be treated as vital, and both generated and transmitted to the propulsion/braking controls in a fail-safe manner, the possibility that an overspeed condition will occur nevertheless exists. Such could arise due to a propulsion/braking control system malfunction which results in an incorrect response to a valid speed command. Therefore, it is essential to provide a fail-safe means of overspeed detection and prompt execution of appropriate restrictive action(s). Likewise, provisions must be made to safely cope with those failure/fault conditions which do not provide input directly to the speed command generation function, but nevertheless require a reduction in train speed. In such cases, it will be necessary to revoke or override the existing speed command and impose such limits as warranted by the failure/fault condition at hand. It is probable that, in most cases, a full stop at either the service or emergency braking rate would be imposed. And, in most instances, normal operation should not be restorable until the failure/fault has been cleared and any speed override provisions which had been activated are reset.

The following discussion of the functional requirements and constraints associated with safe speed enforcement has been separated into two distinct parts—overspeed protection and failure/fault response.

3.3.2.1 Overspeed Protection. The overspeed protection function is specifically directed toward preventing trains from operating at speeds which are in excess of the safe speed commands. This is separate from any speed regulation function directed toward maintaining train speed within a well-defined band around a nominal value (the commanded speed). Here, the concern is to preclude train speeds from becoming unacceptably in excess of the command speeds. Not only are such excess speeds unsafe, but they are indicative of an abnormal condition relative to the propulsion/braking system.

In order to accomplish the overspeed protection function, it is necessary to monitor train speed (i.e., actual speed), detect when it is "excessively" greater than command speed, and initiate responsive action. Actual execution of such action will involve the propulsion and braking functions and may entail the use of both primary and secondary braking systems in a coordinated or independent manner, depending upon the overall maglev system characteristics and operational strategy.

3.3.2.1.1 Monitor Train Speed. As with the generation of command speeds, actual train speeds must be determined in a fail-safe manner. The practice in rail systems has been to utilize tachometers (mounted on the axles) as the primary basis for measuring train speeds. However, this approach cannot be utilized for maglev systems since the trains are not normally in contact with the guideway. It may well be desirable to determine actual speeds at central control and then transmit them to the individual trains for their use in detecting overspeed conditions. It may also be desirable to perform the overspeed detection process at central control as well, and merely provide the trains with appropriate indications of overspeed status. In any case, it is essential that the measurement of actual train speeds be performed in an accurate and fail-safe manner. Actual speed must never be represented as being less than it actually is.

3.3.2.1.2 Detect Overspeed Condition. Detection of overspeed is commonly based upon a direct comparison between command speed and actual speed. And, if the latter is greater than the former by more than a predetermined acceptable amount, an overspeed condition is declared. While, traditionally, such comparison has been an on-board function, as suggested above, other approaches may prove to be desirable as well. Not only must the two speeds to be compared be accurately represented (or, at least, not misrepresented in the unsafe direction), but their comparison must be performed in a fail-safe manner including the generation of the "output signal." Traditional practice calls for the use of an enabling output which is removed/withheld when overspeed is detected.

3.3.2.1.3 Initiate Responsive Action. Once overspeed is detected it is essential to take prompt responsive action. This commonly consists of controlled braking or the initiation of an irrevocable brake application at an appropriate rate (e.g., service or emergency braking rate according to the system design). In the latter case, the affected train will come to a full stop, and stay until appropriate repairs and/or reset is accomplished, anywhere along the guideway. However, for emergency evacuation purposes, some maglev systems (e.g., TR-07) have designated "safe stopping locations" spaced along the guideway. In these cases, it may be necessary to actively control the braking process such that, if possible, the train reaches, and stops at, one of these locations. This will require accurate inputs relative to train speed and location, therefore, the control of the braking process may be best assigned to central control. This process must also recognize that, in the case of long-stator systems, part of the braking capability is on the guideway/wayside and part is on the train. This would compound the difficulties associated with controlling/coordinating emergency braking activities from on-board trains.

3.3.2.2 Failure/Fault Response. The concern here is affecting appropriate responses to those system failures/faults which necessitate a reduction in train speed, including full stop, but which neither impact the generation of the command speed nor the overspeed detection function. Therefore, their occurrence will result in neither reduction of the speed command nor cause detection of an overspeed condition. In consequence, alternative means of affecting train speed reduction, including full stop, must be provided for. In order to accomplish this, it is necessary that detection of the failure/fault be performed and appropriate responsive action be initiated. As with the overspeed protection process, actual execution of such actions will involve utilization and control of the propulsion and braking functions.

It can be expected that the failures/faults of concern here will be system specific. In large part, they will be a consequence of overall train control system design and implementation. The distribution of the control functions, especially those involving train speed and position, between central/wayside and on-board locations will be a major factor. Likewise, the location (i.e., train, guideway, wayside, central) of the potentially faulty system or equipment may dictate the inclusion of its abnormal behavior in the set of failures/faults discussed here. It appears that failures of train-borne functions are more likely candidates than are those associated with other portions of a system. In part, this is a consequence of signal transmission considerations which may dictate minimization of train-to-central transmissions.

Failures/faults of concern include both actual and pending conditions. Possible candidates are: guidance related failures, levitation related failures, braking (e.g., eddy current, aerodynamic, mechanical) related failures, fire and/or smoke detection, excessive temperatures (e.g., cryostat, equipment cabinets), loss of charge on back-up batteries for safety related systems, and, perhaps, train-based obstacle detection.

3.3.2.2.1 Detect Failures/Faults. Suitable means (e.g., sensors, diagnostics) of a fail-safe nature must be provided to detect each of the failures/faults of concern here. This requires that not only should these means never fail to detect the occurrence of the associated abnormal conditions, but they must be designed so that, should they fail of themselves, they will provide the same indication as if the system(s) being monitored had failed. The specific means of detection required must be suitable for the purpose intended, but otherwise can vary in design and implementation.

3.3.2.2.2 Initiate Responsive Action. As with the response to the detection of overspeed, it is essential to take prompt action once a failure/fault condition has been detected. Likewise, the action to be taken may be of a similar nature and have similar considerations as those previously discussed in Section 3.3.2.1.3 of this report.

The possibility exists that it may be desirable and feasible to initiate different response actions according to the specific nature, and expected consequences, of individual failures/faults. It can be expected there will be a limited set of responses (e.g., limit train speed to 44 m/sec, initiate irrevocable service braking, initiate irrevocable emergency braking), each of which is called for by one or more abnormal situations. In such case, all response initiating signals requiring a like response can be summed (OR-ed) together to actuate the actual initiating circuitry. It must be recognized that this entire process and all associated circuits/equipment is of a vital nature.

4.0 TASK 2—AVAILABLE SPEED ENFORCEMENT SYSTEMS

This section presents descriptions of the safe speed enforcement system concepts which were selected. A total of 12 such concepts are described; they apply to the following systems:

Maglev

- German Transrapid (TR-07)
- Japanese HSST-05
- Japanese Linear Express (MLU-002).

High-Speed Rail

- French TGV (Atlantique/Nord)
- German ICE
- Swedish X2000
- Italian ETR-500.

Other

- AEG-Westinghouse People-Mover
- VAL (Lille, France)
- Vancouver Skytrain
- Metropolitan Atlanta Rapid Transit Authority (MARTA)
- Advanced Train Control System (ATCS).

Each description focuses on the safe speed enforcement portion of the automatic train protection (ATP) subsystem. For purposes of this report, an overall automatic train control (ATC) system is comprised of three major subsystems: automatic train protection (ATP), automatic train operation (ATO), and automatic train supervision (ATS). These subsystems are not always separate physical elements of the ATC system. Rather, they represent specific functions that are performed in the overall system. The main function of the ATP subsystem is to ensure safe train operation, particularly concerning such aspects as collision avoidance, overspeed protection, and door control. Thus, safe speed enforcement falls within the ATP area. The ATO subsystem operates the trains (e.g., speed regulation, station stopping) within the safe envelope as provided by the ATP subsystem. The ATS subsystem monitors and directs the operation of trains in order to maintain traffic patterns and schedules.

Each description below includes an overview of the safe speed enforcement concept being utilized and/or intended in the particular application. Also, emphasis is given to a number of related aspects such as train location detection, actual train speed detection, safety related communications (primarily between trains and the wayside/central) and implementation (particularly how the computer equipment is structured/configured to ensure safe operation). There is also some general information relating to the trains such as their make-up, braking provisions, and maximum operating speeds.

It should be mentioned that the level of detail in the available information for the systems varied greatly. This is particularly true regarding the role of the train operator (driver) and the actual equipment implementation. Information in these areas was included as available. In general, the information was sufficient to describe the overall safe speed enforcement concepts. One area in which information was lacking relates to the train control for the Shinkansen high-speed rail system. While a number of articles were obtained on the train control utilized in this system, they were generally very short, older articles which did not provide very complete information. For this reason, the safe speed enforcement concept for the Shinkansen high-speed trains is not included here.

4.1 Transrapid (TR-07) Maglev System

The German Transrapid TR-07 maglev system incorporates electromagnetic suspension and is designed for cruising speeds in the range of 400 to 500 km/h. Testing has been underway on the system at the Emsland test track in Germany. Potential applications in the U.S. include a demonstration project in Florida, an installation on a Los Angeles to Las Vegas route and an installation in the Pittsburgh area.

The portion of the Transrapid TR-07 maglev system that is responsible for the safety, control, and supervision of vehicle operations and their intercommunications is referred to as the Operations Control System (OCS). This system is comprised of on-board, wayside and central elements, each of which performs various train control functions. A general summary of these functions by element is provided in Table 4.

A simplified functional block diagram of the OCS is provided in Figure 1. As can be observed in the figure, the OCS is based on a decentralized philosophy in which each wayside (decentralized) element is assigned to one substation area and is responsible (among other things) for controlling the propulsion/braking of the vehicle via the power inverters and the long stator, guideway-mounted motors.

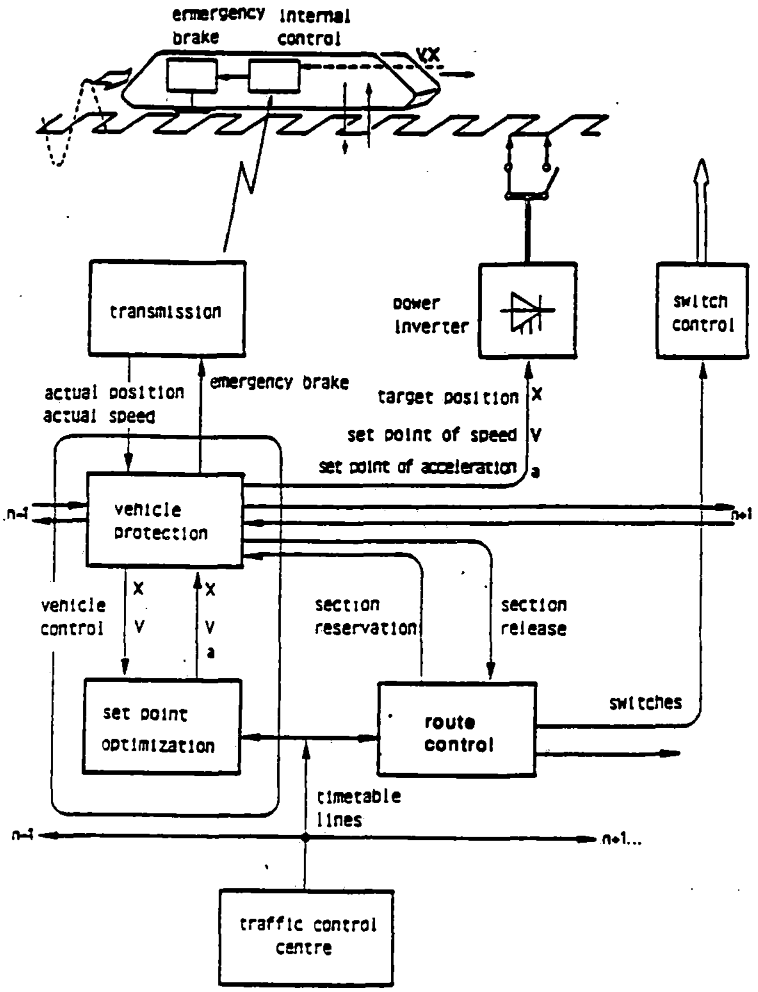
The automatic train protection (ATP) functions including safe speed enforcement are handled by the on-board and wayside (decentralized) elements. The central element (traffic control center), while being responsible for the overall supervision and monitoring of system operation, does not perform any safety critical functions.

Initially, predetermined speed profiles are selected by the central operator and transferred from central to the wayside (decentralized) elements. These profiles are based on system time tables and other factors such as civil speed requirements. The setpoint optimization portion of a wayside element assigns power inverters to the vehicles and determines the propulsion/braking values required to achieve the requested speed profiles and/or to comply with specific operating conditions (e.g., preceding vehicles, position of switches, occupancy of nearby guideway sections, location of next station).

These propulsion values are then checked by the vehicle protection portion of the wayside element in order to ensure safe operation. This vehicle protection portion is the wayside ATP equipment that ensures safe speed commands are generated and that safe speed limits are not exceeded. In order to perform these functions, this ATP equipment receives safety critical vehicle location, speed and direction information from the vehicles in its governing area. It also receives safety critical route integrity information from the route

TABLE 4. MAJOR TR-07 OCS ELEMENTS AND FUNCTIONS

Element	Functions
On-board	● Vehicle detection (e.g., location, speed, direction). ● Vehicle protection and control (e.g., processing of vehicle detection data and error messages, monitoring on-board equipment, control of emergency braking). ● Communications between vehicle and wayside.
Wayside	● Route control (e.g., route setting, locking, releasing). ● Vehicle protection and control (e.g., set point calculations, propulsion/braking control). ● Station supervision and control. ● Communications with vehicles, central and other wayside elements.
Central	● Traffic handling and planning. ● Communications with wayside elements.



Source: Literature Reference (3)

Figure 1. Simplified Block Diagram of TR-07 OCS

control portion of the wayside element and other nearby wayside elements. Included here is information on location of other vehicles, position of switches and occupancy of nearby guideway sections. Other information regarding the status of vehicles in stations and vehicle doors is received from station protection equipment in the wayside element. Vehicle protection equipment uses all of this information plus other information in its own data base (e.g., maximum allowable speed limits for certain guideway portions) to ensure safe headway, and to ensure safe speed limits are not exceeded. The latter is ensured by continually comparing actual vehicle speed with the safe commanded speed. Should actual speed exceed the commanded speed, one of three options can be taken by the vehicle protection equipment on the wayside, depending upon the speed margin: 1) reduction of propulsion, 2) initiation of braking via the long stator motor, or 3) initiation of emergency braking via the on-board eddy current brake system and the landing skids (below 50 km/h). The latter requires 1) removal of propulsion power from the guideway, 2) indication to the vehicle that the emergency brake is required, and 3) control of the braking itself (by train and wayside equipment). Emergency braking is avoided whenever possible.

On-board ATP equipment, in addition to determining vehicle location, speed, and direction, continuously receives specific data from the wayside element so as to permit stopping the vehicle at the next safe stopping area independent of communications with the wayside element. This is necessary in case of loss of communications with the wayside element.

Another function of the on-board ATP is to monitor the status of on-board equipment and transfer that status to the wayside element as appropriate. Some abnormal conditions of operation of on-board equipment may require removal of propulsion power and/or braking via the wayside element.

4.1.1 Train Location Detection

Train/vehicle location (position) is determined via a non-contact measuring system referred to as the Incremental Vehicle Location System (INKREFA). This system incorporates passive position identification markers on both sides of the guideway and two active on-board sensors (readers) on each side of the vehicle. The passive sensors in the guideway, located approximately every 200 m and scanned by the on-board sensors, provide "raw" vehicle position data. These passive sensors each provide a location code, effected by a special arrangement of electrically conducting material on the sensor itself. Each code represents an absolute vehicle position that is stored in the on-board computer data base. Precise vehicle position is determined by counting the number of grooves in the long stator field in the guideway.

The use of multiple passive position identification markers and multiple vehicle sensors provides redundancy in the vehicle position measurement. Further, the position values from the vehicle sensors are verified by the on-board computer. Should position errors occur on both sides of the guideway and be detected by on-board checks, the last location information is used until the next position marker is encountered.

4.1.2 Train Speed Detection

Actual train speed is calculated in a fail-safe manner by the on-board computer from the location information supplied by the INKREFA system. This information is then transmitted to the wayside (decentralized) element responsible for the section of the guideway in which the train is located.

4.1.3 Safety Related Communications

Train/wayside communication functions are handled by a 40 GHz radio link. The system is designed so that two wayside receivers are in range of a vehicle at any one time, and each vehicle is equipped with at least two transmitters/receivers. This assures a high degree of availability for the transmissions which include both voice and data information.

The primary safety critical information transmitted from the vehicle to the wayside includes vehicle position, speed, and direction of travel. The primary safety critical information transmitted from the wayside to the vehicle includes 1) the vehicle and route integrity data that allows the train to stop at a safe stopping area should communications be lost, and 2) the emergency brake signal.

While much of the data transmitted between the train and the wayside is safety critical, the data transmission link itself is not designed to be such. Data both on-board the train (e.g., position, speed information) and at the wayside are safeguarded via special encoding schemes. In this way, the safety of the transmission relies on the fail-safe encoding and decoding performed in the computer system both on-board the train and at the wayside.

A fiber-optic cable link is used to transmit data between the wayside and central elements and other wayside equipment (e.g., switches, power inverters).

4.1.4 Fail-Safe Implementation

The primary safety critical functions relative to safe speed enforcement are performed in computer systems both on-board the vehicle and in the wayside (decentralized) elements. These systems are based on Siemen's SIMIS fail-safe microcomputer system architecture which, in this application, uses a two-out-of-three voting scheme to ensure a high level of safety and fault tolerance. In this scheme, three microcomputer based hardware channels operate in parallel with generally the same software and perform the same functions. Hardware implemented comparators compare the outputs of the channels. Should one of the channels disagree, it is shut down and isolated, and operation continues with the remaining two channels. If another disagreement occurs in the two channels, the system reverts to a fail-safe shutdown of the system. Background tests are also conducted by the software on certain hardware (e.g., memory devices) and/or operational data to detect improper operation and/or latent failures.

The design of these systems is based on two key aspects: independence of the hardware channels and proper development of the software (since all three channels use essentially the same software). The latter is accomplished through the use of a high degree of software modularity as well as structured programming and computer-assisted software engineering techniques.

Safety critical functions performed by station protection equipment in the wayside element (e.g., monitoring the position of vehicles in the station area and the status of doors prior to departure) are implemented in a self-contained unit with simple fail-safe logic. As previously described, station related information is utilized by vehicle protection equipment in the wayside element to help determine that the vehicle is ready for departure and/or boarding.

Vital type relays are utilized on the wayside to ensure removal of propulsion when such condition is deemed necessary and also on-board the vehicle to control the on-board braking systems. The latter is particularly important in the Transrapid system because of the need to control emergency braking and stop the vehicle under such conditions only at safe stopping areas.

4.2 HSST-05 Maglev System

The Japanese HSST-05 maglev signalling and train control system/equipment described below is that which was utilized on the YES '89 line (560 m in length) in the Yokohama Exposition in 1989. In this application, a two-car train operated between two stations at a maximum speed of approximately 45 km/h due to the short travel distance. Although this speed is relatively slow, available information indicates that the system is designed to operate at speeds up to 200 km/h. Available information also indicates that the train control concepts in this application will form the basis of and be similar to larger revenue service applications of the HSST system.

The train control system is comprised of on-board subsystems, a central control facility and wayside equipment that includes both passive and active transponders. In addition, an inductive transmission belt (cable) is laid in the guideway for train speed/location detection purposes (determined on-board the vehicle) and for general train-central communications. The train control system essentially operates automatically under supervision and control by the ATP subsystem. ATP equipment includes the following:

- On-board speed and location detection equipment.

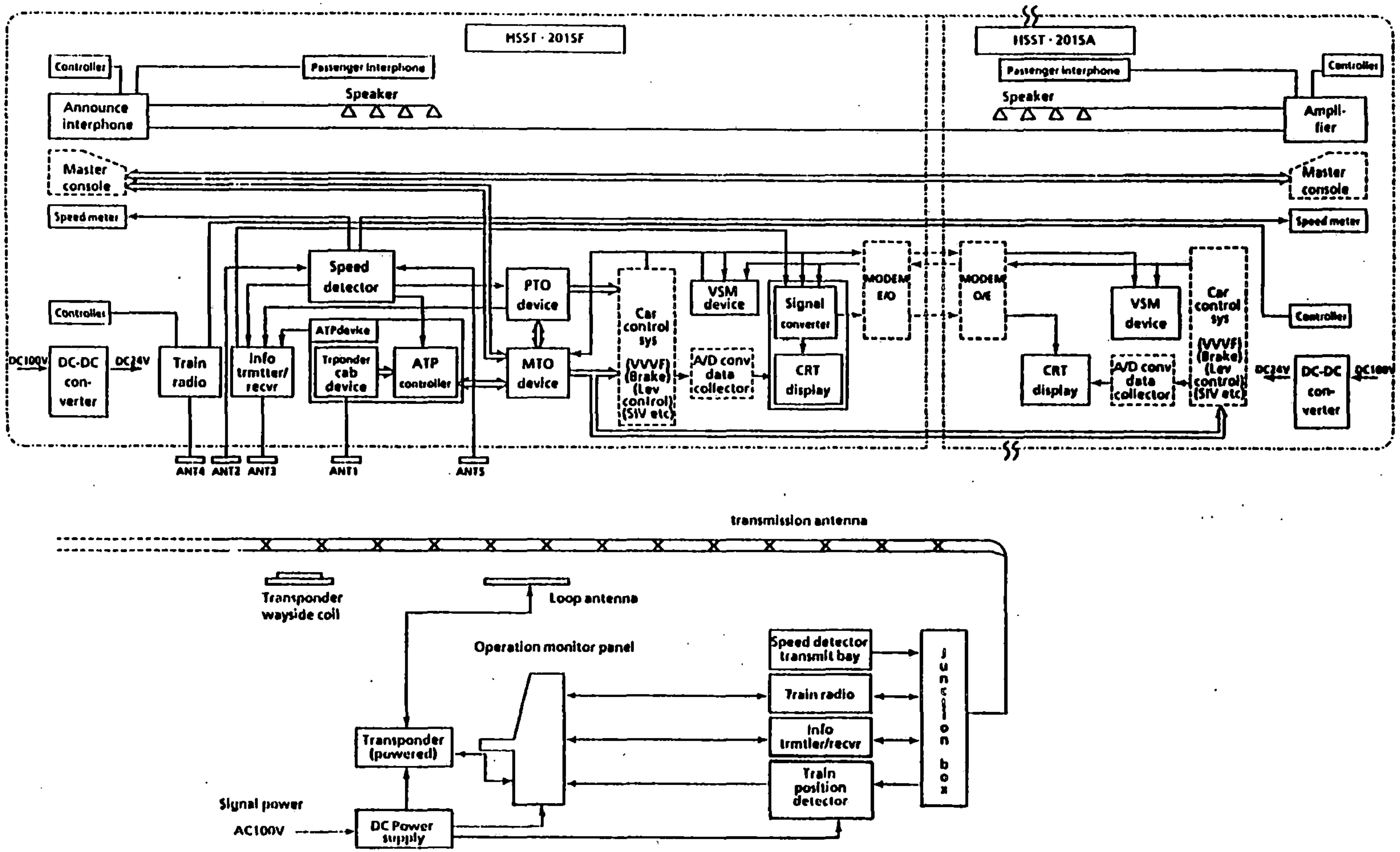
- On-board equipment that 1) compares commanded speed with actual speed, 2) controls the braking system, and 3) controls transmission of train speed, location, and other information to the central facility.
- Central equipment that generates maximum speed commands and processes those commands for transmission to the train.
- Wayside transponders (both actual and passive) that transfer speed commands and specific location information to the train.

A diagram of the overall train control system is shown in Figure 2.

When the train is ready for station departure, specific departure information (e.g., levitation and door status) is transmitted from the train to the central facility via train radio, train mounted antenna, a loop antenna in the guideway and the active transponders. If the train is deemed ready for departure, the central facility transmits a departure signal and initial speed limit to the train. The train operator then initiates departure, and on-board automatic train operation (ATO) equipment generates the appropriate propulsion command within the given speed limit.

While all possible operational modes of the system have not been identified, it is known that the train operator initiates station departure after receiving clearance from the central facility. Once this occurs, operation under normal conditions is fully automatic. Although not confirmed, the operator may also be able to initiate emergency braking and/or manually drive the train under certain failure conditions (e.g., loss of communications with central). This is expected due to the fact that braking and propulsion equipment are located on-board the vehicle.

As the train proceeds on the guideway, on-board ATP equipment determines actual train speed and location via a transmitted signal from central and the transpositions in the inductive transmission belt. Speed and location information as well as status information regarding certain on-board equipment is transmitted back to the central facility when requested by central. Train speed limits, as generated by central ATP equipment, are transmitted to the train at specific control points via the active wayside transponders, associated loop cables, and the vehicle antenna.



Source: Literature Reference (6)

Figure 2. HSST-05 Train Control System

On-board ATP computer-based equipment stores the commanded speed limits received at each control point, generates corresponding speed pulses, and compares these pulses with those which represent actual train speed. Should overspeed occur, the ATP equipment initiates braking via the on-board short stator linear induction motor, mechanical brake system and/or skids if necessary. If on-board ATP equipment senses that speed limits are not being received (loss of transmission from actual wayside transponders), braking is also initiated.

Passive wayside transponders are installed at several control points to provide the train with precise location information. Two sets of these transponders are also used in the vicinity of each station area to initiate station stops. On-board ATP equipment monitors train speed within the locations bounded by the two transponders and controls braking accordingly in order to ensure that the train does not overrun the station area. Should the train overrun the station area due to a brake system failure or other failure, the train will be stopped by a bumper mechanism beyond each station area.

4.2.1 Train Location Detection

Train location is calculated by on-board ATP equipment based on the transpositions detected in the transmission belt by the speed detection equipment and precise location information obtained from the passive wayside transponders. The transmission belt carries two conductors which are transposed at 0.1 m (10 cm) intervals. Central equipment generates a 30 kHz signal which is transmitted in the belt and received by two sets of antenna (three antenna per set) on-board the train.

4.2.2 Train Speed Detection

As indicated, train speed is determined by on-board ATP equipment via the inductive transmission belt (cable) in the guideway. On-board equipment detects the phase changes due to the transpositions in the belt and determines actual train speed accordingly. On-board equipment also includes continually updated speed meters which are used to help cope with intermittent signals in the transmission belt.

4.2.3 Safety Related Communications

Speed commands (speed limits) and departure commands are transmitted from the central facility to the train at specific (control) points on the guideway via the active wayside transponders, associated loop cables, and on-board transponder devices. Information on train speed, train location, and equipment status is transmitted from the train to central via the inductive transmission belt.

All safety critical information is encoded and decoded via special techniques (e.g., cyclic redundant codes—CRC) in both the on-board and central ATP equipment. In addition, critical on-board equipment, wayside devices and central equipment are checked for failure by looping back and verifying transmitted data.

4.2.4 Fail-Safe Implementation

On-board (and probably central) microcomputer-based systems involved in the ATP functions such as speed/location detection, overspeed detection, emergency brake control and command speed generation are arranged in a dual redundant channel configuration with a hardware comparator to detect disagreement between channel outputs. It also appears that different, but functionally similar, software programs are utilized in each channel.

4.3 Linear Express Maglev System

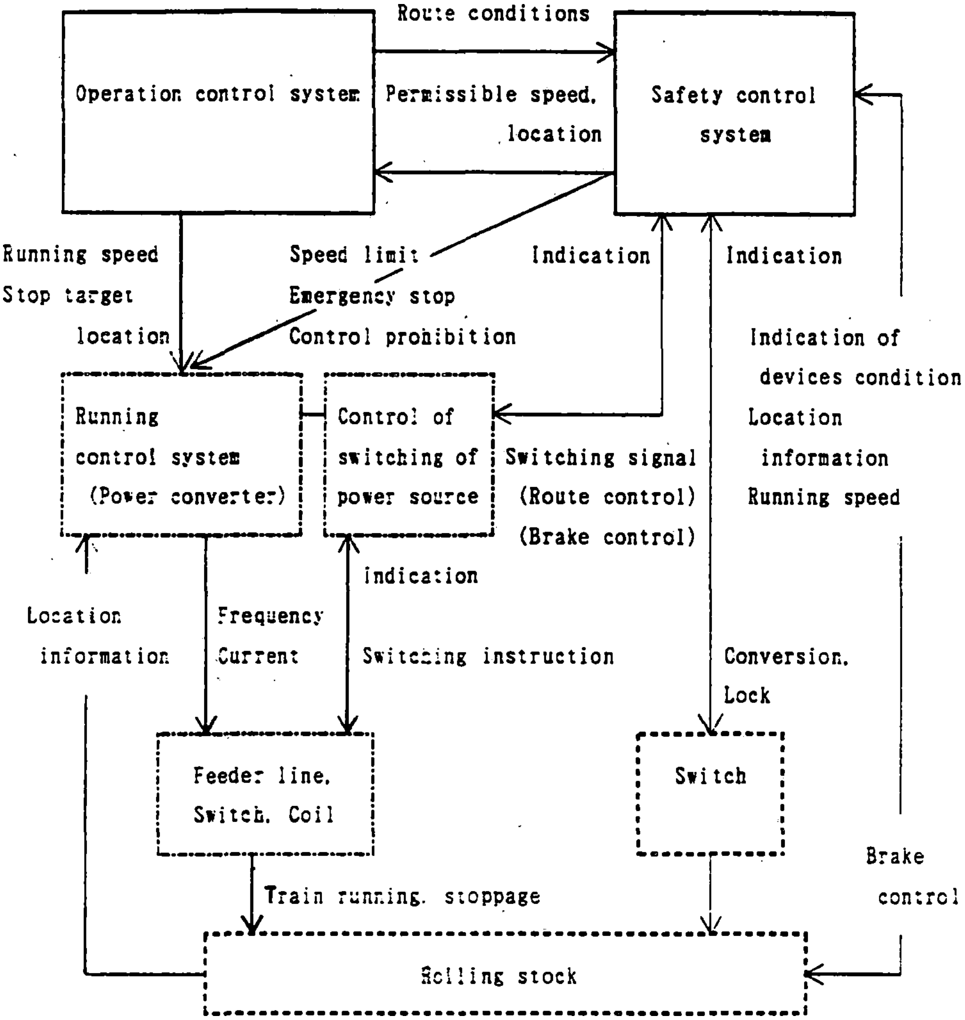
The Japanese Linear Express electrodynamic maglev system, based on superconducting magnet technology for levitation and propulsion, is undergoing testing at the Miyazaki test track in Japan. Speeds of up to 394 km/h have been achieved with the MLU-002 test vehicle. Construction of a new test track (Yamanashi) is planned in order to test the economical and technical feasibility of a 500 km/h commercial maglev system. Should testing be successful, a commercial articulated train with up to 14 cars could be implemented on the 500 km route between Tokyo and Osako; this is not expected to occur until the year 2005. Emphasis to date has been placed on testing the superconducting magnet technology relative to levitation, guidance, and propulsion.

While it appears that the train control system including the ATP subsystem has not been fully defined, a general control structure and operating concept does exist. According to this concept, train control will be handled by an operational safety system that will be comprised of three separate, but interrelated systems: 1) an operation control system, 2) a running control system, and 3) a safety control system.

The operation control system will perform the overall train supervision and control functions. Based on train schedules and train operating data, this system will optimize and generate speed commands, generate route control commands, monitor equipment status, and provide instructions to dispatchers. The running control system will control train propulsion/braking via the long stator linear synchronous motor. The safety control system (both on-board and on the wayside) will perform ATP functions by monitoring and ensuring safe operations of the other two major systems. The three basic functions of the safety control system are as follows:

- Train headway control—Assures a minimum distance between trains is maintained by controlling train speed
- Station yard control—Assures nonconflicting routes
- Speed control—Assures maximum permissible speeds due to track and route conditions are not exceeded.

A diagram showing the structure of the operational safety system and the functional interrelationships between the three major systems (described above) is provided in Figure 3. As can be observed from the figure, inputs to the safety control system will include the following:



Source: Literature Reference (9)

Figure 3. Structure of Linear Express Operational Safety System

- Desired routes from the operation control system
- Switch position status from wayside equipment
- Train location and speed information (from the train itself)
- Condition of certain train equipment.

Based on these inputs, the safety control system on the wayside will perform the following safety critical functions:

- Generate maximum speed commands/limits and emergency brake commands to the running control system
- Generate specific route and brake control signals for use by the running control system
- Control guideway switches
- Generate/transmit brake control signal indications to the train itself.

Based on this structure, the safety control system will generate safe commanded speeds, detect overspeed conditions, and control propulsion/braking systems both on and off the train. While the primary braking is via the guideway mounted linear synchronous motor, the train is to be equipped with electric brakes (shoes) and an aerodynamic brake.

4.3.1 Train Location Detection

Train location will be calculated on-board the train by monitoring (counting) the phase reversals (due to transpositions) in a signal received from an inductive cable installed in the guideway. The distance between transpositions is stored on-board in a data base. It is not known if any other location information will be transmitted to the train (e.g., via transponders) for comparison/use with calculated location data.

4.3.2 Train Speed Detection

Train speed will be detected via the inductive cable installed on the guideway. Train equipment (part of the safety control system) will receive the signals in the cable via an on-board antenna and will determine actual speed by counting the number of phase shifts that occur in the signal (due to the cable transpositions) in a given time period.

4.3.3 Safety Related Communications

Safety critical information from the wayside to the train is transmitted via the inductive cable in the guideway. Train control information of both a safety and non-safety critical nature will be transferred between the train and wayside via an on-board antenna and leaky coaxial cable on the guideway. Train to wayside information includes actual train speed and location data.

4.3.4 Fail-Safe Implementation

Implementation details on the safety critical equipment of the HSST-05 are not known.

4.4 TGV High-Speed System

Several versions of the French high-speed train referred to as Train "Grande Vitesse" (TGV) are either in operation in France or planned for operation in the near future. The earliest version, TGV Sud-Est, began operations between Paris and Lyon in 1981-83 and operates at speeds up to 270 km/h. A later version, the TGV Atlantique (TGV-A), began operations in 1989 and operates at speeds up to 300 km/h with 240 to 300 second (4 to 5 minute) headways. The most recent version, TGV Nord, is planned for the northern part of France (Paris to Lille and on to Brussels) and also for the channel tunnel link. This system is designed for operation at speeds up to 320 km/h with 180 second (3 minute) headways. The TGV Nord is the version most likely to be used for the Texas TGV application.

Below is an brief overview of the TGV-A system followed by a more detailed description of the new TGV Nord system.

4.4.1 TGV Atlantique

The TGV-A train is a fixed consist train with multiple passenger cars and power cars on each end, each power car being equipped with four inverter driven, AC synchronous traction motors. Power for the system is provided by a catenary via roof mounted pantographs. The brake system consists of rheostatic, pneumatic, and electro-pneumatic components. The air operated system is comprised of disk brakes (for passenger cars) and tread brakes (for power cars) which are controlled via brake pipes and complemented by electro-pneumatic trainlines for fast response. The rheostatic system, considered to be fail-safe, is the normal braking system. It normally receives power from the catenary, but emergency power is provided by on-board batteries.

The TGV-A train utilizes a train control system referred to as the TVM 300, developed in part by CSEE-Transport in France. TVM 300 is a cab signalling system based on CSEE-Transport's UM71 AC audio frequency jointless track circuits. These track circuits determine block occupancy and, based on occupancy of adjacent blocks and track characteristics, transmit vital "stepped" or intermittent speed limit information in coded form to the train via the rails and on-board antenna. The transmitted code defines the maximum speed permitted by the train in a given block. Additional speed limit information (e.g., absolute stopping points) is provided to on-board equipment via inductive loops which are placed at selected points on the track. Together, these two pieces of information advise the driver as to the maximum speed allowable in a block. The train operator drives the train according to the displayed speed under supervision by on-board speed control equipment. At higher speeds, the train is typically required to stop at least one block length from a downstream occupied block. In some instances, particularly at lower speeds, the train is permitted to enter the block following an occupied block, but only at a reduced speed. Should the driver exceed the displayed speed limit for the block in either case, an automatic braking system brings the train to a stop.

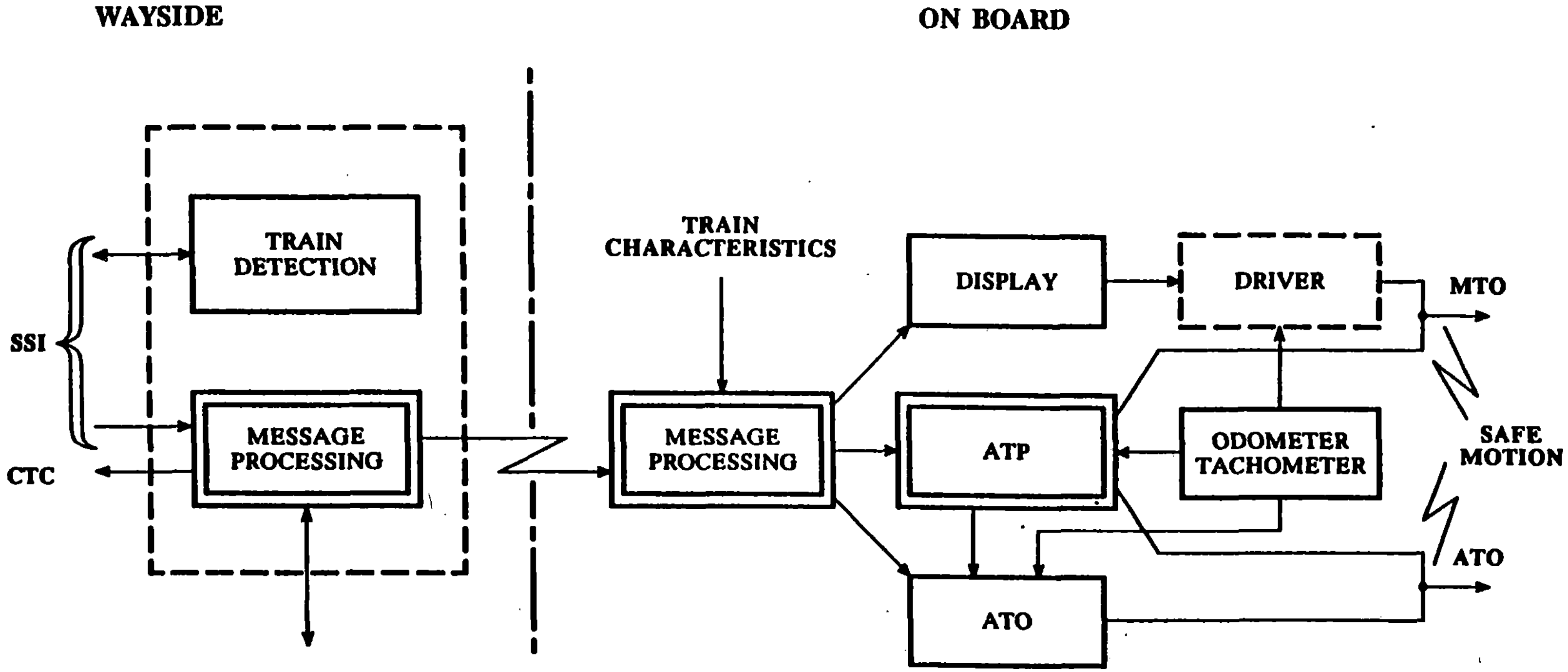
There is also a data processing network on-board the train referred to as TORNAD. This system, which extends throughout the consist, monitors on-board equipment such as braking systems, door-closing mechanisms, the cab signal diagnostic system, and passenger information systems. Equipment failures are annunciated to the operator as they occur so that proper corrective actions can be undertaken.

4.4.2 TGV Nord

The TGV Nord system is similar to that of the TGV-A except that TGV Nord utilizes a newer train control system referred to as TVM 430 (also developed in part by CSEE-Transport). Instead of sending intermittent speed control commands to a train (a single speed limit for a given block), the new system allows for the on-board calculation of maximum speed (speed control curves) based on current train location, as well as speed and target distance information continually received from the wayside. This system allows a dramatic reduction of the contingency length to the required stopping point and offers a higher traffic flow capability.

TVM 430 actually combines the technology of the TVM 300 system (essentially the UM 71 track circuits) with a new digital train control system referred to as SACEM. SACEM is a computerized train control system utilized on the RER Line A of the Paris Metro. Wayside equipment (which includes the UM71 track circuits) is referred to as CAI equipment. Each CAI unit handles several blocks and communicates with other CAI units as well as a central facility. A general diagram of the train control structure is shown in Figure 4.

UM71 coded audio frequency track circuits are used to determine block occupancy and also to send vital information to the train via the rails. In fact, the track circuits can transmit 27 bit messages continuously through the rails. In addition, intermittent speed and location related messages are sent to the train at certain locations via inductive loops laid between the rails. Speed related information sent through the rails by the CAI unit consists of a speed limit associated with a target distance. This speed limit is the maximum allowed speed at a specific distance (target) from the beginning of the block in which the train is located.



Source: Literature Reference (40)

Figure 4. TGV Nord Train Control Structure

Values for the speed limit and target distance are based on track characteristics (e.g., curves, gradients), track occupancy (e.g., presence of other trains), and temporary speed restrictions.

On-board computerized ATP equipment calculates the instantaneous maximum allowable speed according to the current position of the train and displays speed information to the driver. This calculation takes into account train braking characteristics as well as speed limits for certain sections of track. This maximum allowable speed typically follows a continuous parabolic curve. In this manner, the on-board equipment optimizes the stopping distance according to train characteristics and other appropriate parameters. On-board speed calculations are modified based on further speed restrictions obtained via the inductive loops. Current position is calculated on-board based on track circuit information, tachometers, and the inductive loops.

On-board ATP equipment continuously monitors actual train speed via a tachometer and compares it with the calculated instantaneous maximum allowed speed. Wheel-slip/slide is accounted for in the actual speed measurement. If overspeed is detected, the driver is warned to reduce speed via an alarm. If, after a given time, train speed has not been sufficiently reduced below the calculated speed limit curve, the on-board equipment initiates braking accordingly.

4.4.2.1 Train Location Detection. Train location in a particular block is determined on the wayside via UM71 coded AC audio frequency track circuits. These track circuits use four carrier frequencies between 1700 Hz and 2600 Hz which are modulated by low frequency signals (less than 25 Hz) allowing 27 bits to be transmitted in parallel. Train wheels and axles shunt the signals, providing train occupancy indications to the track circuit equipment.

More precise train location is calculated on-board based on the previous fixed reference points (via inductive loops) and the on-board axle-mounted tachometer.

4.4.2.2 Train Speed Detection. As previously stated, train speed is calculated on-board based on signals from an axle-mounted tachometer. Calculations take into account wheel slip and slide.

4.4.2.3 Safety Related Communications. Safety related communications between the wayside CAI units and the trains are implemented in two ways: UM 71 coded track circuits and inductive loops. The track circuits provide speed limit and associated target distance information to trains. Inductive loops at fixed locations are used to provide speed limit restrictions and precise stopping point information.

4.4.2.4 Fail-Safe Implementation. Data processing of safety critical information in the wayside CAI units as well as on-board the train is handled by a single channel, coded safety microprocessor system. Each item of information is dynamically coded in order to build a representative tracer of the variable, the processor which created it, and the date of generation. Also, each process has a unique signature which is checked and compared with a predetermined reference. These codes and checks allow for the detection of improper microprocessor operation. It does not appear that any redundancy is used in hardware or software to help ensure safety.

4.5 ICE High-Speed System

The German Intercity Express (ICE) high-speed train, operated under authority of the German Federal Railway (DB), was introduced on the DB in the summer of 1991 between Hamburg, Frankfurt, and Munich. The train, which typically consists of a power car at each end and passenger cars between, is designed for a maximum speed of 300 km/h. Power is delivered to the train's traction motors via a roof mounted pantograph and catenary system.

Three types of braking are available on-board the train: dynamic regenerative braking via the traction motors, electro-pneumatically and/or pneumatically controlled friction disc brakes and electromagnetic rail brakes. Normal braking is handled by the regenerative system with assistance as required by the friction brakes (on each car). Electromagnetic brakes, which may be replaced by eddy current brakes in the future, are used for emergency braking only. Friction brakes can be manually actuated by the operator via a brake control valve that is connected directly to the pneumatic brake pipe lines.

The highly automated train control system incorporates an integrated ATP system that is based on the German Linienzugbeeinflussung (LZB) continuous speed control system. Vital train/wayside communications are handled via inductive loops that are laid between the rails. ATP functions are performed both on-board the train and at wayside locations. Train operations are monitored from a central control point.

Three operational modes are possible in the system: 1) a fully automatic or "driverless" mode, 2) a semi-automatic mode in which the operator manually selects the desired speed and the speed control system maintains the set speed accordingly, and 3) a fully manual or cab signalling mode in which the operator drives the train based on information presented on the console. An on-board automatic train speed monitoring system is active in all modes.

Prior to departure, the train operator keys in certain information on the console (e.g., train ID, length, status of braking system) regarding the train and its subsystems. This information is transmitted via a train antenna and the inductive loops to the wayside equipment governing that portion of the track. Computerized ATP equipment on the wayside uses this as well as other safety critical information (e.g., locations of other trains, switch status, line gradients, civil speed restrictions) to generate safety critical operating parameters that are transmitted back to the train via the inductive loops. This information includes three key pieces of data: 1) the distance to the next stopping point, 2) the braking curve to be utilized, and 3) the travel direction. On-board computerized ATP equipment uses this data to determine where the train should be on the braking curve relative to the stopping point, and then calculates the required speed. Propulsion and braking commands are generated accordingly. Other non-safety critical information sent to the train from the wayside includes target distance (i.e., location of a definitive change in train speed) and target speed (i.e., instantaneous permissible speed at the target point). This information is used when the train is manually operated.

On-board ATP equipment determines speed commands (based on inputs from the wayside), monitors actual train speed (via pulse generators), and compares the commanded and actual speeds to determine overspeed conditions. If such a condition is detected, emergency braking is initiated. In manual operation, on-board equipment calculates two speed curves, one based on the maximum allowable speed and the other on a lower nominal value (based on a lower braking rate). If train speed exceeds the lower nominal value, the operator is warned and must respond; otherwise, emergency braking is initiated. Also, when operating manually, if the operator does not touch the foot pedal or hand reset for more than 24 seconds, an alarm sounds and the operator must respond within 5 seconds; otherwise, controlled braking is initiated.

Status of braking systems is continuously displayed to the train operator. Any reductions in braking capability are entered into the system by the operator, transmitted to the wayside via the inductive loop and taken into account in the information sent back to the train and in the on-board speed control equipment itself.

While wayside signals are generally not used over the main lines, they are utilized to some extent at interlockings and stations to convey additional speed limiting/routing information.

Audio frequency track circuits are used for broken rail detection and to ensure safe routes. Electronic interlockings, based on Siemen's SIMIS microprocessor based control technology, are utilized for switch/signal control.

4.5.1 Train Location Detection

Train location is detected on the wayside via the audio frequency track circuits and shunting of the signals by the train's wheels and axles. This information is then utilized in generating the safety critical information (e.g., distance to next safe stopping point, braking curve, travel direction) that is transmitted from wayside equipment to the train. Precise train location is determined on-board via signals from pulse generators.

4.5.2 Train Speed Detection

Train speed and direction are determined on-board via redundant pulse generators. Each generator outputs 16 pulses per axle revolution that are counted by the ATP computers. An acceleration meter is also utilized on-board to avoid misinterpretation of the pulse generator's outputs during wheel slip/slide conditions.

4.5.3 Safety Related Communications

Vital information (discussed earlier) is transmitted between the train and wayside via inductive loops laid between the tracks. These loops are approximately 300 m in length and are overlapped every 100 m. Data is transmitted from wayside to train and train to wayside in signals with frequencies of 35 kHz and 56 kHz, respectively. Each train receives wayside information approximately once each second. Data exchange between the train and wayside can occur every 14 seconds.

Information between cars on the train is transferred via a fiber optic data transmission network. It replaces hardwired trainlines used in most transit applications. This network, comprised of two parallel and bi-directional fiber optic cable sets, is used for braking control on all cars and helps ensure synchronization between propulsion motors on the two power cars. It also is used for voice communications (between passengers, crew, and operators), maintenance and diagnostic systems. The lead power car becomes the train's diagnostic center, which collects and stores data from all the vehicle's diagnostic systems. The use of two cables and special connections in each car allows for a high level of fault tolerance in the system.

4.5.4 Fail-Safe Implementation

On-board and wayside computers directly involved in the ATP speed enforcement process are configured in a two-out-of-three arrangement. All three computers operate in parallel and essentially perform the same functions. If two outputs agree, the resulting data is considered acceptable and is utilized. If two of the three do not agree, the resulting data is not utilized and the system reverts to a non-automated control mode. The use of a third computer adds a degree of fault tolerance to the system.

Interlocking plants, while more directly involved in ensuring nonconflicting routes (than enforcing safe speed), are implemented with SIMIS microprocessor-based control systems, developed by Siemens. Each interlocking incorporates two SIMIS-C control elements, each of which utilizes two identical microprocessors in a checked redundant configuration. Only one SIMIS-C element is on-line at any one time. Should disagreement occur between the microprocessor in the on-line SIMIS-C element, control is transferred to the other SIMIS-C element which is on hot standby. This configuration is utilized to provide a high degree of system reliability.

4.6 X2000 High-Speed System

Sweden's X2000 high-speed tilting train was put into revenue service in September 1990 on the Swedish State Railways from Stockholm to Gothenburg. The train, consisting of multiple passenger cars with a power car on each end, operates at speeds up to 210 km/h. Power for the traction motors in the power cars are provided by a catenary system. Braking is accomplished dynamically via the traction motors, electro-pneumatically via disc and tread brakes (on passenger cars only), and magnetically via magnetic rail brakes (for emergency purposes only). The train developer is Asea Brown Boveri (ABB) Traction AB of Sweden, who recently also acquired Ericsson's signalling activities through a Norwegian subsidiary company.

The Florida High Speed Rail Corporation had planned to use a variation of the X2000 to provide service between Miami, Orlando, and Tampa. A demonstration of the X2000 technology is planned for the Northeast Corridor.

The train control system for the X2000 is based on the intermittent transfer of information from wayside to the trains via transponders (beacons) laid between the rails. The concept is similar to that incorporated in Ericsson's JZG 700 train control system.

Wayside equipment that includes interlocking systems and DC track circuits (for train detection) control speed aspects displayed on wayside signals. Information from the wayside signals are encoded on the wayside and fed to the transponders. At least two transponders are provided at each information point. Some transponders contain fixed information (e.g., civil speed limits based on curves, gradients) and are not provided with any variable encoded information from the wayside signals.

When on-board antenna equipment encounters a transponder, the transponder is activated and relays speed limit and track condition information to the train. On-board computer equipment processes the information, computes the maximum allowable safe speed based on this information and other data regarding braking characteristics of the train (entered by train operator), and displays the appropriate speed information to the train operator. Thus, the operator can view an in-cab display (i.e., cab signals) as well as wayside signals. The on-board computer compares actual train speed (via tachometers) with the commanded speed and detects overspeed conditions. If the train operator fails to keep the actual speed within 10 km/h of the commanded speed, the on-board equipment automatically initiates emergency braking. An alarm is initially sounded when actual speed exceeds the commanded speed by 5 km/h. The equipment also automatically stops the train if the train operator fails to activate the alerter actuator in the cab at least once per minute, if grade crossing gates are not down, or if a vehicle is detected on the crossing by special inductive loops.

On-board equipment also includes a fault indication/diagnostics system that is integrated into the control system.

There are plans for the ATC system in the future to utilize radio for data transfer.

4.6.1 Train Location Detection

Train location in specific sections (blocks) of track is determined on the wayside by DC track circuits. Audio frequency track circuits are not utilized in Sweden. This location information is used in the control of wayside signals and is also transmitted to the train via the transponders.

4.6.2 Train Speed Detection

Train speed is detected on-board via axle mounted generators (tachometers) and calculated by the on-board computer. Provisions are included to account for wheel slip.

4.6.3 Safety Related Communications

All safety related communications between the wayside and the trains are handled via the transponders in the track bed (usually installed in groups of two). Antenna on the train continually scan the track bed at a modulated frequency of approximately 27 MHz. This signal activates the transponders which send messages back to the train on a 4.5 MHz carrier. Messages can be sent at least eight times to trains traveling at speeds as high as 300 km/h. The transponders transfer the speed aspect information to the train for the upcoming (downstream) block that is also displayed on the corresponding wayside signals.

4.6.4 Fail-Safe Implementation

On-board computer systems involved in the processing of safety critical information are implemented with two independent redundant channels of similar hardware. The channels operate on diverse software programs, developed by separate programming teams from a common specification.

The computer outputs are compared to determine agreement. The output is accepted only if both channels agree. Otherwise, an alarm is sounded and the train is braked.

4.7 ETR-500 High-Speed System

The ETR-500 is a developmental high-speed train that is expected to run on the Milano-Roma line in Italy at speeds up to 300 km/h. An order has been placed for up to 30 train sets by the Italian Railways (FS) for utilization in the 1995-97 timeframe. Trains are being manufactured by a consortium referred to as TREVI, including ANSALDO Transporti, Asea Brown Boveri (ABB), Breda, Fiat, and Firema. At the present time, tests are being run on at least two prototypes.

The non-tilting trains are expected to have a 14-car consist with a power car at each end. Power cars will contain traction motors that will be supplied with DC power via a catenary system and roof mounted pantographs.

Development is underway on the train control concept to be utilized on the ETR-500. According to an engineer with ANSALDO Transporti, the system will incorporate coded AC audio frequency jointless track circuits for train location detection via shunting by the steel wheels and axles. Wayside ATP equipment will transmit speed command and other information in a "discontinuous" or intermittent manner (e.g., speed command for entire block) to trains via the coded track circuits and on-board antenna. Inductive loops are placed at certain locations along the track to provide supplemental information (e.g., station stopping commands) to trains. Certain information on the train (e.g., status of brake systems) will be transmitted via the rails back to the wayside equipment. Speed limit information will be displayed to the train operator as in typical cab signalling systems, but the system is also expected to include full ATO with operation monitored by the operator. On-board equipment will measure actual train speed via tachometers and other means (not specified), and compare actual speed with the commanded speed. Should overspeed occur, braking will be initiated.

It is not known if the train equipment will calculate more precise location data and instantaneous maximum speed to determine a continuous braking curve (like TGV Nord). However, based on the "discontinuous" transmission system, it appears that on-board equipment will not perform these functions. Rather, the planned concept for the train control system appears to be similar to that utilized in the TGV Atlantique high-speed train.

4.8 AEG-Westinghouse People-Mover System

AEG-Westinghouse people-mover systems such as those at the Atlanta, Orlando, and Miami Airports are rubber-tired Automated Guideway Transit (AGT) systems that operate on dedicated guideways at speeds up to approximately 50 km/h. Electrical power is transferred to the traction motors in the multiple-car trains via rails located on a guidebeam in the center of the guideway. Braking is typically controlled via dynamic brakes, air controlled friction brakes, and emergency spring brakes.

The ATC system is fully automated and performs the basic ATO, ATS, and ATP functions via on-board, wayside, and central equipment. ATO equipment is responsible for such functions as train speed regulation and station stopping within the safe envelope as established by the ATP subsystem. ATS equipment monitors and directs system operations also within constraints of the ATP subsystem. ATP functions include speed command generation and reception, overspeed protection, rollback protection, direction control, and others. These functions are performed by on-board and wayside ATP equipment. On-board ATP functions are very similar to those utilized on the Bay Area Rapid Transit System (BART), and the Sao Paulo, Brazil, Metro transit system except that slightly different implementations are utilized.

The guideway is divided into a number of sections or blocks as in most conventional rail transit systems. Each block has associated with it a track circuit with a transmitter on one end and a receiver on the other. Each track circuit transmitter can transmit a speed code command to the train in its block via signal rails (mounted on the guidebeam in the center of the guideway). These encoded commands are transmitted at an 18 Hz rate using a frequency shift keying (FSK) technique in the range of 5 to 10 kHz. The command is comprised of a six-bit word which, via a pair of frequencies, conveys two identical but complementary speed commands. The location of trains in downstream blocks, switch positions, and other information are used by the wayside ATP equipment to establish a safe speed profile for the train. These commands represent the maximum allowable safe speed for a given block. Other commands sent to the train can include emergency stop commands, reset commands (i.e., for starting of trains and resetting alarms) and direction control commands.

The speed commands are picked-up inductively via dual on-board antenna which are located beneath the vehicles in close proximity to the signal rails. Propulsion and braking are controlled automatically. Each of two on-board microprocessor based channels in the ATP equipment separately decodes the two complementary speed commands, determines validity of the commands, and compares the commanded speed with the actual train speed (obtained from on-board tachometers). Each channel of on-board ATP equipment generates a speed error signal based upon the comparison of actual and commanded speed. As long as actual speed is less than commanded speed (for both complementary speed commands), the on-board equipment holds off the emergency brakes and allows the application of propulsion power. Should overspeed occur as indicated by either complementary speed error signal, emergency braking is initiated and propulsion power is withheld. The train is held in the emergency braking position until a reset command is received via wayside ATP or the system is manually reset on-board the train at perhaps the next station. Emergency braking is also initiated if vehicle "rollback" is sensed via tachometers and/or if improper train direction is sensed.

Additional protection for removal of propulsion power is provided by other on-board ATP equipment which detects improper tachometer operation (e.g., improper phase relationship). Zero speed commands are needed from wayside ATP equipment to safely control vehicle doors.

4.8.1 Train Location Detection

Train location is detected via the coded track circuit equipment with insulated joints, the signal rails, and brushes (collector shoes) on the vehicles. Brushes, mounted to the rear of the speed command receiving antenna on the vehicles, shunt the signal (in the signal rails) originating from the rear of the train. Normally, the transmitted speed code is received at the receiver and sent back to the transmitter. If no code or the improper code is sent back, block occupancy is assumed.

4.8.2 Train Speed Detection

Train speed is detected on-board in a fail-safe manner via dual independent tachometers and the on-board ATP computer equipment. Each computer calculates actual speed based on signal pulses from its associated tachometer. Tachometer outputs are phased to allow for direction of travel determinations. The integrity of each tachometer is continually checked automatically via on-board equipment.

4.8.3 Safety Related Communications

The primary safety related communications in the system involves the transmission of speed code and other information (e.g., emergency stop, reset, direction control) from the wayside to the trains. This is accomplished via the wayside and/or station ATP equipment, the signal rails, and on-board receiving antenna.

4.8.4 Fail-Safe Implementation

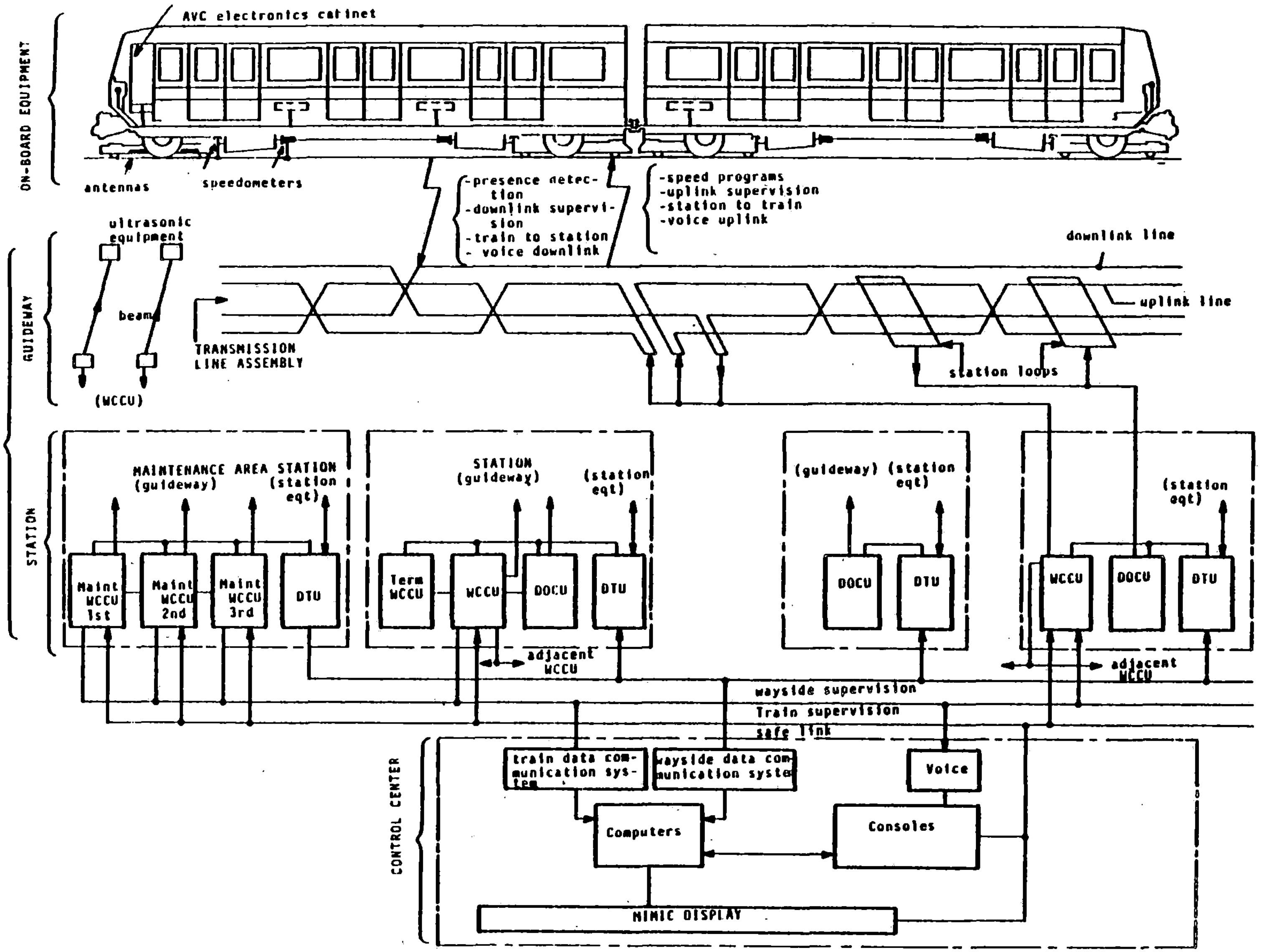
On-board ATP equipment consists of a combination of vital relays, discrete hardware and dual channel redundant microprocessors. As previously described, each microprocessor channel separately determines overspeed by processing complementary data. Detection of overspeed by either microprocessor channel results in the application of emergency braking and the removal of propulsion power via additional discrete hardware and vital relays. Each microprocessor also has its own tachometer for actual speed measurement.

Wayside ATP equipment is implemented with discrete hardware including vital relays.

4.9 VAL System (Lille)

The VAL (Vehicle Automatique Leger or Light Automated Vehicle), in Lille, France, is a fully automated rubber-tired transit system that has been in operation since 1983. Two to four car trains operate at an average speed of 35 km/h with a maximum speed of 80 km/h. The system is designed for 60 second headways during peak hours. There are two traction motors per vehicle which are powered by 750 volts DC via the power (and guide) rails. Braking is accomplished both regeneratively and with pneumatic friction disk brakes.

The ATC system, provided by MATRA Transport, is comprised of ATP, ATO, and ATS subsystems which are located in equipment at three locations: central control center, wayside, and on-board the vehicle. A block diagram of the ATC system equipment is provided in Figure 5. The central control facility provides for the overall monitoring and scheduling of train operations. Wayside equipment, located at stations as well as on and



Source: Literature Reference (28)

Figure 5. Block Diagram of VAL Control System Equipment

along the guideway, performs a variety of control and communications functions, some of which pertain to collision avoidance, overspeed protection and station dwell control. On-board equipment continuously communicates with the wayside and has primary responsibility for preventing/controlling overspeed situations.

The backbone of the ATC system is a transmission line which is laid in the guideway and which permits transmission of data to and from the train. The transmission line actually consists of two separate two-wire transmission lines, each of which have transpositions at fixed intervals. These lines relay speed and other information to the train, and also are used (just one of the lines) in the detection of train location.

The guideway is divided into sections, each of which contains a number (usually five) of smaller blocks. Each section is controlled by a separate wayside control unit. The wayside control unit determines occupancy in these smaller blocks and relays the appropriate speed information to the train. Thus, the VAL system is a fixed block system.

ATP functions including safe speed enforcement are performed by wayside and on-board equipment. After block occupancy is determined by the wayside equipment, it has the option of selecting one of two (i.e., normal or stopping) speed program commands for transmission to the train in one of the two transmission lines. One of the lines corresponds to a normal speed program, and is selected by the wayside if a downstream block is unoccupied. Speed commands in this transmission line are inherent in the distance between the conductor transpositions since the on-board equipment is designed to detect those transpositions at 0.3 second intervals. The carrier frequency signal in this normal speed program is also phase-modulated by two audio signals. One of the modulating audio signals indicates 1) which speed command program (i.e., normal or stopping) is to be followed by the vehicle and 2) whether or not a push-recovery mode is to be used. In this latter mode, speed of the train is limited to 2.88 km/h (0.8 m/sec). The other audio signal indicates train direction. No modulation generally results in the initiation of emergency braking by on-board equipment.

If the next downstream block is determined occupied, the wayside equipment selects the stopping program command in the other transmission line and indicates to the on-board equipment (via modulation of the normal speed program) to respond to the stopping command. As in the other transmission line, conductor transpositions are spaced such that the on-board equipment is to detect the phase reversals at 0.3 second intervals. Thus, transpositions can be place in the transmission line to obtain a specific stopping profile.

On-board ATP equipment receives the signals in the transmission lines and determines which speed program (i.e., normal or stopping) to respond to based on the modulation present in the signals. Propulsion and/or service braking is controlled automatically. The equipment counts the phase reversals in the received signal and compares the time intervals of these reversals against an on-board clock (one for the normal speed program and another for the stopping program). If the time between phase reversals (transpositions) is less than 0.27 seconds, an overspeed condition is assumed, propulsion is removed, and emergency braking is initiated. Under normal conditions without overspeed, on-board equipment generates a brake hold-off command signal which inhibits the emergency brakes. Thus, when emergency braking is deemed necessary, the brake hold-off command is not generated by on-board equipment. Although emergency braking is initiated directly by on-board ATP equipment, it can also be initiated by wayside and/or central equipment via the modulation (or lack thereof) in the transmitted signals to the train.

Separate on-board ATP equipment determines overspeed for the normal and stopping speed programs. In addition, other ATP equipment determines overspeed (greater than 2.88 km/h) when the train is operated in the push-recovery mode. In this mode, actual train speed is based on pulses received from phonic wheels mounted on the train axles.

Doors on the train are interfaced with on-board ATP equipment, and are not opened unless the equipment detects zero speed and proper train position. Zero speed is detected via on-board mounted tachometers. After station dwell is completed, the ATP system permits a train to leave a station only if all doors are closed.

4.9.1 Train Location Detection

As mentioned, the guideway is divided into sections with a number of smaller blocks in each section. The occupancy of a train in any of these blocks and or sections is determined in the wayside ATP logic by a combination of positive and negative detection techniques. Positive detection signals are generated on-board the train and transmitted to the wayside via the transmission line. These signals are also transmitted into small loops at stations and block boundaries for added protection. The presence of a train in a block causes a specific signal to appear in the transmission line and/or loops. Wayside equipment detects these signals and uses them in conjunction with the negative detection signals to determine occupancy.

The negative detection technique is implemented using redundant ultrasonic transmitters and receivers at the ends of guideway sections and at stations. The passage of a train across the path of the ultrasonic transmission results in the loss of a signal from the devices and indication to wayside equipment that the train has entered or left the area.

4.9.2 Train Speed Detection

Except in the push-recovery mode and when determining zero speed (e.g., for door control), train speed is not directly measured by ATP equipment. Rather, the on-board clocks in the ATP equipment are used for providing the timing base in determining the frequency of the phase reversals in the speed programs. As described, phase reversals that occur more often than 0.27 seconds indicates overspeed.

A phonic wheel is used to indicate train speed when the train is operated in the push-recovery mode. The phonic wheel is a rotating disk (tied to the vehicle axle) which has magnets that are sensed by magnetic sensors. Pulses generated by the magnets provide accurate low speed indications.

Tachometers are used by the ATP subsystem to detect zero speed which is utilized in the control of train doors. The tachometers are also utilized by the ATO subsystem to provide actual train speed information.

4.9.3 Safety Related Communications

All ATP related communications between trains and the wayside are handled via the guideway mounted transmission line. This line contains dual two-wire conductors (transmission channels) which are imbedded in a plastic-coated wrapping. One of the lines is used for transmitting the normal speed program from the wayside to the trains and for the transmission of train detection related signals from the trains to the wayside. The other line is used for transmission of the stopping program from the wayside to the vehicle. Frequencies used for the normal and stopping programs are 42 kHz (modulated) and 33 kHz, respectively. Train detection signals from trains to the wayside have a frequency of approximately 69 kHz.

Other non-ATP related communications between trains and the wayside and/or central control facility are also handled by the guideway transmission line.

4.9.4 Fail-Safe Implementation

ATP functions both on-board the train and at the wayside are implemented to be fail-safe with hybrid technology using discrete components. Microprocessors are not utilized in ATP equipment at the Lille Metro.

4.10 Vancouver Skytrain System

The Vancouver Skytrain is a fully automated steel-wheeled transit system that serves the Vancouver (British Columbia, Canada) metropolitan area. Two-to-six-car trains operate over a 21.4 km route at an average speed of 50 km/h, with a maximum operating speed of approximately 80 km/h. Traction is provided by linear induction motors.

Skytrain utilizes an automatic train control system called Seltrac, developed by Standard Elektrik Lorenz (SEL). The system is based on a moving block concept in which a train may operate up to a safe braking distance from the end of a preceding train. An inductive loop cable laid between the rails allows for the continuous transfer of train control data between trains and the wayside.

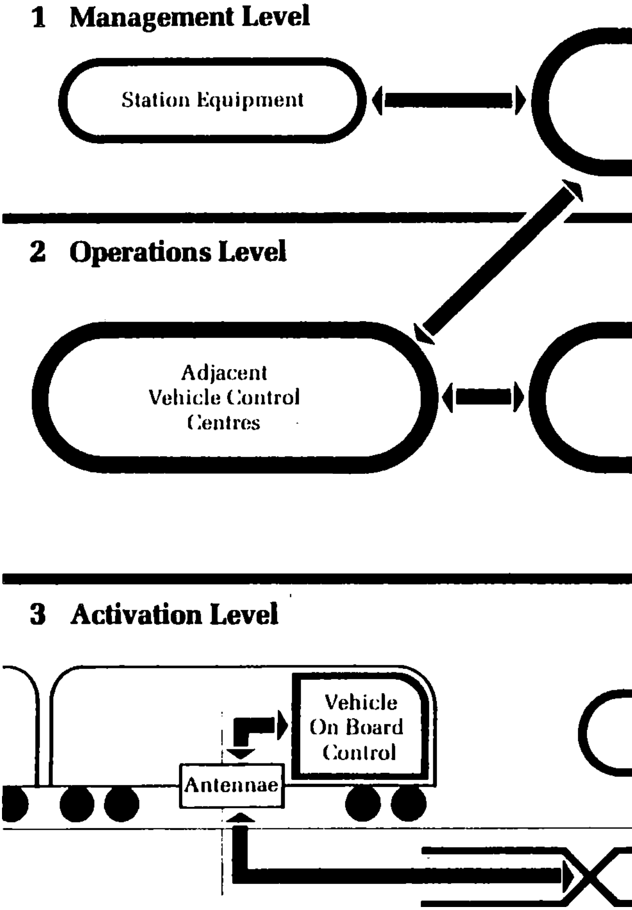
The system is designed to operate in a fully automatic mode without intervention by train operators. However, the system can also operate in a cab signalling mode in which safe operation (e.g., proper train speed) is enforced by on-board equipment. A manual mode is also possible in which the train operator can drive the train at a reduced speed.

Seltrac utilizes a three level hierarchical structure consisting of a System Management Center (SMC), Vehicle Control Center (VCC), and Vehicle On-Board Control (VOBC); this structure is shown in Figure 6. The SMC acts as the central control facility and is responsible for train supervision functions including dispatching, routing, and monitoring. The VCC is a wayside system that is primarily responsible for safe train separation. Each VCC is responsible for a section of track and interfaces with the SMC, the VOBCs on the trains in a specific section of track, and adjacent VCCs. The VOBC on each train is responsible for safe train operation within the limits imposed by the VCC. ATP functions including safe speed enforcement are handled by the VCC and VOBC elements.

VCCs on the wayside receive train position, speed, and travel direction information from each train in their given territory via the inductive loops in the rails. Based on this data and other data pertaining to route integrity, (e.g., information from interlocking equipment and switch machines), the VCC generates an output telegram that is transmitted to the train via the inductive loops. This cycle occurs approximately once each second. Safety critical information generated at the VCC and transmitted in the output telegram to the train includes the following: 1) the safe stopping point, 2) maximum permitted speed and target speed (at the end of the allowed travel distance), and 3) braking characteristics based on the track gradient profile. Safe stopping distances are determined by the VCC based on the most restrictive of the following conditions:

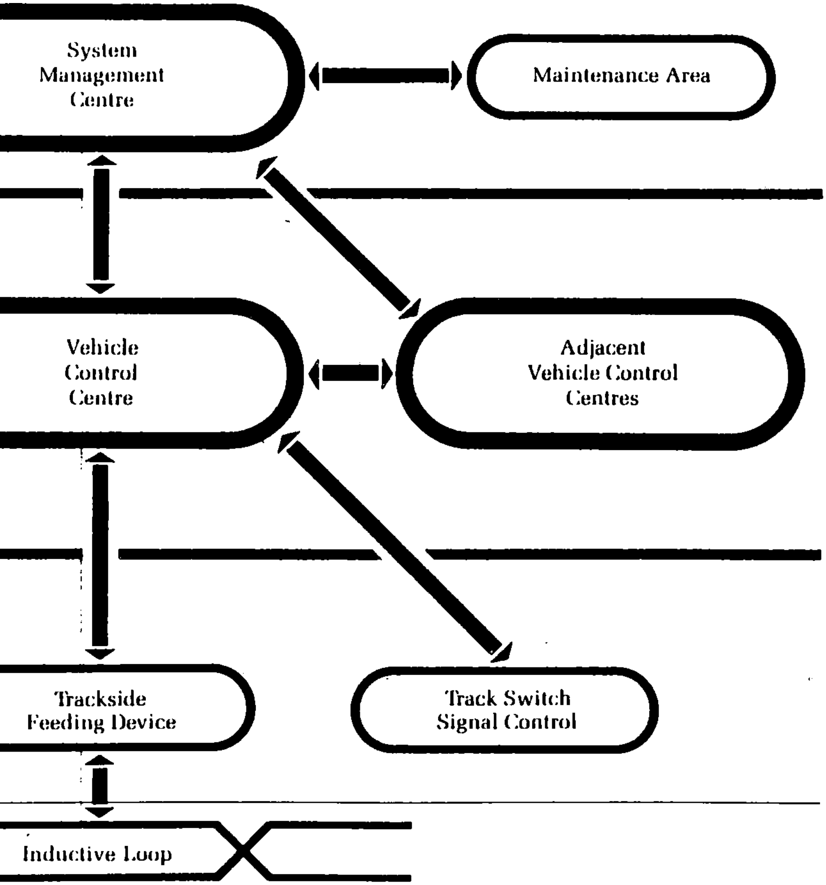
- The last verified position of a preceding train
- An unlocked or unreserved switch point
- A speed restriction (based on civil speed limits, gradient, etc.), or
- A station stop.

Speed limit commands to the trains are based on the most restrictive of the following conditions: 1) speed limit for a section of track, 2) temporary (slow) speed order, or



Source: Literature Reference (24)

Figure 6.



Structure of Seltrac ATC

3) speed restriction requested for scheduling adjustment purposes. The VCC also provides control signals to switch machines and interlockings.

Each train is equipped with two VOBCs, one for each end of the train consist. The VOBC in control receives the telegram from the wayside VCC via the inductive loops and on-board antenna. Functions performed by the VOBC include interpretation of the telegram commands, control of the train within velocity and distance limits imposed by the VCC and the transmission of train position, speed, travel direction, and subsystem status information back to the VCC. VOBC equipment calculates the required braking curve and controls propulsion and braking accordingly. Train speed is monitored via axle mounted tachometers and compared with the commanded speed from the VCC and the calculated braking curve. Should overspeed occur or a different unsafe situation be detected on-board, the VOBC inhibits generation of the brake hold-off signal, resulting in application of the emergency brakes. If the controlling VOBC fails, control is switched automatically to the other VOBC in the other end of the train, or the train can be operated manually at a reduced speed. Safe speeds are enforced during automatic and cab signalling operation. As mentioned, normal operation on the Skytrain is the fully automatic mode.

4.10.1 Train Location Detection

Train location is determined in part by the VOBC element via signals injected into the inductive loops by the VCC. The inductive loops are laid along the full length of the rails and have transpositions at fixed intervals (25 m). Signals injected in the loops by the VCC have a carrier frequency of 36 kHz. VOBC equipment receives the signals from the loops via special antenna and counts the phase shifts (due to transpositions) in order to determine "raw" train location. Axle mounted tachometers provide signals to the VOBC that are used to get fine position measurements for each train. This fine train location data is transmitted to the controlling VCC (via the inductive loops) at a carrier frequency of 56 kHz.

4.10.2 Train Speed Detection

Actual train speed is determined in the VOBC element by monitoring signals from redundant axle mounted digital tachometers. These are the same tachometers which are used for fine position measurement.

4.10.3 Safety Related Communications

Safety related information is passed between the wayside VCC units and trains via the inductive loop cable. This includes speed related commands from the VCC to the train as well as train speed, position, travel direction, and equipment status information from the train to the VCC.

Several techniques are used to ensure the integrity of data communications between trains and the wayside. Redundancy bits are generated in the VCC and inserted in the telegram that is sent to the train. VOBC equipment on the train tests the incoming telegrams from the VCC for errors via redundancy, persistency, and plausibility checks. The VOBC requires that in order for the safety critical information to be deemed acceptable, it must be received more than once. Each VOBC (and thus train) has its own unique address. Messages will not be processed unless the VOBC recognizes its assigned address.

VCC equipment also performs plausibility and persistence checks on data received from the VOBC. Data is checked against expected values based on previously received telegrams.

In the case of lost communications from the train, the VCC assumes the worst case situation and transfers the information as appropriate to adjacent VCCs. If communications are lost from the VCC, the train is braked and the operator can manually operate the train at reduced speed.

4.10.4 Fail-Safe Implementation

As previously indicated, ATP functions regarding safe speed enforcement are performed in the wayside VCC and on-board VOBC elements. Each of these incorporate computers to perform the necessary safety critical functions associated with generation and enforcement of safe speed commands.

The VCC incorporates three computers, but only two are performing processing functions at any one time; the third is on hot-standby for availability reasons. The two on-line processors receive common input data from the train and other sources (e.g., other VCCs, switches, interlocking equipment) and verify the validity of the input data. Each computer generates an output command which is compared bit-by-bit with the output command from the other computer. The external comparator units are functionally checked by circulating certain bits in a portion of the telegram. If an error is detected in one of the computers, it is switched out and operation continues with the two remaining computers.

The VOBC incorporates two microprocessors in a checked redundant configuration. Each microprocessor receives the same telegrams from the VCC, and generates identical commands for on-board equipment and for transmission to the wayside VCC. This includes the calculation of train position, speed, travel direction, and the braking curve. Should disagreement occur in the microprocessor outputs, the emergency brake hold-off signal will be inhibited, resulting in emergency braking. As mentioned, failure of a VOBC causes switchover to the other VOBC. In the case of failure of both VOBCs, the train can be operated manually.

4.11 MARTA System

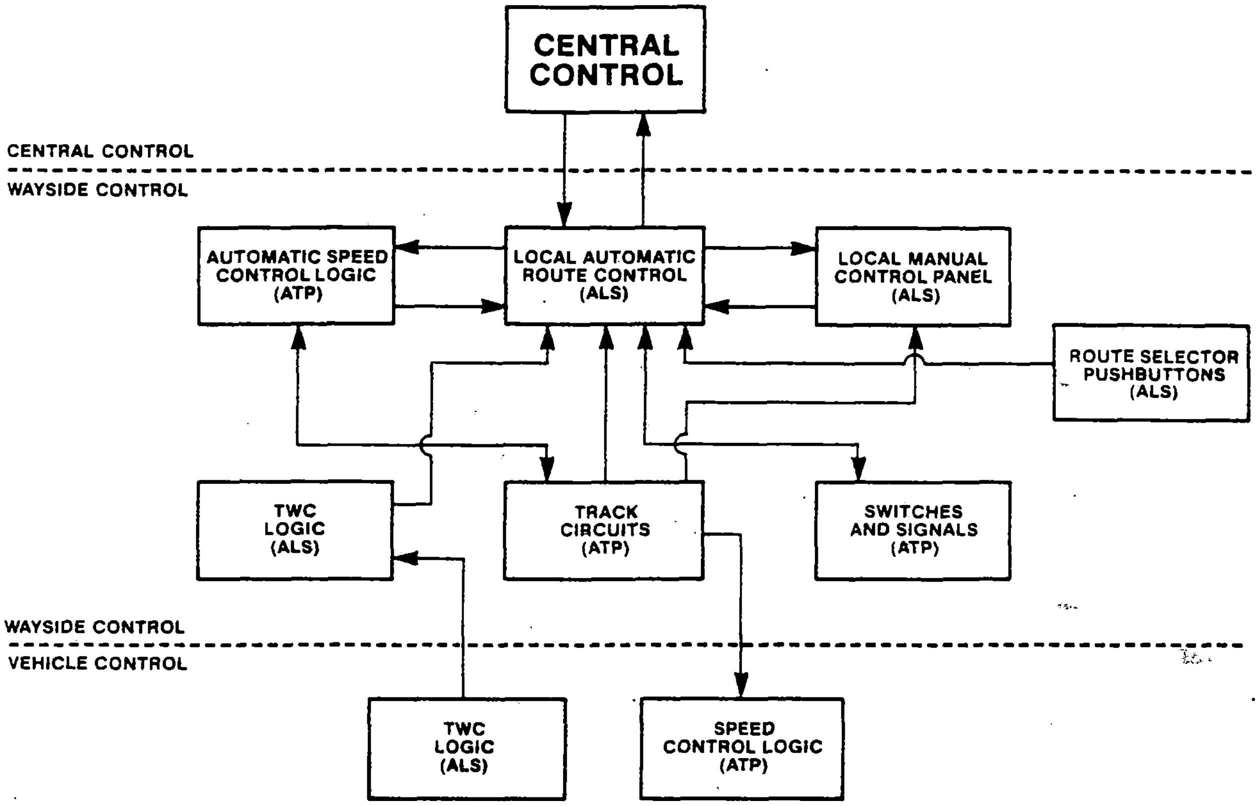
The train control system described here, developed by General Railway Signal (GRS), represents that utilized on the transit system operated by the Metropolitan Atlanta Rapid Transit Authority (MARTA). However, this same concept is also utilized on numerous other transit systems including the Washington Metro (WMATA) and the Shanghai Metro. The latter system represents one of GRS's most recent applications of ATO, ATP, and ATS equipment.

The GRS ATC system at MARTA is comprised of three major integrated subsystems (i.e., ATP, ATO, ATS), the operations of which are coordinated through a Central Control Facility (a part of ATS). The ATO subsystem regulates train speeds and provides for automatic station stopping. The ATS subsystem controls the arrival and departure of trains at/from stations and generally provides for the supervision of train operations. The ATP subsystem maintains safe stopping distance, ensures safe door operation, ensures conformance with speed restrictions and ensures nonconflicting routes. A general system block diagram of the ATC equipment is provided in Figure 7.

Trains, which typically are run at speeds between 55 and 119 km/h (35 and 75 mph), are normally operated in a fully automatic mode in which the operator initiates operation via a pushbutton on the console. The train can also be operated in a cab signalling mode in which maximum permissible speed commands are displayed to the operator in the train cab.

ATP functions including those pertaining to safe speed enforcement are performed in both wayside and on-board equipment. Wayside ATP equipment is comprised of audio frequency track circuits which detect the presence of trains in blocks (track sections) and send speed commands to the trains via the rails. When a train is detected in a track circuit or block, a speed command signal is fed into the rails intended for that track circuit only. The speed command is generated in the track circuit equipment by modulating a carrier frequency with a low frequency signal. This modulating signal turns the carrier signal on and off at a specific code rate that corresponds to the maximum safe speed to be transmitted. This code rate is dependent upon the presence of trains in downstream track circuits, switch positions, and civil speed restrictions for the particular block of track. Interlocking equipment, information from other track circuits, and dedicated vital relays establish the proper code rate for a given track circuit. The coded speed command signal is applied to the rails via coupling components (e.g., WEE-Z impedance bonds or loops) and is sensed by dual receiver coils mounted ahead of the first axle of the train.

In the Shanghai Metro, the speed command code rate is provided by GRS's Vital Processor Interlocking (VPI) microprocessor based interlocking system. If there are no clear



Source: Literature Reference (16)

Figure 7. MARTA ATC Block Diagram

blocks ahead, no ATP speed command is transmitted. This is interpreted (by on-board equipment) as a stop command.

On-board ATP equipment at MARTA which processes the speed commands and ensures safe operation is referred to as the GRS Cabmatic (or Microcabmatic in the case of the Shanghai Metro) cab signal and automatic train control system. This system filters, amplifies, and decodes the coded speed command signal from the receiver coils in order to determine the safe command speed for the train. In the case of fully automatic operation, the detected code is used to control the speed of the train automatically by adjusting the propulsion drive. In the case of manual operation (e.g., cab signal mode), resulting command speed is displayed to the operator and is used to apply brakes if the train operator fails to maintain safe speed. At least six different speed codes are used at MARTA (and up to eight at Shanghai). On-board ATP logic circuits assure that only one speed code command is being received at any one time. The absence of any valid speed command is interpreted as a stop command.

The Cabmatic ATP system measures actual train speed via an on-board speed sensor and compares actual speed with the commanded speed in order to detect overspeed conditions. This comparison is done in an electronic frequency responsive governor (FRG) circuit. Two vital outputs are generated from this circuit. One output energizes a motion detection relay (MD) when actual speed is greater than 4.75 km/h (3 mph). Another output energizes the Under Speed Relay (USR) when actual speed is less than the commanded speed. When the USR relay is de-energized (i.e., overspeed condition exists), propulsion is disabled and the train is put into a full service brake mode. If overspeed occurs in the manual mode, an alarm is sounded, an overspeed light flashes, and the operator must initiate braking within a specified time period. If the operator fails to respond in the specified time, full service braking is automatically initiated.

Logic circuits in Cabmatic also control the emergency braking mode via an emergency brake relay (EBR). Whenever the relay is de-energized, the train is forced into emergency braking. The logic circuits energize the relay only when certain conditions such as overspeed is not detected and when more than one speed code is not being received.

There is also a brake assurance function performed on certain cars which don't have a fail-safe service brake. This function is partially implemented by a gravity driven pendulum which swings forward when brakes are actually applied. Sensors detect the motion of this pendulum when braking is requested/required. Insufficient forward motion of this pendulum results in application of emergency braking via on-board ATP equipment.

Although doors are operated manually at MARTA, emergency brakes are initiated by on-board ATP equipment if the train doors are open and train movement is sensed.

4.11.1 Train Location Detection

Trains are detected by the wayside audio-frequency track circuits. Generally, there is one track circuit per block (or section of track), but two or more track circuits are used for longer blocks. Each track circuit incorporates a train detection transmitter and receiver. The transmitter at the leaving end of the track circuit feeds an audio-frequency signal to the track via a GRS WEE-Z impedance bond (coupling transformer). Another impedance bond at the entering end of the track circuit receives the signal and energizes a corresponding vital relay if the transmitted signal is not shunted by a train in the block. If a train is present, the signal is shunted and the relay de-energizes, indicating the presence of a train.

The transmitted signal consists of an audio frequency carrier which is modulated (turned on and off) at a specific code rate typically between 1 and 30 Hz. In order to energize the relay, the received signal must be of the correct carrier frequency, must have sufficient amplitude and must be properly modulated by the correct code rate for at least three cycles of the code. Adjacent track circuits use different carrier frequencies to avoid interaction between track circuits.

As mentioned earlier, the coded train detection signal coupled to the rails is separate from the coded speed command signal which is transmitted only if a train is detected in the block.

4.11.2 Train Speed Detection

Train speed is determined on-board via a single reluctance type speed sensor which senses gear motion in the gearbox. The signal from this sensor is fed to the electronic frequency responsive governor, which calculates the actual train speed. In the Shanghai system, two speed probes are used.

4.11.3 Safety Related Communications

Safety related communications pertaining to the safe speed enforcement area involve transmission of the safe speed commands from the wayside audio-frequency track circuit equipment to the on-board speed control equipment via impedance bonds, the rails, and on-board mounted antenna. As previously described, these speed commands are audio-frequency carrier signals which are modulated at a low frequency code rate. Each speed command has associated with it a unique code rate.

Non-safety critical information is transmitted between trains and the wayside via a Cabmatic Train-to-Wayside Communications (TWC) system. This system monitors and transmits on-board data for the purpose of dispatching, dwell control, routing, and general monitoring by the central control facility. The frequency-shift-keyed (FSK) signal is transmitted to the rails via a separate on-board antenna.

4.11.4 Fail-Safe Implementation

ATP equipment at MARTA including wayside audio-frequency track circuit equipment and the on-board Cabmatic system is implemented in a fail-safe manner using solid state discrete components and vital relays.

Wayside track circuit equipment at the Shanghai Metro also uses discrete components and vital relays, but the code rates which determine the speed commands originate from the vital microprocessor based interlocking system referred to as VPI (Vital Processor

Interlocking). On-board speed control equipment at Shanghai is structured around a microprocessor based version of the Cabmatic system referred to as Microcabmatic.

The on-board Microcabmatic and wayside VPI systems at Shangai utilize single microprocessors and are based on GRS's Numerically Integrated Safety Assurance Logic (NISAL) concept to ensure safe operation. In this concept, internal diagnostics are used to generate a checkword which indicates safe operation of the computer system. This checkword, which is generated approximately once every 100 milliseconds, verifies the following:

- Inputs to the system microprocessor are correct
- Program is executed correctly
- Program has not changed
- Data tables have not changed
- Inputs and variable data are current
- Outputs are correct
- Outputs have not been changed by device failure.

An incorrect checkword results in the removal of power from the vital output circuits. As a result, less restrictive or zero speed commands are issued if the bad checkword is formed in VPI equipment. If the bad checkword is in the on-board Microcabmatic equipment, power is removed and braking is initiated.

4.12 ATCS

The Advanced Train Control System (ATCS) is a radio-based system which was developed as a joint venture of the Association of American Railroads (AAR) and the Railway Association of Canada. In ATCS, trains determine their own location via wayside transponders and odometers, and send this information via data-radio to a central dispatch which, in turn, issues movement authorities back to the trains via the radio link. The system has not been implemented in full by any railway, but various aspects of the system (e.g., data links, train detection) have been undergoing testing for some time. A set of ATCS specifications have been developed which define the overall system architecture, the components in the various subsystems, and guidelines for testing hardware and software. The specifications essentially define performance requirements without specifying each component's specific architecture. A large number of suppliers either currently provide and/or are developing equipment/components for the various ATCS subsystems.

Burlington Northern Railroad has been working with Rockwell in the development of an Advanced Railroad Electronic System (ARES) based on the use of satellites for obtaining train location information. While there appears to be some similarities between the ARES and ATCS systems, ARES is generally not compliant with the ATCS specifications. Therefore, the description here is primarily directed to ATCS.

To permit a gradual implementation and modular expansion of ATCS, several levels of complexity/enhancements have been defined by the specifications. Those are as follows:

- Level 10. Computer-aided dispatching system utilizing centralized route and block interlocking logic. This is the simplest system.

- Level 20. Automated movement authority sent from central to trains via a data communications link and displayed on-board. Includes manual reporting of train location by operators.

- Level 30. Automatic location reporting system will full train tracking, automated movement authorities from central to train, and enforcement of speed limits and location authority.

- Level 40. Integration of ATCS within centralized train control (CTC) system.

The description below is based on the Level 30 ATCS.

ATCS is comprised of the following five major subsystems:

- Central Dispatch. This subsystem, based on computerized equipment, is the center for the overall control, monitoring, and operation of the ATCS. It provides automatic train tracking, status monitoring, monitoring and control of wayside devices, issuance of movement authorities and control of track occupancy, and control planning functions.

- Locomotive System. This subsystem, also based on computerized equipment, determines and reports train location, displays speed and movement authorities to the operator, enforces safe operation within speed limits via a brake system interface and monitors locomotive equipment health.

- Wayside Interface Unit (WIU). The WIU provides the means for the monitoring and control of switches, interlockings, highway crossing warning systems, track integrity devices, and other wayside equipment.

- Track Forces Terminal (TFT). The TFT provides the means for maintenance-of-way crews to obtain train arrival forecasts, receive occupancy permits and apply temporary slow orders to trains.

- Communications Network. This subsystem provides the means for the transfer of information of both a vital and non-vital nature among all system elements. Radio transmission is used between trains, central dispatch and wayside base stations, WIUs, and TFTs. Microwave or fiber-optics are used between wayside base stations and the central dispatch.

A general block diagram of the major ATCS subsystems and their relationship is shown in Figure 8. ATO, ATP, and ATS functions are integrated throughout the ATCS.

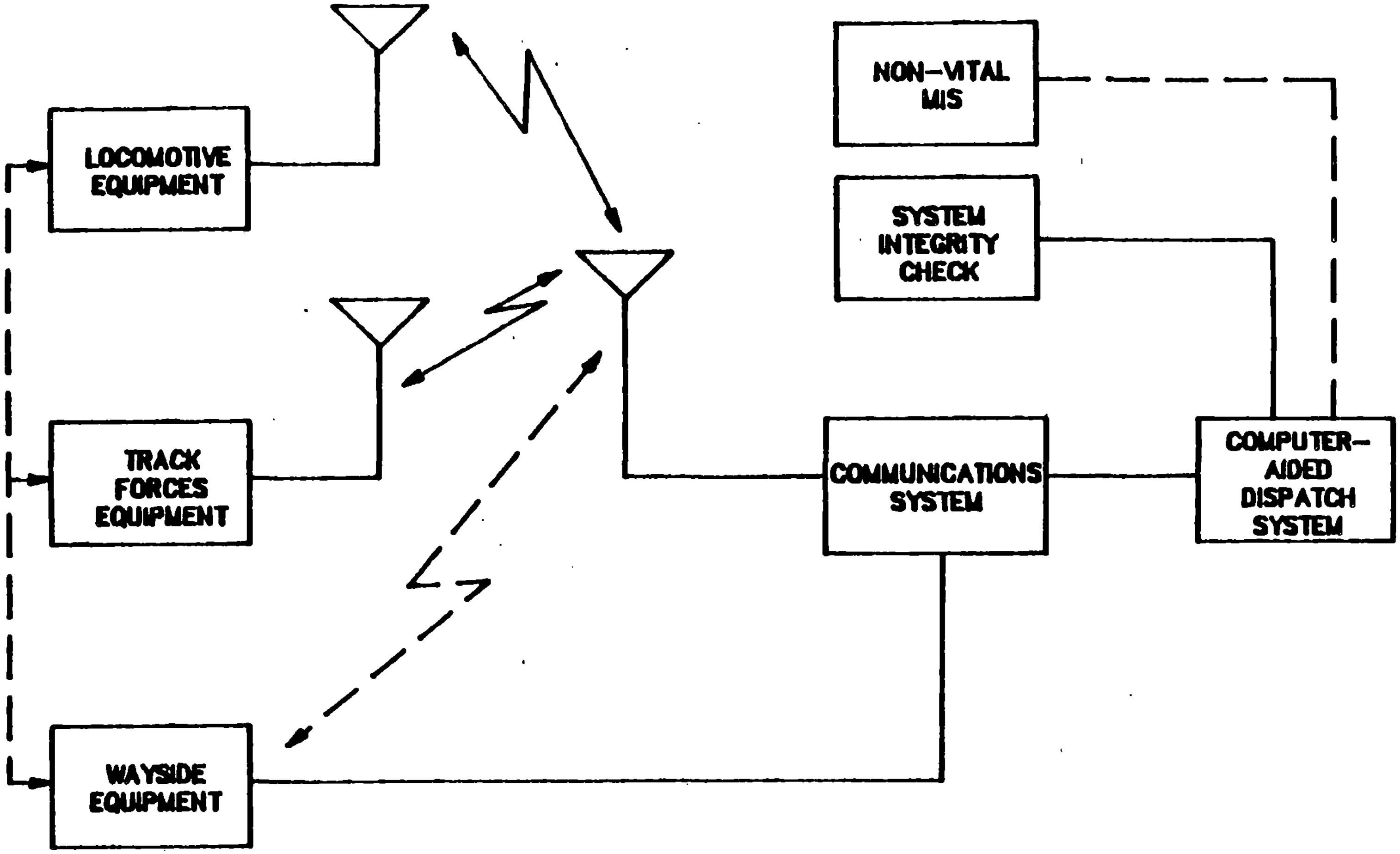


Figure 8. Block Diagram of ATCS Subsystems

As a train is initialized before it leaves a station, the central dispatch computer downloads a data base to the train via the radio link. Included in the data base is vital information on the allowed track speed for all portions of the track over which the train may travel, an initial movement authority for a section of track, and any temporary slow orders which are in effect. Thus, central dispatch has knowledge of any speed restrictions on the track as well as route integrity information (e.g., location of other trains, switch positions). Switch position information is obtained from the WIUs via fiber optics or microwave. Central dispatch aligns switches as necessary for the assigned route.

The computer on the locomotive receives the data from the central dispatch and, based on an existing data base with information on train characteristics (e.g., length, weight), calculates the appropriate speed and braking distance to comply with the received movement authority. Speed limits for projected distances ahead are displayed to the train operator for his use in driving the train. Thus, speed commands to trains are actually inherent in the movement authorities and the data base downloaded to trains when they are initialized.

As the train proceeds over its assigned route, it interrogates fixed track-bed transponders to get precise train location information. This data is supplemented by on-board odometers. The on-board computer calculates train location and transmits a train location report to the base stations via the radio link and on to the central dispatch computer. In addition to train location, the report includes information on train speed, where the head of the train is, and where the end of the train is located. Trains must report location at set intervals, otherwise a timer will expire and central dispatch will not issue a further movement authority. As a train proceeds, the central dispatch can issue temporary slow orders over the data link as the need arises.

Based on the location reports received from the train, the location of other trains and route integrity information (e.g., switch positions), central dispatch issues further movement authorities as necessary. Central has the responsibility of ensuring that the proper movement authorities are sent to the proper trains.

On-board computer equipment receives actual train speed information from axle generators and compares actual train speed with the speed limits in its data base. Should the on-board computer determine that overspeed exists, the operator is warned to decrease speed.

If the operator does not decrease speed accordingly, the throttle is reduced back and a penalty full service brake application results.

Under normal conditions when a train approaches a field device (e.g., switch), it interrogates the switch to verify that the switch is in the proper position. Switches are normally set by central dispatch. Under certain circumstances the operator can request permission from central to activate a switch from the train. Such activation is verified by central before any switches are remotely set by the train operator.

4.12.1 Train Location Detection

Train location is detected on-board the train via interrogators, odometers, and passive track-bed transponders. As a train passes over a transponder, the interrogator transmits an AC signal (of approximately 200 kHz) to the transponder. The transponder converts the signal into DC power and transmits its identification information back to the interrogator at a frequency of near 27 MHz. Each transponder is programmed with a serial number which is identified by an on-board data base. Transponders are located at varying distances but are more numerous at interlockings and switches. In general, transponders are located so that the reading of the train's position is never off by more than one percent of the distance from the last transponder, with the 1 percent never to exceed 150 meters. Position information from a transponder location itself is within ± 1.5 m of actual position.

The transponder data is supplemented by data from dual axle generators. These generators produce pulses based on wheel rotation. Software corrects for wheel-slip and determines actual train location based on the axle generators and transponders. As mentioned, this train location is transmitted at regular intervals to the central dispatch via the radio link.

Track circuits are generally not used. However, "island" track circuits are planned for switch and interlocking areas.

4.12.2 Train Speed Detection

As previously indicated, actual train speed is determined by the on-board computer and dual axle generators.

4.12.3 Safety Related Communications

The backbone of ATCS is the data-radio communications network which permits the transfer of information between a train and wayside interface units (WIUs), track force terminals (TFTs), and the central dispatch (via wayside base stations). This radio system utilizes a 900 MHz UHF frequency to transfer up to 4,800 bits of information per second.

The data communications network consists of a front end processor (FEP), cluster controller (CC), base communication package (BCP), mobile communication package (MCP) for trains and track force terminals, and a wayside communication package (WCP). The front end processor is the control computer for the data network. It provides the interface between the CCs and central dispatch and determines which CC should receive a given message. The cluster controller (CC) provides the interface between the FEP and the radio base stations. It determines which base station is used for communications with a given locomotive or WIU. Communications between the CC and base stations are handled by fiber optics, a microwave link, or other medium. BCPs, located about 39,600 m (25 miles) apart, communicate via radio with trains, WIUs, and TFTs.

A mobile communications package (MCP) is used on each train and each track forces terminal (TFT). These packages permit radio communications with the base communication packages (BCPs). A wayside communication package (WCP), located at strategic wayside locations, is used to communicate via radio with the BCPs and, in some instances, with the train itself. The WCP interfaces with the WIU which controls track switches and interlockings.

The communications protocol in ATCS is based on the international standard seven-layer open system interconnect (OSI) concept. This system allows the prioritizing of messages so that most important messages are transmitted first. Extensive use is made of cyclic redundant codes (CRCs) in the encoding/decoding process in order to achieve a very low probability of undetected errors in transmitted messages. "Protocol stacks" on each end of the transmission perform the encoding/decoding process.

4.12.4 Fail-Safe Implementation

ATCS specifications do not require a specific implementation for safety or non-safety related equipment. However, the specifications require that all safety critical systems (including computer based equipment) be demonstrated to have an acceptably small probability of failing to an unsafe mode. And, based on the system concept, safety critical computer systems are required at least at central dispatch and on the trains as well as possibly in TFTs, WIUs, and communications equipment.

5.0 TASK 3—APPLICABILITY OF AVAILABLE CONTROLS

This section presents the basic results of Task 3 in which the system concepts described in Task 2 were assessed relative to their applicability to the maglev safe speed enforcement requirements and functions identified in Task 1. Results of this assessment are provided in two parts. First, tables are presented which describe the results of the detailed assessment of each system concept against the requirements and functions of Task 1. Second, individual summary assessments are provided in text for each system concept.

5.1 Detailed Assessments

As mentioned above, a detailed assessment was performed on each system concept described in Task 2 (except for the Italian ETR-500 system, which is in the very early stages of development and for which very little information exists). Also, the TGV Nord concept was assessed rather than the TGV Atlantique since the Nord concept is newer and offers an improvement in headway over the Atlantique concept. A tabular format was chosen to document the results of the individual assessments. These tables are provided in Appendix B (Tables B-1 through B-11).

There are three columns of information in the tables. The first column consists of a list of the basic functional requirements of a maglev safe speed enforcement system. These requirements were extracted from the Task 1 results, and are organized in a similar manner to the Task 1 information presented earlier in this report. For example, the requirements are separated into two major categories--those pertaining to the generation of safe speed commands (e.g., civil speed restrictions) and those pertaining to the enforcement of safe speed limits (e.g., detection of overspeed conditions) as defined by those commands or otherwise imposed upon trains. These requirements are considered safety critical except where noted. The second column contains entries which address the manner in which the system being assessed performs each of the functions identified in the first column. For example, in response to the civil speed restriction requirement, the entry in the second column describes how the specific system concept or aspect thereof meets that requirement.

Although not directly stated in the tables, it should be noted that each specific system assessed is designed to perform a particular function (except where noted) in a fail-safe manner. However, the actual fail-safe nature of the implementation has not been confirmed in this study. The third column contains entries which describe the applicability of the specific system concept or aspect thereof in meeting the needs of a maglev safe speed enforcement system. Reasons are given in cases where the system concept/aspect is not considered applicable. Information in these tables was then utilized to prepare the individual summary assessments which follow.

Consideration was given in the tables to the applicability of the specific system concept/aspect to short and long stator type systems. In many instances a specific system aspect was found to be best suited to either a long or short stator system. While this indicates that the specific aspect is best for a particular type of system (short or long stator), it does not always mean that the aspect cannot be utilized in the other type of system. Rather, it indicates that, in order to utilize the aspect in the other type of system, considerable modifications would be required. It should be emphasized that, even though an aspect is judged to be directly applicable, modifications in hardware and/or software may still be required to incorporate it into a maglev system, particularly if the system being assessed is not maglev. And, of the 11 system concepts assessed, only three are existing/developmental maglev systems. The others are steel-wheeled or rubber-tired systems.

It must be stressed that this program is in the nature of an overview of the suitability and availability of existing safe speed concepts and those areas in which additional research/development may be needed relative to safe speed enforcement. It was not the intent to determine precise modifications which would be necessary to utilize existing system concepts or aspects thereof. A more definitive description of the expected U.S. maglev system and its operating characteristics/philosophy would be needed to accomplish that.

5.2 Individual Summary Assessments

Based on the detailed assessments in Tables B-1 through B-11, an individual summary was prepared for each of the 11 system concepts. Each summary provides the following: 1) a brief overview of the system concept, 2) a summary of the applicability of the concept to maglev, including unsuitable and key suitable aspects for both short and long stator systems, and 3) the identification of areas or functions which could not be fully assessed without further information relative to the system concept under consideration.

5.2.1 Transrapid (TR-07) System

In the Transrapid maglev system, safe speed commands are generated in wayside (decentralized) computer elements and used to directly control propulsion and dynamic braking in specific sections of the guideway (and thus, any vehicles in those sections). Train location and actual train speed are determined on-board, and the data are sent to the appropriate wayside elements via a radio link. The wayside elements check for overspeed by comparing actual train speed with the commanded speed. Should overspeed occur, propulsion and braking are controlled via the long stator elements and also via the on-board eddy current and/or landing skid braking systems. The latter is based on radio transmission of braking control signals from the wayside elements to the train itself.

The Transrapid safe speed enforcement concept (assessed in Table B-1) is generally suitable for direct application to a U.S. maglev system that employs long stator propulsion technology. This is not only because the concept generally meets all requirements described in Table B-1, but also because the Transrapid system is, itself, a maglev system that utilizes long stator propulsion. The train location, speed measurement, and communication systems are designed (and have been tested to some extent) for high speed applications in the range of 400 to 500 km/h.

The overall concept is not directly applicable to short stator systems. One primary reason involves the determination of actual train location and speed. Train location and speed are determined, in part, by counting the grooves in the long stator field in the guideway. This method would not work in a short stator system in which the active propulsion elements are located on-board rather than in the guideway. Some other method would be needed to determine precise train location and speed information. Another and more important reason involves the basic nature of the Transrapid and other long stator systems in which safe speeds and headways are ensured, in part, by controlling power for sections of guideways rather than just controlling on-board train propulsion and braking systems. These control methods require different logic, algorithms and implementations, and are also dependent upon the operating philosophy and headway requirements of the maglev system.

Although the Transrapid concept is not directly applicable to short stator systems, it does possess some key characteristics which could be utilized in short stator environments. One involves the existence of vital computer processing capability both in the wayside and on-board elements. These elements could be used to perform the general speed command generation and overspeed protection functions that would be needed in short stator systems. Another key aspect is the radio communications system which could be used to transfer information and control signals between trains and the wayside.

Overall, it is expected that substantial modifications would be required in both wayside and on-board elements to utilize this safe speed enforcement concept in short stator applications.

There are several areas which could not be fully assessed without further information. The three areas identified are: 1) determination of precise train/vehicle location in the station area, 2) the degree to which the system considers human factor limitations in assigning speed commands (under manual train operation), and 3) the detection (and resulting responsive actions) of specific failures/conditions which affect modification of the speed commands and those which do not affect the commands but could otherwise be unsafe. Further work is needed in these areas to ensure applicability of the concept.

5.2.2 Japanese HSST-05 System

In the Japanese HSST-05 maglev system, safe speed commands are generated by the central facility and transmitted to the trains at specified points on the guideway via wayside and on-board loop antenna. On-board computer equipment compares these commands with actual train speed and, should overspeed occur, controls the short stator propulsion motor and the mechanical braking system and/or skids accordingly. Train location and speed are determined on-board via signal transpositions in an inductive transmission belt, and are sent to the central facility (in the same transmission belt) for use in generating the proper speed commands.

This safe speed concept (assessed in Table B-2) is generally suitable for direct application in a U.S. maglev system that employs short stator technology. This is not only because the concept generally meets all requirements in Table B-2, but also because the HSST-05 system is, itself, a maglev system that is based on short stator propulsion. There are, however, two areas of concern which involve the determination of actual train location and speed via the signals and associated transpositions in the inductive transmission belt. While the general concept appears feasible and operation has been proven at relatively low speeds (up to approximately 45 km/h), operation has not been demonstrated at higher speeds such as those to be expected in a U. S. maglev system.

Although the safe speed concept is not entirely applicable to a long stator system "as is", the concept does employ certain aspects which could be utilized and/or modified for a long stator environment. First, the method of determining train location and speed on-board by counting signal phase changes (due to cable transpositions) appears feasible, as long as it accommodates the higher speeds. Also, the on-board communications capability and guideway transmission belt could be utilized for transferring vital information between trains and a central facility. Second, the existence of vital computer processing both on-board the train and at central could allow for the generation of proper control signals at those locations. For example, the central computer could generate appropriate propulsion/braking control signals for the long stator coils in the various guideway sections. The HSST system design utilizes a form of this basic concept since it already generates intermittent speed commands for sections of the guideway and transfers those commands to the train via the loop cables. Vital on-board computer equipment could be used to control on-board braking systems in response to commands from central, and to process and transfer failure/abnormal condition information back to central for restriction of speed commands and/or direct control of wayside propulsion/braking.

While various aspects of this overall safe speed concept as described above may be applicable to a long stator maglev system, considerable modifications in both logic and implementation appear necessary.

Several areas were identified which could not be fully assessed without further information. Those areas are: 1) determination of precise train/vehicle location in station areas, 2) the degree to which the system considers human factor limitations in assigning speed commands (under manual train operation), 3) the detection (and resulting actions) of specific failures/conditions which affect modification of the speed commands and those which do not affect the commands but could otherwise be unsafe, and 4) the generation of overriding brake/propulsion control signals by central. Further work is needed in these areas to ensure applicability of the concept.

5.2.3 Linear Express Maglev System

Although the train control aspects of the Linear Express electrodynamic maglev system (based on superconducting magnet technology) are not fully defined in available documentation, the general safe speed concept to be employed is generally known. In this concept, wayside equipment generates safe speed commands for control of propulsion and braking via the long stator coils in specific sections of the guideway. Actual train location and speed, determined via on-board computer equipment and the signal transpositions from guideway-mounted inductive cables, are sent to the wayside computer via an on-board antenna and leaky coaxial cable. Wayside equipment compares actual train speed with the commanded speed and, should overspeed occur, issues appropriate commands to the long stator coils as well as to the train for control of the on-board electric and aerodynamic brakes. The latter is accomplished via the inductive cable in the guideway.

This safe speed concept (assessed in Table B-3) is generally suitable for direct application in a U.S. maglev system that employs long stator technology. This is not only because the concept generally meets the requirements in Table B-3, but also because the Linear Express system is, itself, a maglev system that is based on long stator technology. As in the HSST system, the two major areas of concern involve determination of the train location and train speed. While the general concept employed (counting of signal transpositions by on-board equipment) appears feasible and the system has been tested at speeds of up to almost 400 km/h, successful operation at these and higher speeds is not clear in available documentation.

The overall concept is not directly applicable "as is" to a short stator system. This is primarily because the concept is specifically designed for long stator applications in which safe speeds and headways are ensured in part by controlling power for certain sections of guideways rather than controlling on-board propulsion and braking systems of individual trains/vehicles. As mentioned for the Transrapid system, control methods for long and short stator systems require different logic,algorithms and implementations. Also, such methods are dependent upon the operating philosophy including headway requirements/needs of a given maglev system.

The Linear Express system does possess some key characteristics which could allow it to be modified for use in a short stator environment. First, given that the train location and actual speed concepts (based on signal transpositions from an inductive cable) work properly in high speed environments, they could be utilized directly in a short stator system. Further, the existing communications concept of transferring vital information from trains to the wayside via leaky coaxial cables and vital information from wayside to trains via the inductive cable is also applicable. Using these mechanisms, speed commands including braking control signals could be sent to the appropriate trains. Also, failure information of on-board equipment could be sent to the wayside for modification of speed commands. Another key feature is the vital computer processing capability in the wayside equipment. Although the present concept in the Linear Express is to send speed commands to the long stator guideway sections, the vital computer on the wayside could permit the generation of appropriate propulsion/braking signals for individual trains. While on-board ATP equipment for the control of on-board braking systems does exist in the Linear Express, the general processing/computing capability of the on-board equipment is not clear from available documentation. Therefore, the suitability of the on-board systems in controlling propulsion and braking is not known at this time.

While most of the basic aspects of the safe speed concept appear applicable to a short stator system, it is apparent that considerable modifications would be needed in terms of logic and implementation.

Due to the train control system not being well defined by available literature, a number of areas were identified in which could not be fully assessed without further information. Those areas are:

- Issuance of temporary speed restrictions
- Recognition of normal braking capabilities by wayside equipment
- Determination of departure readiness at stations or in sidings
- Determination of the precise train/vehicle location in station areas
- Operation within and in vicinity of sidings
- The detection (and resulting actions) of specific failures/conditions which affect the speed commands and those which do not affect the commands but could otherwise be unsafe
- The degree to which the system considers human factor limitations in assigning speed commands (under manual train operation).

5.2.4 TGV Nord High Speed System

In the TGV Nord system, wayside track circuits determine block occupancy and computer equipment (CAI units) sends speed limit and target distance information to trains via the steel rails and on-board sensors. Based on this information and precise train location data from an axle-mounted tachometer, on-board computer equipment calculates the instantaneous maximum allowable speed and displays the speed to the driver. On-board equipment continuously compares the trains actual speed (based on the tachometer) with the calculated speed. Should overspeed occur and the driver not respond properly, braking is initiated accordingly. This concept eliminates the buffer block that normally exists in standard fixed block systems.

There are several aspects of the TGV safe speed concept (assessed in Table B-4) that are unsuitable for application to a maglev system, whether it be short or long stator. One aspect is the determination of train location via track circuits and shunting of the rails by a train's wheels and axles. Another aspect is the determination of train speed via tachometers. Neither of these are suitable in maglev systems due to the lack of wheels/axles and the lack of gear motion which directly corresponds to train movement.

Still another unsuitable aspect involves the communication system. First, the transmission of vital (or non-vital) data from wayside to the trains via the rails is unsuitable for obvious reasons. Second, the TGV Nord system has no apparent provisions for sending vital information from the trains to the wayside. And, the transmission of vital information in both directions between trains and the wayside/central is considered necessary in a U.S. maglev system. In short stator systems, information from the train to the wayside may include train location and/or actual speed data. In long stator systems, such information is expected to include failure data/status of critical on-board systems.

Although the aspects described above are considered unsuitable for either short or long stator maglev systems, there are some aspects of the TGV Nord system concept that could be applicable. First, consider short stator applications. The TGV Nord concept (except for the areas addressed above) is best suited to short stator maglev systems. This is primarily because the on-board equipment directly controls the propulsion and braking systems based on specific vital information from the wayside. The specific speed control concept used in the TGV Nord (i.e., on-board equipment continuously calculates instantaneous maximum allowable speed based on the presence of a train in the downstream block) could be utilized in a short stator maglev system to not only enforce safe speed but also to improve headway (over conventional fixed block systems). Further, the existence of on-board and wayside vital computer processing capability could allow the necessary modifications to be made in propulsion/braking control signals.

In terms of long stator systems, the basic speed control concept described above could be applicable. However, the calculation of instantaneous allowable speed would have to be performed in the wayside computer (instead of on-board) so that the long stator elements could be controlled. This is feasible given the wayside computer processing capability. Also, the on-board equipment would have to control whatever braking systems were employed. This, too, is considered feasible given the on-board computer. The major concern in a long stator application is the lack of a vital train to wayside communication path in the TGV Nord system. As described above, this would be necessary to relay failure information to the wayside for appropriate control (removal) of propulsion. As can be observed, while some of the basic elements and concepts appear applicable, substantial modifications in logic and implementation would be necessary.

Only two areas were identified which could not be fully assessed without further information. Those are: 1) the degree to which the system considers human factor limitations in assigning speed commands (under manual train operation), and 2) the detection (and resulting actions) of specific failures/conditions which affect the speed commands and those which do not affect the commands but could otherwise be unsafe. Although not confirmed, the TGV system most likely accounts for item 1) since the primary mode of operation is via an operator. Further investigation is needed in these areas, especially the latter.

5.2.5 ICE High Speed System

In the ICE system, wayside track circuits determine block occupancy and computer equipment sends vital speed related data (e.g., distance to the next stopping point and braking curve to be utilized) via inductive loops to the train. On-board equipment uses this data plus precise train location information from pulse generators to calculate required instantaneous speed commands. Resulting commands control propulsion and braking. On-board equipment also compares these speed commands with the train's actual speed and, should overspeed occur, initiates braking accordingly. The concept is very similar in nature to the TGV Nord system.

There are two key aspects of the ICE safe speed concept (assessed in Table B-5) that are unsuitable for application to a maglev system, whether it be short or long stator. These involve determination of train location and actual train speed. Train location in a specific block is determined via track circuits and shunting of the rails by the wheels and axles. More precise train location and actual speed are determined on-board via signals from pulse generators. Neither of these methods are suitable for use in a maglev environment for reasons previously discussed.

There are several aspects of the ICE system which could be applicable to maglev. First, consider a short stator system. Like the TGV Nord, the ICE system is perhaps best suited to short stator applications due to on-board propulsion and braking control. The overall speed control concept (i.e., the wayside continuously sends stopping related data to the train which generates corresponding speed commands) could be utilized in a short stator application. As with the TGV Nord, this concept could provide overspeed protection as well as improve headway over conventional fixed block systems. The use of inductive loops to transfer vital speed related information to the trains is also suitable. In addition, the existence of on-board and wayside vital computer processing capability would facilitate the modifications that would be necessary to perform the appropriate logic and generate the appropriate propulsion and braking commands for a maglev system. Of course, as mentioned above, the train location and speed determination functions would have to be performed in some other manner. The inductive loops in the ICE system could also serve as a suitable means for sending train location, speed, and other vital information from trains to the wayside if necessary.

In terms of a long stator system, the basic speed control concept described above could also be applicable, but additional modifications would be required. For example, the calculation of speed commands (performed on-board) from the stopping data (sent from the wayside) would have to be performed on the wayside. This is feasible, given the vital wayside computer. Also, the on-board equipment would have to control the on-board braking systems, and would have to communicate in a vital manner with the wayside. This is also feasible given the vital on-board computer and the inductive loop communication system. In this sense, the ICE system has an advantage over the TGV Nord system since the

TGV system does not appear to incorporate a vital train-to-wayside communication link. While the concept may be applicable to a long stator system, considerable modifications in terms of logic and implementation would be required.

Several areas were identified which could not be fully assessed without further information. Those are: 1) determination of the precise location of the train/vehicle in station areas, 2) the degree to which the system considers human factor limitations in assigning speed commands (under manual train operation), and 3) the detection (and resulting actions) of specific failures/conditions which affect speed commands and those which do not affect the commands but could otherwise be unsafe.

5.2.6 X2000 High Speed System

In the X2000 system, wayside equipment determines block occupancy via DC track circuits, and encodes and sends intermittent speed limit information to the train at specific points via wayside transponders and on-board interrogators. On-board computer equipment calculates the maximum allowable speed based on this and other information (e.g., braking capability) and displays the speed limit to the operator. This same on-board equipment compares the calculated speed limit with the actual speed and, should overspeed occur and the operator not respond properly, initiates braking via magnetic rail brakes.

There are several aspects of the X2000 system (assessed in Table B-6) that are unsuitable for application to a maglev system, whether it be short or long stator. These involve determination of train location and actual train speed, and communication of vital information to the wayside from the train. The use of track circuits with wheel/axle shunting of the rails for train location detection and the use of tachometers for determining train speed are considered unsuitable in a maglev system for reasons previously discussed. Also, the X2000 does not appear to incorporate a means for transferring vital data from the train to the wayside. This function would be necessary in a any maglev system, particularly if train location and actual speed data are determined on-board. Wayside/central equipment would need this information to ensure safe headways and to control all trains in the system.

There are several aspects of the X2000 system which could be applicable to maglev. The X2000 concept is perhaps best suited to a short stator system due to the on-board propulsion and braking. The overall concept of sending speed limit commands intermittently (for specific sections of the track) via transponders and calculating allowable speed on-board appears suitable for a short stator maglev application. The successful use of these transponders has already been demonstrated at speeds of up to 300 km/h. Transponders could be placed wherever and as often as desired in the guideway to control speed accordingly. The existence of the vital on-board computer would facilitate the modifications that would be necessary to control the short stator elements and on-board braking systems in response to wayside commands.

In terms of long stator systems, the basic safe speed concept and aspects thereof are not well suited. Signals generated from track circuits in the X2000 system are encoded and sent to trains via transponders where allowable speeds are calculated and compared with actual speed to determine overspeed conditions. First of all, a maglev system would not use conventional track circuits (as previously discussed). Further, the lack of vital wayside computer capability would result in substantial modifications in terms of implementation to produce appropriate control signals for the long stator elements and to perform the required overspeed protection function. In addition, as previously discussed, the X2000 does not appear to include a vital train to wayside communication link which would be necessary in a long stator maglev system (i.e., to get train location/speed data from all trains at a wayside/central location and to get failure status information on critical on-board equipment). One aspect of the X2000 system that would be suitable for long stator applications is the vital on-board computer which could be used for the control of on-board braking systems. However, in general, the overall safe speed concept of the X2000 is not well suited for long stator applications.

Three areas were identified which could not be fully assessed without further information. Those areas are: 1) determination of the precise train/vehicle location in station areas, 2) the degree to which the system considers human factor limitations in assigning speed commands (under manual train operation), and 3) the detection (and resulting actions thereof) of specific failures/conditions which affect the speed commands and those failures/conditions which do not affect the commands but could otherwise be unsafe.

5.2.7 AEG-Westinghouse People Mover System

In the AEG-Westinghouse system, wayside equipment determines block occupancy via track circuits (and sliding brushes on the vehicles) and sends coded speed commands (which represent speed limits for the blocks) to the rubber-tired trains/vehicles via signal rails in the center guidebeam and on-board antenna. These commands are used to control propulsion and braking. On-board computer equipment compares these speed commands with actual speed and, should overspeed occur, removes propulsion and initiates braking accordingly.

Several aspects of this system concept (assessed in Table B-7) are unsuitable or questionable for application to a maglev system, whether it be short or long stator. One aspect involves the determination of train/vehicle speed via tachometers. This method is unacceptable for maglev for reasons previously discussed. Another aspect involves the lack of a vital train to wayside communication link. It is expected that such a link would be needed in any maglev application. The last aspect involves the determination of train location which is performed by brushes on the vehicles which shunt the signal rails in specific blocks or sections of the guideway. This concept has been successfully utilized in numerous AEG-Westinghouse systems at speeds up to approximately 50 km/h, and may indeed be feasible for higher speeds in a maglev environment. However, the proper operation of this train detection concept at higher speeds would need to be proven.

While the overall concept is not suitable "as is" to maglev, there are several aspects of the AEG-Westinghouse system which would be applicable to short stator systems due to the on-board control of braking and propulsion. The basic method of coupling speed and braking commands to the trains for specific blocks of guideway via signal rails and on-board antenna is suitable. Also, the vital on-board computer could be used to generate the proper braking and propulsion signals for short stator elements and other systems in response to the wayside commands. However, considerable hardware modifications would be necessary for the wayside due to the absence of vital wayside computer equipment.

The basic safe speed concept and aspects thereof are not particularly suitable for a long stator system. This is due to the lack of a vital wayside computer, the lack of a vital train to wayside communication path and the other concerns discussed above. Substantial logic modifications would be needed on the wayside to control the long stator elements, and the lack of a vital computer would result in substantial equipment revisions to implement those changes. The lack of a train to wayside communication path would preclude the transfer of train location, speed, and equipment failure status information to the wayside.

Two areas were identified in Table B-7 which could not be fully assessed without further information. Those areas are: 1) the degree to which the system considers human factor limitations in assigning speed commands (under manual train operation), and 2) the detection (and resulting actions thereof) of specific failures/conditions which affect the speed commands and those failures/conditions which do not affect the commands but could otherwise be unsafe.

5.2.8 VAL System (Lille)

In the VAL system (at Lille, France), train location is determined on the wayside via signals produced on-board and fed into a guideway mounted transmission line (i.e., positive detection), and via ultrasonic transmitters/receivers at specific locations (i.e., negative detection). Wayside equipment sends speed related signals back to the trains via one of two guideway transmission lines (i.e., normal and stopping). Speed commands are inherent in the fixed transpositions in the transmission lines. On-board equipment uses the appropriate speed command (based on signal modulation) and compares the transposition intervals against a clock signal to determine overspeed. Should overspeed occur, propulsion and braking are controlled accordingly.

One aspect of the VAL safe speed concept (assessed in Table B-8) that may be suitable to maglev in general is the determination of train location (on the wayside) via the positive and negative detection techniques. These techniques have been proven in the VAL system at speeds up to approximately 80 km/h, and appear to be feasible for application in higher speed systems. If operation at these higher speeds is proven, these methods would be applicable to either short or long stator systems. The techniques provide train location information relative to specific (fixed) blocks of the guideway.

The overall concept and several aspects thereof utilized in the VAL system are best suited to short stator applications. This is due to the on-board propulsion/braking and, especially, to the speed commands that are inherent in the guideway transmission lines. Transmission lines of this nature are considered feasible for use in transferring speed commands to a maglev train. Also, the general concept of using on-board clocks and transposition intervals for determining overspeed is considered feasible. However, it appears that tachometers and phonic wheels are also utilized to determine actual train speed under certain conditions (e.g., very low speeds). Some additional investigation would be required to assess whether or not these or other means (in addition to the transmission line and clocks) would be needed in a short stator maglev application. Although the VAL system does not appear to utilize a vital train-to-wayside communication path, this aspect may not be needed if this overall concept is used in a short stator maglev system. This is primarily due to the existing determination of train location on the wayside. If vital data had to be transmitted to the wayside from the train, this could be done via the existing guideway transmission lines.

One drawback of the VAL system relative to short stator applications is the lack of computer equipment both on-board and at the wayside. This would necessitate considerable equipment modifications. However, the VAL system has been in operation since 1983, and newer installations may utilize vital computer equipment which would facilitate modifications (for a maglev system) .

The VAL safe speed concept is not well suited at all (except for the determination of train location as described above) to a long stator maglev system. The primary reason is the dependence upon the fixed transpositions in the guideway transmission lines for transferral of speed commands to the train. The use of such lines would not be applicable in long stator systems. Also, actual train speed would have to be determined in some other manner (than using on-board clocks and fixed transpositions of the transmission line). Further, there is no vital train to wayside communication link nor is there vital on-board and wayside computers.

There was only one aspect which could not be fully assessed without further information. This involves the detection (and resulting actions) of specific failures/conditions which affect the speed commands and those which do not affect the commands but could otherwise be unsafe.

5.2.9 Vancouver Skytrain System

In the Vancouver system, wayside computer equipment sends continual speed command information (i.e., safe stopping point, permitted speeds, braking characteristics) to trains via inductive loops between the rails. These commands are based in part on train location and actual speed information sent from the trains to the wayside via the same inductive loops. On-board equipment compares actual train speed (from tachometers) with the speed commands and, should overspeed occur, controls propulsion and braking accordingly.

Two aspects of this system concept (assessed in Table B-9) are unsuitable either in full or in part for application to a maglev system, whether it be long or short stator. They involve the determination of train location and train speed. Train location is determined via transpositions in the inductive loops (raw position) and signals from the tachometers (precise position). The raw position method is suitable for maglev, but the precise position is not since the method is based on tachometers and corresponding gear movement. Train speed is determined on-board via signals from digital tachometers. This method is unsuitable for the above reasons.

The Vancouver system basic safe speed concept is best suited to a short rather than long stator system primarily because of on-board propulsion and braking control. Given that train location and speed could be determined on-board in some other manner, the information could be sent to the wayside via the inductive loop vital communication system. Then, the wayside computer equipment could generate and send the appropriate speed commands back to the train via the same inductive loops. On-board computer equipment could provide the necessary overspeed protection functions (as long as actual speed is determined in some other manner) and could generate the appropriate propulsion and braking control signals for the on-board equipment. Thus, the communication link and vital wayside and on-board computer systems are key aspects which could be applicable to short stator systems. The vital computers would facilitate modifications that would be necessary both on the wayside and on-board the train. The use of this concept could provide improvements in headway over conventional fixed block system since the concept utilizes a moving block approach.

While the safe speed concept is not particularly well suited to long stator applications, there are several aspects that could be utilized. One is the communication link (inductive loops) that could transfer vital information in both directions between trains and wayside locations. The other is the vital wayside computers which could be used to generate the appropriate speed commands for the long stator elements. The wayside computer would have to perform some of the similar functions (e.g., overspeed detection) that are presently performed in the on-board computer, plus the additional logic to control and manage power to guideway sections. The vital on-board computer could control on-board braking systems. Overall, considerable modifications would be required to utilize the Vancouver system equipment in a long stator system. Plus, as described above; the determination of train location and speed would need to be performed in some other manner.

Several areas were identified which could not be fully assessed without further information. Those are: 1) determination of the precise location of the train/vehicle in station areas, 2) the degree to which the system considers human factor limitations in assigning speed commands (under manual train operation), and 3) the detection (and resulting actions) of specific failures/conditions which affect speed commands and those which do not affect the commands but could otherwise be unsafe.

5.2.10 MARTA System

In the MARTA system, wayside track circuit equipment determines train location in specific blocks via shunting of the wheels/axles, and sends coded speed commands for specific blocks to the trains via the rails and on-board antenna. On-board equipment uses this and other information to automatically control propulsion. This same on-board equipment compares these commands with the train's actual speed and, should overspeed occur, controls propulsion and braking accordingly.

Several aspects of this concept (assessed in Table B-10) are not suitable for application to a maglev system, whether it be short or long stator. One aspect involves the use of conventional track circuits that rely on the shunting of the rails by the wheels and axles for determining train location. Another involves the use of reluctance type speed sensors based on gear motion to determine train speed. A third involves the transfer of vital information (e.g., speed commands) to trains via the steel rails and on-board antenna. None of these aspects are directly applicable to maglev for reasons previously discussed. Another aspect involves the lack of a vital train to wayside communication path which, as discussed earlier, is expected to be required in both short and long stator systems.

The basic concept of generating speed commands on the wayside, sending them to trains and detecting overspeed conditions on-board is suited for short stator applications. Also, as can be observed in Table B-10, many of the functions of a maglev system are performed (to some extent) in the MARTA system. However, due to the above discussion, it is expected that extensive modifications would be required to utilize the MARTA system equipment in a short stator application. Furthermore, the lack of a vital wayside computer (and capability of making software revisions) would make it even more difficult to apply this system to a maglev system with short stator propulsion.

In light of the above discussion, neither the concept nor the equipment in the MARTA system would be very suitable to a long stator application. This is also considered to be the case even in some of the newer applications of similar systems such as the Shanghai Metro in which vital computer equipment is involved.

One area was identified in which it was not possible to fully determine the applicability of the MARTA system concept to a U.S. maglev system. This involves the detection (and resulting actions) of specific failures/conditions which affect the speed commands and those failures/conditions which do not affect the commands but could otherwise be unsafe.

5.2.11 ATCS

In the Advanced Train Control System, train location and actual speed are determined on-board and the data are sent at regular intervals from the trains to a central computer via radio. The central computer sends vital movement authorities and allowable speed limit commands back to the trains via the radio. On-board computer equipment calculates speed and braking distance information and compares the speed limit commands with actual train speed to determine overspeed conditions. Should overspeed occur and the operator not respond, the on-board equipment will control the throttle and braking accordingly.

Two aspects of ATCS (assessed in Table B-11) are not totally suitable for application to a maglev system, whether it be short or long stator. These involve the determination of train location and train speed. Train location is determined via trackbed transponders and on-board interrogators (raw position) and via axle generators (fine position). While the method for determining raw position is considered suitable, the use of axle generators based on gear movement for fine position is not for reasons previously discussed. It should be mentioned that at least one other railroad is investigating the use of satellites to determine train position. Further work would be required to investigate the suitability of this concept. In terms of determining train speed, the same axle generators are utilized. Therefore, the determination of actual speed is unsuitable.

Although the two aspects above are not suitable for maglev, the basic system concept (i.e., sending movement authorities and associated speed limits to trains at regular intervals) and several key aspects of ATCS are suitable for application to a short stator maglev system. One key aspect involves the use of vital central and on-board computers. This equipment could generate the appropriate commands for all trains and also generate the appropriate control signals on-board the train for control of the short stator elements and on-board braking systems. Another key aspect is the radio-based communication system. This system could provide the vital communication link in both directions between trains and the central computer.

While the concept is not particularly well suited to long stator maglev systems, there are two major aspects of ATCS which could be applicable. They involve the same two aspects discussed above--vital computers both on-board and at the wayside, and the radio communication system. The vital computers would facilitate the modifications which would be necessary to control long stator guideway elements and on-board braking systems, and the radio link would provide the necessary two-way vital communications between trains and the central computer.

One area was identified which could not be fully assessed without further information. This involves the detection (and resulting actions) of specific failures/conditions which affect the speed commands and those failures/conditions which do not affect the commands but could otherwise be unsafe.

6.0 OVERALL SUMMARY

Major results of the assessment relative to the availability and suitability of safe speed enforcement concepts for a U.S. maglev application are summarized in Table 5. The system concepts in the left column are listed in the order in which they were assessed. Key suitable and unsuitable aspects are identified for each system concept and for both short and long stator maglev applications. Also included is an indication as to the extent of the modifications which would be required to utilize the system equipment in either a short or long stator application. Four levels of modifications were used: minimal, moderate, considerable, or extensive. It should be noted that the level of modifications identified in the table applies to the entire system and not just to one or more aspects of the system.

As can be observed, the three existing/developmental maglev systems assessed are most suitable for a U.S. maglev application due to their basic nature of being, themselves, either short or long stator maglev systems. However, each of these maglev systems is best suited to either a short or long stator application and not both. For example, the Transrapid system (being long stator in nature) is best suited for a long stator application in the U.S. because the aspects of train detection and speed determination could not be utilized in a short stator environment. Whereas it is expected that only minimal modifications would be necessary to utilize the Transrapid equipment in a long stator system, considerable modifications would be expected to apply the Transrapid equipment to a short stator system. This is not only due to the unsuitability of the train detection and speed determination aspects, but also to the basic problem of having to control speed and headway of each train rather than the propulsion/braking of trains via long stator elements in sections of guideway. There are differences in the required control equipment and processing logic in each case.

It should be observed that although a particular maglev concept is best suited for a short or long stator application, there are aspects of each existing/developmental Maglev system that could be utilized. Consider the Japanese HSST-05 system. Although it is best suited to a short stator application, it does incorporate some key features/aspects that could be utilized in a long stator system (e.g., train detection and speed determination methods,

TABLE 5. ASSESSMENT SUMMARY

	Short Stator			Long Stator		
System	**Suitable Aspects**	**Unsuitable Aspects**	**Modifications Required(1)**	**Suitable Aspects**	**Unsuitable Aspects**	**Modifications Required(1)**
Transrapid (TR-07)	Two-way vital communication link (radio) Vital on-board and wayside computers	Basic Concept Train detection (groove counting) Speed determination (groove counting)	Considerable	Most to all	None	Minimal
HSST-05	Most to all (train detection and speed measurement concepts need proven at higher speeds)	None	Minimal	Train detection (transmission belt and transponders) Speed determination (transmission belt) Two-way vital communication link (inductive transmission belt) Vital on-board and wayside computers	Basic concept	Moderate

TABLE 5. ASSESSMENT SUMMARY
(Continued)

	Short Stator			Long Stator		
System	**Suitable Aspects**	**Unsuitable Aspects**	**Modifications Required**[(1)]	**Suitable Aspects**	**Unsuitable Aspects**	**Modifications Required**[(1)]
Linear Express	Train detection and speed measurement (inductive cable) Vital train-to-wayside communication link (antenna and leaky coaxial cable) Vital wayside-to-train communication link (inductive cable) Vital wayside computer	Basic concept	Moderate	Most to all (train detection and speed measurement concepts need proven at higher speeds)	None	Minimal
TGV Nord	Basic concept Vital on-board and wayside computers	Train detection (wheel/axle shunting) Speed measurement (tachometers) Vital wayside-to-train communication link (rails) Lack of vital train-to-wayside communication link	Considerable	Vital on-board and wayside computers	Train detection (wheel/axle shunting) Speed measurement (tachometers) Vital wayside-to-train communication link (rails) Lack of vital train-to-wayside link	Considerable

TABLE 5. ASSESSMENT SUMMARY
(Continued)

	Short Stator			Long Stator		
System	**Suitable Aspects**	**Unsuitable Aspects**	**Modifications Required(1)**	**Suitable Aspects**	**Unsuitable Aspects**	**Modifications Required(1)**
ICE	Basic concept Two-way vital communication link (inductive loops) Vital on-board and wayside computers	Train detection (wheel/axle shunting) Speed measurement (pulse generators)	Moderate	Two-way vital communication link (inductive loops) Vital on-board and wayside computers	Train detection (wheel/axle shunting) Speed measurement (pulse generators)	Moderate
X2000	Basic concept Vital wayside-to-train communication link (transponders) Vital on-board computer	Train detection (wheel/axle shunting) Speed measurement (tachometers) Lack of vital train-to-wayside communication link. Lack of vital wayside computer	Considerable	Vital on-board computer	Train detection (wheel/axle shunting) Speed measurement (tachometers) Lack of vital train-to-wayside communication link. Lack of vital wayside computer	Considerable

TABLE 5. ASSESSMENT SUMMARY
(Continued)

	Short Stator			Long Stator		
System	**Suitable Aspects**	**Unsuitable Aspects**	**Modifications Required**$^{(1)}$	**Suitable Aspects**	**Unsuitable Aspects**	**Modifications Required**$^{(1)}$
AEG-Westinghouse People Mover	Basic concept Vital wayside-to-train communication link (signal rails and antenna) Vital on-board computer	Train detection$^{(2)}$ (brushes and signal rails) Speed measurement (tachometers) Lack of vital train-to-wayside communication link. Lack of vital wayside computer	Considerable	Vital on-board computer	Train detection$^{(2)}$ (brushes and signal rails) Speed measurement (tachometers) Lack of vital train-to-wayside communication link Lack of vital wayside computer	Considerable
VAL (Lille)	Basic concept Train detection (guideway transmission line and ultrasonic devices) Speed measurement at higher speeds (transmission line and on-board clocks) Vital wayside-to-train communication link (transmission line)	Speed measurement at low speeds (tachometer) and phonic wheels) Lack of vital on-board and wayside computers Lack of vital train-to-wayside communication link (although transmission line could be used)	Moderate	Train detection (guideway transmission line and ultrasonic devices)	Speed measurement Lack of vital train-to-wayside communication link (although transmission line could be used) Lack of vital on-board and wayside computers	Extensive

TABLE 5. ASSESSMENT SUMMARY
(Continued)

	Short Stator			Long Stator		
System	Suitable Aspects	Unsuitable Aspects	Modifications Required(1)	Suitable Aspects	Unsuitable Aspects	Modifications Required(1)
Vancouver Skytrain	Basic Concept Train detection (inductive loops for "raw" position) Vital two-way communication link (inductive loops) Vital on-board and wayside computers	Train detection (tachometers for precise position) Speed measurement (tachometers)	Moderate	Train detection (inductive loops for "raw" position) Vital two-way communication link (inductive loops) Vital on-board and wayside computers	Train detection (tachometers for precise position) Speed measurement (tachometers)	Considerable
MARTA	Basic concept Vital on-board computers (in newer applications)	Train detection (wheel/axle shunting) Speed measurement (reluctance-type sensors Vital wayside-to-train communication link (rails) Lack of vital wayside computer Lack of vital train-to-wayside communication link.	Extensive	Vital on-board computer (in newer applications)	Train detection (wheel/axle shunting) Speed measurement (reluctance-type sensors) Vital wayside-to-train communication link (rails) Lack of vital train-to-wayside communication link Lack of vital wayside computer	Extensive

TABLE 5. ASSESSMENT SUMMARY
(Continued)

	Short Stator			Long Stator		
System	Suitable Aspects	Unsuitable Aspects	Modifications Required[1]	Suitable Aspects	Unsuitable Aspects	Modifications Required[1]
ATCS	Basic concept Train detection (transponders for "raw" position) Two-way vital communication link (radio) Vital on-board and central computers	Train detection (axle generators for precise position) Speed measurement (axle generators)	Considerable	Train detection (transponders for "raw" position) Two-way vital com-link (radio) Vital on-board and central computers	Train detection (axle generators for precise positions) Speed measurement (axle generators)	Considerable

(1) Apply to overall system.

(2) Questionable method.

vital two-way communication link and vital on-board and wayside/central computers). All of these are considered key system aspects that would be required in a high speed maglev system. The latter example (i.e., vital computers) would facilitate the modifications that would have to be made in logic to convert to either a short or long stator system.

All of the other eight systems assessed involve either steel-wheeled or rubber-tired vehicles (i.e., AEG-Westinghouse People Mover, VAL) which incorporate on-board propulsion and braking. The basic safe speed enforcement concepts utilized in these systems are considered to be best suited to short stator (and not long stator) maglev systems primarily for this reason. These systems generally perform (in a safe manner) the functions that would also need to be performed in a short stator maglev system. Also, these functions are generally performed either on-board, at the wayside, or at a central location, such as would be required in a short stator system. However, due primarily to the contact nature of the vehicles in these systems with either steel rails or a guideway, considerable modifications would generally be necessary to utilize this equipment in a maglev application. Even more extensive modifications would be needed to utilize this equipment in long stator applications. This is due to the differences in logic relative to controlling individual vehicles versus controlling power in guideway sections.

As can be observed in Table 5 and in the system descriptions in Section 3.0 of this report, a wide range of variations exist in the safe speed enforcement approaches and system operating philosophies used in these various non-maglev systems. Some send speed commands or speed related information to trains on a continual basis, while others send such information on an intermittent basis for specific sections of track or guideway. Also, on a related matter, the systems incorporate different "block" concepts. While most of the systems are based on a standard fixed block approach (i.e., trains are detected in various blocks or sections of track/guideway and speed limits are fixed for those sections) to ensure the proper headway, one of the systems (i.e., Vancouver Skytrain) is based on a moving block approach. In this concept, there are no established blocks or sections of guideway/track. Rather, trains operate within the minimum braking distance of the preceding train, based in part on the speed of that train and its own speed. Also, unlike standard fixed block systems in which a "buffer" block is incorporated between trains, some of the systems assessed (i.e., TGV Nord, ICE) do not use this "buffer" block. Instead, they allow the on-board calculation of allowable speed based on stopping distance information sent from the wayside. Such systems allow for shorter distances between trains, thus improving headway over standard fixed block systems. Further, in the Transrapid system, the guideway is divided into a number of "blocks" or sections of guideway of fixed lengths to allow for the individual control of each train's propulsion and dynamic braking. This system most closely resembles a fixed block system (as opposed to moving block) since a train is prevented from entering a downstream occupied block regardless of the speed of the train in that block. However, due to the continual calculation of precise train location and actual train speed within a particular guideway section and the continual enforcement of safe speed limits throughout the section, shorter headways can be achieved than those in systems employing intermittent speed commands—commands which remain the same for a given block or section of track/guideway.

In this assessment, all of these approaches were considered acceptable with the understanding that each has certain advantages/disadvantages. The specific concept utilized in a U.S. maglev system is dependent in part on the headway requirements and operating philosophies to be incorporated. These have not been fully defined.

It should be noted that there were several areas or aspects encountered in the assessments of the various systems which could not be fully assessed without further information. These generally involved items such as the following: 1) determination of the precise train/vehicle location in station areas, 2) the extent to which the system considers human factor limitations in assigning speed commands (under manual train operation), and 3) the detection (and resulting responsive actions) of failures/conditions which affect the speed commands and those which do not affect the commands but could otherwise be unsafe. However, the lack of descriptive information in these areas did not adversely impact the results of this assessment. Some of the issues in these areas are addressed in the Recommendations section (8.0) of this report.

6.1 Suitable Aspects For Maglev Systems

Although none of the non-maglev system safe speed concepts/equipment assessed was found to be directly applicable "as is" to short or long stator maglev systems, there are a number of key aspects of the various systems which are considered suitable for maglev. And, these aspects cover the basic needs and could be used as the basic building blocks of a U.S. maglev safe speed enforcement system. The major areas and aspects that are considered suitable in each are described below. They apply to both short and long stator systems except where noted. Further information on these aspects can be obtained from Table 5, the individual assessment summaries and system descriptions in Sections 5.0 and 3.0, respectively, of this report.

It should be noted that it was not the intent of this program to verify the fail-safe nature, or lack thereof, of the equipment or systems assessed. Further studies would be required to determine if the equipment that is used to implement these suitable aspects provides an acceptable level of safety.

6.1.1 Train Detection

- Transponders and on-board interrogators (Transrapid, ATCS)—"raw" position only
- Guideway inductive transmission belt and/or inductive loops (HSST-05, Linear Express, Vancouver Skytrain)
- Guideway inductive loops in combination with ultrasonic transmitters/receivers (VAL)

6.1.2 Train Speed Determination

- Counting long stator grooves (Transrapid)—long stator only
- Transpositions in transmission belt (HSST-05, Linear Express)
- Transpositions in transmission belt and on-board clocks (VAL)

6.1.3 Communications Links

- Two-way link (train-to-wayside and wayside-to-train)—radio (Transrapid, ATCS)
- Two-way link—inductive loops (ICE, Vancouver Skytrain)
- Two-way link—inductive transmission belt (VAL)
- Wayside-to-train link—small loop cables and transponders (HSST-05)
- Wayside-to-train link—inductive transmission belt (Linear Express)
- Wayside-to-train link—transponders (X2000)
- Wayside-to-train link—special signal rails and antenna (AEG-Westinghouse)—a questionable method
- Train-to-wayside link—inductive transmission belt (HSST-05)
- Train-to-wayside link—antenna and leaky coaxial cable (Linear Express)

6.1.4 Computer Equipment

- Vital on-board computer (Transrapid, HSST-05, TGV Nord, ICE, X2000, AEG-Westinghouse, Vancouver Skytrain, ATCS)
- Vital wayside-central computer (Transrapid, HSST-05, Linear Express, TGV Nord, ICE, Vancouver Skytrain, ATCS)

7.0 CONCLUSIONS

Based on the results of this assessment, the following overall conclusions can be made:

1) Safe speed enforcement concepts and equipment in existing/developmental maglev systems (i.e., Transrapid, HSST-05, Linear Express) are generally suitable "as is" or with minimal modifications to fulfill the functions and needs of a U.S. maglev safe speed enforcement system. However, this holds true if existing long and short stator systems are applied to a U.S. system employing long and short stator technology, respectively.

2) While none of the existing non-maglev safe speed enforcement system concepts assessed are directly applicable "as is" or with minimal modifications, these systems do incorporate various aspects and equipment which are suitable to maglev (both short and long stator) and which could fulfill the basic needs of a maglev system relative to safe speed enforcement. An overview of these suitable aspects is provided in the Overall Summary Section (6.0) of this report.

8.0 RECOMMENDATIONS

The following recommendations are made as a result of the work performed under the subject contract:

1) The operation of various system aspects (e.g., train detection, train speed determination, communication links) should be confirmed/tested at higher speeds such as those to be expected in the U.S. maglev system. More information on those aspects to be confirmed is provided in the individual assessment summaries in Section 5.0.

2) Although suitable aspects were identified in existing/developmental maglev and non-maglev systems, additional research is recommended in two key areas (i.e., train detection and train speed measurement) in order to investigate other suitable methods of implementing these functions.

3) The detection of failures/abnormal conditions of on-board and wayside/central maglev equipment and the resulting effects on speed commands and enforcement thereof should be investigated.

4) The role of the train operator relative to override capabilities in initiating braking should be investigated, particularly as it relates to the operating philosophy and headway requirements of the U.S. maglev system.

5) Headway requirements/optimization and operating philosophies of the U.S. maglev system and their associated advantages/disadvantages should be investigated.

6) It may be desirable to investigate additional system concepts (e.g.. Japanese Shinkansen, Burlington Northern's variation on ATCS) and their suitability to maglev.

7) While it was not the intent of this program to do so, it may be desirable to investigate the level of safety inherent in some of the candidate system equipment for maglev (e.g., train detection, communication decoding/encoding schemes, on-board and wayside/central computer equipment).

8) Different braking system options for maglev trains (particularly on-board systems) and their capabilities in ensuring proper and safe levels of braking at high speeds should be investigated.

APPENDIX A

INFORMATION SOURCES

APPENDIX A

INFORMATION SOURCES

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APPENDIX B

DETAILED ASSESSMENTS

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. Safe Speed Command Generation A. Determination/Production of Command Speed 1. Civil Speed Restriction a. Determine location of train	Yes—determined on-board via sensors and guideway mounted transponders (INKREFA system) for raw position and counting long stator grooves for precise position.	Yes—INKREFA and groove-counting directly applicable to long stator systems; groove-counting not applicable to short stator systems.
b. Assign/restrict speed command based on train location and associated stored values	Yes—performed by wayside (decentralized) computer based vehicle protection elements.	Yes—directly applicable to long stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—requested by control room operator and verified by wayside vehicle protection elements.	Yes—directly applicable to long stator systems.
2. Headway Control a. Determine locations of, distance between, and direction of trains	Yes—location and direction determined on-board by same system; distance between trains determined in wayside vehicle protection elements.	Yes—directly applicable to long stator systems.
b. Recognize normal braking capabilities/characteristics	Yes—stored in wayside (vehicle protection) and on-board computers.	Yes—directly applicable to long stator systems.

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—determined on-board via INKREFA system, groove counting and computers.	Yes—for long stator systems; groove counting not applicable to short stator systems.
d. Assign/restrict speed command accordingly	Yes—performed by wayside vehicle protection elements.	Yes—directly applicable to long stator systems.
3. Route Integrity		
a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—route integrity information obtained from wayside route control elements.	Yes—directly applicable to long stator systems.
b. Recognize normal braking capabilities/characteristics	Yes—stored in wayside and on-board computer elements.	Yes—directly applicable to long stator systems.
c. Assign/restrict speed command accordingly	Yes—performed by wayside protection elements.	Yes—directly applicable to long stator systems.
4. Schedule Control		
a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests from central control room checked by wayside vehicle protection elements.	Yes—directly applicable to long stator systems.

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—performed in wayside vehicle protection elements; some information obtained from station protection equipment.	Yes—directly applicable to long stator systems.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	Yes—see response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—stored in wayside and on-board computer elements.	Yes—directly applicable to long stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Undetermined, but capability for precise location exists with INKREFA system; not known if additional sensors used (could exist in station protection equipment).	Undetermined, but would be directly applicable to long stator systems.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—performed in wayside vehicle protection elements.	Yes—directly applicable to long stator systems.
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—performed by wayside vehicle protection elements with input from route integrity and station protection equipment; train rests on skids until ready to depart.	Yes—directly applicable to long stator systems.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Yes—speed checked on-board in acceleration zone of guideway; information available in on-board and wayside computer elements.	Yes—directly applicable to long stator systems.
7. Siding Utilization		
a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes (if siding used)—can be performed in wayside vehicle protection element with input from route integrity equipment.	Yes—directly applicable to long stator systems.

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—see response to I.A.6.b.	Yes—directly applicable to long stator systems.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Undetermined—but probably done since manual operation is possible.	Undetermined, but would be applicableto long stator systems.
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Status/condition of certain equipment (e.g., braking, levitation) monitored on-board and at wayside; specific failures/conditions monitored are undetermined.	Yes—directly applicable to long stator systems; failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Yes—information processed by wayside vehicle protection elements.	Yes—directly applicable to long stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes (if yards exist and other than manual operation used)—could be performed by wayside vehicle protection element.	Yes—directly applicable to long stator systems.
B. Encoding/Transmission of Critical Information 1. Encode/transmit speed command to point of utilization	Speed commands generated and used on the wayside; signals are hardwired.	Yes—directly applicable to long stator systems.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Yes—on-board critical information encoded in computer and sent to wayside vehicle protection element via radio.	Yes—directly applicable to long stator systems.
C. Decoding/Validation of Critical Information 1. Decode/validate speed command prior to utilization	Speed commands are generated and used by the wayside; signals are hardwired.	Yes—directly applicable to long stator systems.
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Validation not necessary since commands used directly on wayside.	Yes—directly applicable to long stator systems.

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. Decode other critical information (e.g., speed, location)	Yes—performed by wayside vehicle protection element.	Yes—directly applicable to long stator systems.
II. <u>Safe Speed Enforcement</u>		
A. Providing Overspeed Protection		
1. Determine actual speeds of trains—values determined must not be less than true value	Yes—determined on-board via INKREFA system and computers.	Yes—for long stator systems; groove counting not applicable to short stator systems.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—continual comparison done by wayside vehicle protection element.	Yes—directly applicable to long stator systems.
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—action depends on speed margin: 1) reduce propulsion, 2) dynamic braking, or 3) emergency braking (eddy current brakes and/or skids); can also remove propulsion on wayside.	Yes—directly applicable to long stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Yes—information available on-board; on-board computer can control braking if needed.	Yes—directly applicable to long stator systems.

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
B. Responding to Failures/Faults and Abnormal Conditions 1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Yes—on-board and vehicle protection elements (on wayside) monitor status of certain equipment; specific failures/conditions undetermined.	Yes—directly applicable to long stator systems; specific failures/conditions to be monitored should be defined.
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—vehicle protection (on wayside) and/or on-board elements can control braking and propulsion, in response to failure; specific responses are undetermined.	Yes—directly applicable to long stator systems; specific responses should bedefined.
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Yes—on-board element receives information from wayside and can control braking under certain failure conditions.	Yes—directly applicable to long stator systems.
C. Encoding/Transmission of Critical Information 1. Transmit actual speed and location information to points of utilization—encode if necessary	Yes—on-board critical information encoded in computer and sent to wayside vehicle protection element via radio.	Yes—directly applicable to long stator systems.

TABLE B-1. GERMAN TRANSRAPID (TR-07) SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Yes—vehicle protection element can send control signals to other wayside equipment (hardwired) and on-board element (via radio).	Yes—directly applicable to long stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Yes—see response to II.B.3.	Yes—directly applicable to long stator systems.
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Yes—performed by vehicle protection element (on wayside)	Yes—directly applicable to long stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Yes—performed by on-board and vehicle protection elements (on wayside) as appropriate.	Yes—directly applicable to long stator systems.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Yes—can be performed by on-board and vehicle protection (wayside) elements.	Yes—directly applicable to long stator systems.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. Safe Speed Command Generation		
A. Determination/Production of Command Speed		
1. Civil Speed Restriction		
a. Determine location of train	Yes—determined on-board via phase changes in signal due to transpositions in inductive belt, and precise location from wayside transponders.	Yes—operation and accuracy at high speeds to be determined.
b. Assign/restrict speed command based on train location and associated stored values	Yes—performed by central computer.	Yes—directly applicable to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—performed by central computer at request of operator.	Yes—directly applicable to short stator systems.
2. Headway Control		
a. Determine locations of, distance between, and direction of trains	Yes—location and direction determined on-board via signals from inductive belt and transponders; distance between trains determined at central.	Yes—directly applicable to short stator systems.
b. Recognize normal braking capabilities/characteristics	Yes—stored in central (and perhaps on-board) computers.	Yes—directly applicable to short stator systems.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—determined on-board via signals from inductive transmission belt.	Yes—accuracy at high speeds to be determined.
d. Assign/restrict speed command accordingly	Yes—performed by central computer.	Yes—directly applicable to short stator systems.
3. Route Integrity a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—information obtained by central computer.	Yes.
b. Recognize normal braking capabilities/characteristics	Yes—stored in central (and perhaps on-board) computers.	Yes—directly applicable to short stator systems.
c. Assign/restrict speed command accordingly	Yes—performed by central computer.	Yes—directly applicable to short stator systems.
4. Schedule Control a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests verified by central computer.	Yes—directly applicable to short stator systems.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—passive wayside transponders provide precise train locations on approach to stopping areas; associated stopping locations and distance to go determined by central computer.	Yes—directly applicable to short stator systems.
c. Determine speed of subject train	Yes—determined on-board via signals from inductive transmission belt.	Yes.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—stored in central (and perhaps on-board) computers.	Yes—directly applicable to short stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Undetermined, but capability for precise location exists with transponders and inductive belt.	Undetermined, but applicable if performed by current system.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—performed by central computer.	Yes—directly applicable to short stator systems.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	Yes. See response to I.A.1.a.
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—readiness to proceed determined by train operator (e.g., doors closed, levitation o.k.) and central computer (e.g., headway and route integrity clearances); central computer issues command.	Yes—directly applicable to short stator systems.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Yes—train speed and location determined on-board.	Yes—directly applicable to short stator systems.
7. Siding Utilization		
a. Determine train location	Yes—see response to I.A.1.a.	Yes. See response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—can be performed by central computer based on appropriate inputs.	Yes—directly applicable to short stator systems.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—can be performed by central computer with appropriate departure information from trains and other inputs (e.g., route integrity).	Yes—directly applicable to short stator systems.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Undetermined, but limitations most likely determined at central since some manual operation appears to be possible.	Undetermined, but would be applicable if function exists.
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Status/condition of certain equipment (e.g., braking, levitation) monitored on-board and at wayside; specific failures/conditions monitored undetermined.	Yes—directly applicable to short stator systems; failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Yes—performed by central computer.	Yes—directly applicable to short stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—can be performed by central computer.	Yes—directly applicable to short stator systems.
B. Encoding/Transmission of Critical Information		
1. Encode/transmit speed command to point of utilization	Yes—commands encoded and sent to trains at designated points via wayside transponders, loop cables, and on-board sensors.	Yes—directly applicable to short stator systems using intermittent (rather than continual) speed commands; commands can also be hard-wired in long stator systems.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Yes—safety critical information sent from trains to central via inductive transmission belt.	Yes—directly applicable to short stator systems.
C. Decoding/Validation of Critical Information		
1. Decode/validate speed command prior to utilization	Yes—command decoded/validated by on-board computer.	Yes—directly applicable to short stator systems.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Yes—action (braking) initiated by on-board computer.	Yes—directly applicable to short stator systems.
3. Decode other critical information (e.g., speed, location)	Yes—train speed and location information decoded by central computer.	Yes.
II. <u>Safe Speed Enforcement</u>		
A. Providing Overspeed Protection		
1. Determine actual speeds of trains—values determined must not be less than true value	Yes—speed determined on-board via signals from inductive cable; on-board speed meters updated continuously.	Yes.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—comparison performed by on-board computer.	Yes—directly applicable to short stator systems.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—braking applied accordingly (i.e., dynamic, mechanical brake, and/or skids).	Yes—directly applicable to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Information already available and used on-board.	Yes—directly applicable to short stator systems.
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Yes—at least some on-board equipment monitored; specific items or failures monitored are undetermined.	Yes—directly applicable to long stator systems; specific items and failures/conditions to be monitored should be defined.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—capability exists but specific actions are undetermined.	Undetermined, but would be directly applicable to short stator systems; specific actions should be defined.
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Information already available and used on-board.	Yes—directly applicable to short stator systems.
C. Encoding/Transmission of Critical Information		
1. Transmit actual speed and location information to points of utilization—encode if necessary	Yes—train speed, location, and certain status information sent to central via inductive cable.	Yes.
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Yes—overriding braking propulsion control signals generated and used on-board.	Yes—directly applicable to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Information available both on-board and at central.	Yes—directly applicable to short stator systems.

TABLE B-2. HSST-05 MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Yes—performed by central computer.	Yes.
2. Decode overriding braking/propulsion control signals—validate if necessary	Undetermined if central sends such signals to train.	Yes—if such signals (other than normal commands) are sent to trains from central.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Undetermined if central sends such signals to train.	Yes—if such signals (other than normal commands) are sent to trains from central.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. <u>Safe Speed Command Generation</u>		
A. Determination/Production of Command Speed		
1. Civil Speed Restriction		
a. Determine location of train	Yes—determined on-board via phase changes in signal due to transpositions in inductive cable.	Yes—operation and accuracy at high speeds to be determined.
b. Assign/restrict speed command based on train location and associated stored values	Yes—performed by safety control system on wayside.	Yes—directly applicable to long stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Undetermined, but may be possible via safety control system.	Undetermined.
2. Headway Control		
a. Determine locations of, distance between, and direction of trains	Yes—location and direction determined on-board via signals from inductive cable; distance between trains determined in wayside safety control system.	Yes.
b. Recognize normal braking capabilities/characteristics	Undetermined, but values could be stored in wayside safety control system computer.	Undetermined.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—determined on-board via signals from inductive cable.	Yes—operation and accuracy at high speeds to be determined.
d. Assign/restrict speed command accordingly	Yes—performed by wayside safety control system.	Yes—directly applicable to long stator systems.
3. Route Integrity		
a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—information obtained by wayside safety control system.	Yes.
b. Recognize normal braking capabilities/characteristics	Undetermined, but values could be stored in wayside safety control system.	Undetermined.
c. Assign/restrict speed command accordingly	Yes—performed by wayside safety control system.	Yes—directly applicable to long stator systems.
4. Schedule Control		
a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed commands verified by wayside safety control system.	Yes—directly applicable to long stator systems.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations) a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.
b. Determine stopping location of train and distance to go	Can be determined in wayside safety control system.	Yes—if function exists.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	Yes—see response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Undetermined, but may be possible in wayside safety control system.	Undetermined.
e. May need to determine accurate location in station area—obtain input from sensing devices	Undetermined.	Undetermined.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—related speed command generated in wayside safety control system.	Yes—directly applicable to long stator systems.
6. Station Departing (and start-up) a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Undetermined, but may be possible via safety control system.	Undetermined.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Yes—train speed and location information determined on-board.	Yes.
7. Siding Utilization a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Undetermined, but may be possible via safety control system.	Undetermined.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Undetermined, but may be possible via safety control system.	Undetermined.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Undetermined, but may be possible via safety control system.	Undetermined.
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Yes—certain on-board equipment monitored; specific items or failures/conditions monitored are undetermined.	Yes—failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Yes—speed command and/or braking can be controlled by wayside safety control system.	Yes—directly applicable to long stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	Yes—see response to I.A.1.a.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—can be performed by safety control system.	Yes—directly applicable to long stator systems.
B. Encoding/Transmission of Critical Information		
1. Encode/transmit speed command to point of utilization	Yes—commands encoded via safety control system and sent to long stator elements.	Yes—directly applicable to long stator systems.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Yes—safety critical information sent from trains to safety control system via on-board antenna and leaky coaxial cables.	Yes—directly applicable to long stator systems.
C. Decoding/Validation of Critical Information		
1. Decode/validate speed command prior to utilization	Command generated and utilized at wayside.	Yes—directly applicable to long stator systems.
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Command generated and utilized at wayside.	Yes—directly applicable to long stator systems.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. Decode other critical information (e.g., speed, location)	Yes—train speed and location decoded by wayside safety control system.	Yes.
II. <u>Safe Speed Enforcement</u>		
A. Providing Overspeed Protection		
1. Determine actual speeds of trains—values determined must not be less than true value	Yes—see response to I.A.2.c.	Yes—see response to I.A.2.c.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—comparison done by wayside safety control system.	Yes.
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—specific responses undetermined, but safety control system controls braking via long stator elements and via brake control signals to train.	Yes—directly applicable to long stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Yes—train speed and location information available on-board.	Yes—directly applicable to long stator systems.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Yes—certain on-board equipment monitored; specific items and/or failures/conditions monitored are not determined.	Yes—directly applicable to long stator systems; specific items and/or failures/conditions to be monitored should be determined.
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—wayside safety control system controls braking (wayside and on-board) accordingly.	Yes—directly applicable to long stator systems.
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Yes—train speed and location information available on-board.	Yes—directly applicable to long stator systems.
C. Encoding/Transmission of Critical Information		
1. Transmit actual speed and location information to points of utilization—encode if necessary	Yes—train speed and location information sent from train to wayside safety control system via on-board antenna and leaky coaxial cable.	Yes—directly applicable to long stator systems.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Yes—brake control signals sent from safety control system to long stator elements and to train (via inductive loop).	Yes—directly applicable to long stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Yes—information available on-board.	Yes—directly applicable to long stator systems.
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Yes—performed by wayside safety control system.	Yes—directly applicable to long stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Yes—brake control signals from safety control system decoded on-board; other braking/propulsion signals used on wayside.	Yes—directly applicable to long stator systems.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Specific responsive action by on-board equipment is undetermined; safety control system on wayside directly controls braking/propulsion via long stator elements.	Yes—if function exists.

TABLE B-3. LINEAR EXPRESS MAGLEV SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Yes—brake control signals sent from safety control system to long stator elements and to train (via inductive loop).	Yes—directly applicable to long stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Yes—information available on-board.	Yes—directly applicable to long stator systems.
D. Decoding/Validation of Critical Information 1. Decode actual speed and location information	Yes—performed by wayside safety control system.	Yes—directly applicable to long stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Yes—brake control signals from safety control system decoded on-board; other braking/propulsion signals used on wayside.	Yes—directly applicable to long stator systems.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Specific responsive action by on-board equipment is undetermined; safety control system on wayside directly controls braking/propulsion via long stator elements.	Yes—if function exists.

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. <u>Safe Speed Command Generation</u> A. Determination/Production of Command Speed 1. Civil Speed Restriction a. Determine location of train	Yes—performed on wayside via track circuits and wheel/axle shunting; precise location calculated on-board via intermittent signals from inductive loops and tachometers.	No—wheel/axle shunting and use of tachometers are unacceptable.
b. Assign/restrict speed command based on train location and associated stored values	Yes—taken into account by wayside equipment in generation of speed limit and target distance.	Yes—best suited to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—taken into account by wayside equipment in generation of speed limit and target distance.	Yes—best suited to short stator systems.
2. Headway Control a. Determine locations of, distance between, and direction of trains	Yes—distance between and direction of trains determined on wayside based on information from track circuits.	Yes—as long as train location is determined by some other means.
b. Recognize normal braking capabilities/characteristics	Yes—recognized on-board in calculation of maximum allowable speed.	Yes—best suited to short stator systems.

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—calculated on-board based on signals from tachometers.	No—tachometers are unacceptable.
d. Assign/restrict speed command accordingly	Yes—wayside generates speed limit and associated target distance, and on-board equipment generates max allowable speed.	Yes—best suited to short stator systems.
3. Route Integrity a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—wayside equipment obtains inputs from interlocking and other route integrity equipment.	Yes.
b. Recognize normal braking capabilities/characteristics	Yes—recognized on-board.	Yes—best suited to short stator systems.
c. Assign/restrict speed command accordingly	Yes—wayside equipment generates speed limit and associated target distance.	Yes—best suited to short stator systems.
4. Schedule Control a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed commands checked and considered in generation of speed limit and target distance.	Yes—best suited to short stator systems.

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—performed by wayside equipment and considered in generation of speed limit and target distance.	Yes—best suited to short stator systems.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	No—see response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—performed on-board.	Yes—best suited to short stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Yes—train gets accurate location information from inductive loops.	Yes—best suited to short stator systems.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—on-board equipment calculates instantaneous maximum allowable speed command.	Yes—best suited to short stator systems.
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—performed together by wayside (speed limit and target distance) and on-board equipment (maximum speed command); the latter takes into account readiness to proceed based on e.g., doors closed.	Yes—best suited to short stator systems.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Train speed determined on-board but not available at wayside.	No—tachometers are unacceptable.
7. Siding Utilization		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—considered by wayside equipment when generating speed limit and target distance.	Yes—best suited to short stator systems.

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—see response to I.A.6.b.	Yes—see response to I.A.6.b.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Undetermined—but most likely taken into account by on-board equipment when generating maximum allowable speed limit.	Undetermined, but best suited to short stator systems (if function exists).
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Yes—certain on-board equipment (e.g., braking systems) monitored; specific items/ failures/conditions monitored are not determined.	Yes— best suited for short stator systems; specific items/failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Yes—considered by on-board equipment in generation of maximum allowable speed; may require some input by train operator.	Yes—best suited to short stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—performed by wayside equipment in generation of speed limit and target distance.	Yes—best suited to short stator systems.
B. Encoding/Transmission of Critical Information		
1. Encode/transmit speed command to point of utilization	Yes—speed limit and target distance sent to trains via track circuits.	No—conventional track circuits are unacceptable.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Other critical information utilized directly on-board.	Yes—best suited to short stator systems.
C. Decoding/Validation of Critical Information		
1. Decode/validate speed command prior to utilization	Yes—on-board equipment decodes speed limit and target distance information from wayside; validation undetermined, but most likely occurs.	Yes—best suited to short stator systems.
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Specific response undetermined, but both braking and propulsion can be controlled accordingly.	Undetermined, but best suited to short stator systems (if function exists).

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. Decode other critical information (e.g., speed, location)	Other information used directly on-board.	Yes—best suited to short stator systems.
II. Safe Speed Enforcement A. Providing Overspeed Protection 1. Determine actual speeds of trains—values determined must not be less than true value	Yes—see response to I.A.2.c.	No—see response to I.A.2.c.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—performed on-board (compares actual speed with generated maximum allowable speed).	Yes—best suited to short stator systems.
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—on-board equipment initiates braking accordingly, and can also remove propulsion.	Yes—best suited to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is controlled only on-board; speed and location information is available.	Yes—best suited to short stator systems.

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Such failures/conditions are undetermined.	Undetermined; specific items/failures/conditions to be monitored should be defined.
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Specific actions are undetermined, but braking and propulsion can be controlled on-board.	Undetermined, but best suited to short stator systems (if function exists).
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is directly controlled on-board, where speed and precise location information is available.	Yes—best suited to short stator systems.
C. Encoding/Transmission of Critical Information		
1. Transmit actual speed and location information to points of utilization—encode if necessary	Train speed and (precise) location information determined and used directly on-board.	Yes—best suited to short stator systems.

TABLE B-4. TGV NORD HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Braking/propulsion control signals generated directly on-board.	Yes—best suited to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Braking is directly controlled on-board, where speed and precise location information is available.	Yes—best suited to short stator systems.
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Train speed and location information determined and used directly on-board.	Yes—best suited to short stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Braking/propulsion control signals generated directly on-board; validation not necessary.	Not applicable.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Validation not performed—responsive action not applicable.	No applicable.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. <u>Safe Speed Command Generation</u>		
A. Determination/Production of Command Speed		
1. Civil Speed Restriction		
a. Determine location of train	Yes—performed on wayside via track circuits and wheel/axle shunting; precise location calculated on-board via signals from pulse generators.	No—wheel/axle shunting and use of pulse generators are unacceptable.
b. Assign/restrict speed command based on train location and associated stored values	Yes—taken into account by wayside equipment in generation of braking curve, and distance to next stopping point.	Yes—best suited to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—taken into account by wayside equipment in generation of braking curve and distance to next stopping point.	Yes—best suited to short stator systems.
2. Headway Control		
a. Determine locations of, distance between, and direction of trains	Yes—distance between and direction of trains determined on wayside based on information from track circuits.	Yes—as long as train location is determined by some other means.
b. Recognize normal braking capabilities/characteristics	Yes—recognized on wayside in generation of braking curve, and on-board in generation of speed command.	Yes—best suited to short stator systems.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—calculated on-board via signals from pulse generators.	No—pulse generators are unacceptable.
d. Assign/restrict speed command accordingly	Yes—wayside generates braking curve and distance to next stop while on-board equipment generates actual speed command.	Yes—best suited to short stator systems.
3. Route Integrity a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—wayside equipment obtains inputs from interlocking and other route integrity equipment.	Yes.
b. Recognize normal braking capabilities/characteristics	Yes—recognized by wayside and on-board equipment.	Yes—best suited to short stator systems.
c. Assign/restrict speed command accordingly	Yes—wayside generates braking curve and distance to next stop, and on-board equipment generates speed command.	Yes—best suited to short stator systems.
4. Schedule Control a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests considered in generation of braking curve and distance to next stop by wayside equipment.	Yes—best suited to short stator systems.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—performed by wayside equipment and considered in generation of braking curve and, especially, distance to next stop.	Yes—best suited to short stator systems.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	No—see response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—recognized on-board and at wayside.	Yes—best suited to short stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Undetermined.	Undetermined.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—wayside generates braking curve and distance to next stop while on-board generates speed command.	Yes—best suited to short stator systems.
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—performed together by wayside (braking curve and distance to next stop) and on-board equipment (speed command); the latter takes into account readiness to proceed based on e.g., doors closed.	Yes—best suited to short stator systems.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Train speed determined on-board but not available at wayside.	No—pulse generators are unacceptable.
7. Siding Utilization		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—taken into account by wayside equipment when generating braking curve and distance to next stop.	Yes—best suited to short stator systems.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—see response to I.A.6.b.	Yes—see response to I.A.6.b.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Undetermined—but most likely taken into account by on-board equipment when generating speed command.	Undetermined, but best suited to short stator systems (if function exists).
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Yes—certain on-board equipment (e.g., braking and control systems) monitored; specific items/failures/conditions monitored are not defined; may require input by train operator.	Yes—best suited to short stator systems; specific items/failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Yes—considered by both wayside and on-board equipment.	Yes—best suited to short stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—performed by wayside equipment in generation of braking curve and distance to next stop.	Yes—best suited to short stator systems.
B. Encoding/Transmission of Critical Information 1. Encode/transmit speed command to point of utilization	Yes—braking curve and distance to next stop sent to trains via inductive loops.	Yes—best suited to short stator systems.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Yes—train speed and location information generated and used directly on train and at wayside, respectively; certain equipment failure status sent to wayside via inductive loops.	Yes—best suited to short stator systems.
C. Decoding/Validation of Critical Information 1. Decode/validate speed command prior to utilization	Yes—on-board equipment decodes braking curve and distance to next stop information from wayside; validation undetermined, but most likely occurs.	Yes—best suited to short stator systems.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Specific response undetermined, but both braking and propulsion can be controlled accordingly.	Undetermined, but best suited to short stator systems.
3. Decode other critical information (e.g., speed, location)	Other information used directly on-board.	Yes—best suited to short stator systems.
II. Safe Speed Enforcement		
A. Providing Overspeed Protection		
1. Determine actual speeds of trains—values determined must not be less than true value	Yes—see response to I.A.2.c.	No—see response to I.A.2.c.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—performed on-board (compares actual speed with generated speed command).	Yes—best suited to short stator systems.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—on-board equipment initiates braking accordingly, and can also remove propulsion (not confirmed).	Yes—best suited to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is controlled only on-board, where speed and precise location information is available.	Yes—best suited to short stator systems.
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Such failures/conditions are undetermined.	Undetermined; specific items/failures/conditions to be monitored should be defined.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Specific actions are undetermined, but braking and propulsion can be controlled on-board.	Yes—best suited to short stator systems (if function exists).
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is directly controlled on-board, where speed and precise location information is available	Yes—best suited to short stator systems.
C. Encoding/Transmission of Critical Information		
1. Transmit actual speed and location information to points of utilization—encode if necessary	Train speed information used on-board while location information used at wayside.	Yes—best suited to short stator systems.
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Braking/propulsion control signals generated and used directly on-board.	Yes—best suited to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Braking is directly controlled on-board where speed and precise location information is available.	Yes—best suited to short stator systems.

TABLE B-5. ICE HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
D. Decoding/Validation of Critical Information 1. Decode actual speed and location information	Train speed information used on-board while location information used at wayside.	Yes—best suited to short stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Braking/propulsion control signals generated directly on-board; validation not necessary.	Not applicable.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Validation not performed—responsive action not applicable.	Not applicable.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. <u>Safe Speed Command Generation</u> A. Determination/Production of Command Speed 1. Civil Speed Restriction a. Determine location of train	Yes—performed on wayside via DC track circuits and wheel/axle shunting.	No—wheel/axle shunting is unacceptable.
b. Assign/restrict speed command based on train location and associated stored values	Yes—speed limit commands pre-established and encoded in track bed transponders.	Yes—best suited to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—wayside equipment encodes associated speed limits into transponders.	Yes—best suited to short stator systems.
2. Headway Control a. Determine locations of, distance between, and direction of trains	Yes—distance between and direction of trains determined by wayside equipment based on information from track circuits.	Yes—as long as train location is determined by some other means.
b. Recognize normal braking capabilities/characteristics	Yes—recognized on wayside in generation of speed limit, and on-board in generation of maximum allowable speed.	Yes—best suited to short stator systems.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—calculated on-board via signals from tachometers.	No—tachometers are unacceptable.
d. Assign/restrict speed command accordingly	Yes—wayside generates speed limits and distance to next information point and on-board generates maximum allowable speed.	Yes—best suited to short stator systems.
3. Route Integrity		
a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—wayside obtains inputs from interlocking and other route integrity equipment.	Yes.
b. Recognize normal braking capabilities/characteristics	Yes—recognized by wayside and in generation of speed limits.	Yes—best suited to short stator systems.
c. Assign/restrict speed command accordingly	Yes—wayside generates speed limits and distance to next information point, and on-board generates maximum allowable speed.	Yes—best suited to short stator systems.
4. Schedule Control		
a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests considered by wayside equipment in generation of speed limits.	Yes—best suited to short stator systems.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—stopping location and distance to go encoded in fixed wayside transponders.	Yes—best suited to short stator systems.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	No—see response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—recognized by wayside and on-board equipment.	Yes—best suited to short stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Undetermined, but may be done with additional transponders.	Undetermined.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—wayside generates speed limits and distance to next information point while on-board generates maximum allowable speed.	Yes—best suited to short stator systems.
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—performed by wayside (speed limits) and on-board (max allowable speed); the latter considers readiness to proceed based on e.g., doors closed.	Yes—best suited to short stator systems.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Train speed determined on-board but not available at wayside.	No—tachometers (for speed) are unacceptable.
7. Siding Utilization		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—considered by wayside in generation of speed limits and distance to next information point.	Yes—best suited to short stator systems.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—see response to I.A.6.b.	Yes—see response to I.A.6.b.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Undetermined—but most likely taken into account by on-board equipment in generation of max allowable speed.	Undetermined, but best suited to short stator systems (if function exists).
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Braking capacity is monitored, but other specific items/failures/conditions monitored are undetermined; may require input by train operator.	Undetermined; specific items/failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Yes—braking abnormalities considered by on-board equipment in generation of maximum allowable speed; reactions to other conditions undetermined.	Undetermined, but best suited to short stator systems (if functions exist).
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	No—see response to I.A.1.a.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—performed by wayside equipment in generation of speed limits and distance to next information point.	Yes—best suited to short stator systems.
B. Encoding/Transmission of Critical Information 1. Encode/transmit speed command to point of utilization	Yes—speed limit and distance to next information point encoded and sent to trains via transponders.	Yes—best suited to short stator systems.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Other information generated and utilized directly either on-board or at wayside.	Yes—best suited to short stator systems.
C. Decoding/Validation of Critical Information 1. Decode/validate speed command prior to utilization	Yes—on-board equipment decodes and validates speed limit information received from wayside transponder.	Yes—best suited to short stator systems.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Specific response is undetermined, but both braking and propulsion can be controlled accordingly.	Undetermined, but would be best suited to short stator systems.
3. Decode other critical information (e.g., speed, location)	Other information utilized directly on-board or at wayside.	Yes—best suited to short stator systems.
II. <u>Safe Speed Enforcement</u> A. Providing Overspeed Protection 1. Determine actual speeds of trains—values determined must not be less than true value	Yes—see response to I.A.2.c.	No—see response to I.A.2.c.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—on-board equipment compares actual speed with generated maximum allowable speed (based on speed limits, distance to next information point, and train characteristics).	Yes—best suited to short stator systems.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—on-board equipment initiates braking accordingly, and can remove propulsion (not confirmed).	Yes—best suited to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is controlled only on-board, where speed and stopping location information is available.	Yes—best suited to short stator systems.
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Such failures/conditions are undetermined.	Undetermined; specific items and/or failures/conditions to be monitored should be defined.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Specific actions are undetermined, but braking and propulsion can be controlled on-board.	Undetermined, but would be best suited to short stator systems (if function exists).
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is directly controlled on-board, where speed and stopping location information is available.	Yes—best suited to short stator systems.
C. Encoding/Transmission of Critical Information		
1. Transmit actual speed and location information to points of utilization—encode if necessary	Train speed and location information generated and used on-board and at wayside, respectively.	Yes—best suited to short stator systems.
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Braking/propulsion control signals generated and used directly on-board.	Yes—best suited to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Braking is controlled directly on-board, where speed and stopping location information is available.	Yes—best suited to short stator systems.

TABLE B-6. X2000 HIGH SPEED SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Train speed and location information generated and used on-board and at wayside, respectively.	Yes—best suited to short stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Braking/propulsion control signals generated directly on-board; validation not necessary.	Not applicable.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Validation not performed—responsive action not applicable.	No applicable.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. Safe Speed Command Generation		
A. Determination/Production of Command Speed		
1. Civil Speed Restriction		
a. Determine location of train	Yes—performed on wayside via coded track circuits and brushes (collector shoes) on vehicle.	Yes, but only if brushes can operate reliably at higher speeds.
b. Assign/restrict speed command based on train location and associated stored values	Yes—wayside generates speed commands accordingly.	Yes—best suited to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—wayside restricts speed commands accordingly.	Yes—best suited to short stator systems.
2. Headway Control		
a. Determine locations of, distance between, and direction of trains	Yes—distance between and direction of trains determined on wayside via information from track circuits.	Yes—as long as brushes can operate at higher speeds to determine train location.
b. Recognize normal braking capabilities/characteristics	Yes—recognized by wayside in generation of speed commands.	Yes—best suited to short stator systems.
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—determined on-board via tachometers.	No—tachometers are unacceptable.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
d. Assign/restrict speed command accordingly	Yes—wayside generates speed command accordingly.	Yes—best suited to short stator systems.
3. Route Integrity		
a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—wayside obtains inputs from interlockings and other route integrity equipment.	Yes.
b. Recognize normal braking capabilities/characteristics	Yes—recognized by wayside equipment in generation of speed command.	Yes—best suited to short stator systems.
c. Assign/restrict speed command accordingly	Yes—wayside generates speed command accordingly.	Yes—best suited to short stator systems.
4. Schedule Control		
a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests considered by wayside equipment in generation of speed command.	Yes—best suited to short stator systems.
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Determine stopping location of train and distance to go	Yes—determined in wayside equipment.	Yes.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	See response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—recognized by wayside equipment in generation of speed command.	Yes—best suited to short stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Yes—programmed station stop antenna on vehicle and inductive cable with crossovers used for precise location.	Yes—best suited to short stator systems.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—wayside generates speed command, but ATO generates stop profile (not safety critical).	Yes—best suited to short stator systems.
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—wayside issues speed command based on applicable considerations (e.g., headway, route integrity, clearances), while train controls braking/propulsion based on e.g., doors closed.	Yes—best suited to short stator systems.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Train speed determined on-board but not available at wayside.	No—if train speed information is indeed needed on wayside.
7. Siding Utilization a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—considered by wayside in generation of speed command.	Yes—best suited to short stator systems.
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—see response to I.A.6.b.	Yes—see response to I.A.6.b.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Undetermined.	Undetermined.
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Certain on-board equipment (e.g., tachometers) is monitored, but other items or failures/conditions monitored are undetermined; alarm conditions sent via radio to central.	Undetermined; specific items/failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Responses to abnormal conditions undetermined, but central equipment can request speed reduction.	Undetermined.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—performed by wayside equipment.	Yes—best suited to short stator systems.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
B. Encoding/Transmission of Critical Information		
1. Encode/transmit speed command to point of utilization	Yes—speed command encoded and sent from wayside to train inductively via signal rails and on-board antenna.	Yes—best suited to short stator systems.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Other critical information generated and used either on-board or at wayside; failure status information sent via radio from trains to central (not safety critical in this application).	Yes—best suited to short stator systems.
C. Decoding/Validation of Critical Information		
1. Decode/validate speed command prior to utilization	Yes—on-board equipment decodes and validates speed command from wayside.	Yes—best suited to short stator systems.
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Yes—on-board equipment initiates braking and removes propulsion.	Yes—best suited to short stator systems.
3. Decode other critical information (e.g., speed, location)	Other critical information generated and used either on-board or at wayside.	Yes—best suited to short stator systems.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
II. <u>Safe Speed Enforcement</u>		
A. Providing Overspeed Protection		
1. Determine actual speeds of trains—values determined must not be less than true value	Yes—see response to I.A.2.c.	See response to I.A.2.c.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—on-board equipment makes comparison.	Yes—best suited to short stator systems.
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—on-board equipment initiates braking and removes propulsion.	Yes—best suited to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is controlled only on-board.	Yes—best suited to short stator systems.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Such failures/conditions are undetermined.	Undetermined; specific items/failures/conditions to be monitored should be defined.
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Specific actions are undetermined, but braking and propulsion can be controlled on-board.	Undetermined but would be best suited to short stator systems (if function exists).
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is directly controlled on-board.	Yes—best suited to short stator systems.
C. Encoding/Transmission of Critical Information		
1. Transmit actual speed and location information to points of utilization—encode if necessary	Train speed and location information generated and used on-board and at wayside, respectively.	Yes—best suited to short stator systems.

TABLE B-7. AEG-WESTINGHOUSE PEOPLE-MOVER SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Braking and propulsion control signals generated and used directly on-board, but wayside also can send emergency stop signal.	Yes—best suited to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Braking is controlled directly on-board.	Yes—best suited to short stator systems.
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Train speed and location information generated and used on-board and at wayside, respectively.	Yes—best suited to short stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Braking/propulsion control signals generated and used on-board, but emergency stop signal from wayside is decoded and validated as well.	Yes—best suited to short stator systems.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Validation performed on-board for emergency stop signal from wayside; invalid command itself results in braking.	Yes—best suited to short stator systems.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. <u>Safe Speed Command Generation</u>		
A. Determination/Production of Command Speed		
1. Civil Speed Restriction		
a. Determine location of train	Yes—determined on wayside via signals transmitted from train into a transmission line (positive detection), and ultrasonic transmitters and receivers (negative detection).	Yes—operation and accuracy at higher speeds should be confirmed.
b. Assign/restrict speed command based on train location and associated stored values	Yes—performed by modulated signal from wayside and fixed-transposition transmission line.	Yes—best suited to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—performed by modulated signal from wayside and fixed-transposition transmission line with request from central control.	Yes—best suited to short stator systems.
2. Headway Control		
a. Determine locations of, distance between, and direction of trains	Yes—determined on wayside.	Yes.
b. Recognize normal braking capabilities/characteristics	Yes—inherent in speed program transmission lines.	Yes—best suited to short stator systems.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—determined on-board via clocks and transpositions of signals in transmission line; also uses tachometers at very low speeds and phonic wheel in push-recovery mode.	Use of signal transpositions and on-board clocks may be acceptable (if proven at higher speeds), but tachometers and phonic wheels are not.
d. Assign/restrict speed command accordingly	Yes—performed by wayside via modulated signal and fixed-transposition transmission lines.	Yes—best suited to short stator systems.
3. Route Integrity		
a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—wayside obtains inputs on switch positions from interlocking equipment.	Yes.
b. Recognize normal braking capabilities/characteristics	Yes—inherent in speed program transmission lines.	Yes—best suited to short stator systems.
c. Assign/restrict speed command accordingly	Yes—performed by wayside via modulated signal and fixed-transposition transmission lines.	Yes—best suited to short stator systems.
4. Schedule Control		
a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests considered by wayside equipment.	Yes—best suited to short stator systems.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—inherent in transpositions of stopping program transmission line.	Yes—best suited to short stator systems.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	See response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—inherent in speed program transmission lines.	Yes—best suited to short stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Yes—determined via ultrasonic devices and transmission lines.	Yes—best suited to short stator systems.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—performed by wayside via modulated signal in selected fixed-transposition transmission line.	Yes—best suited to short stator systems.
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—performed by wayside in modulated signal to trains via transmission lines and on-board equipment (e.g., checks when doors closed).	Yes—best suited to short stator systems.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Train speed information is available on-board, but not at wayside.	No—if train speed information is indeed needed on wayside.
7. Siding Utilization a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—performed by wayside via modulated signal in fixed-transposition transmission line.	Yes—best suited to short stator systems.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—see response to I.A.6.b.	Yes—best suited to short stator systems.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Not performed since operation is fully automatic.	Not applicable.
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Certain on-board equipment is monitored, but all specific items or failures/conditions monitored are undetermined.	Undetermined; specific items/failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Specific responses to abnormal conditions undetermined, but wayside and/or on-board equipment can require speed reduction/braking.	Yes—best suited to short stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—performed by wayside equipment via modulated signal in fixed-transposition transmission line.	Yes—best suited to short stator systems.
B. Encoding/Transmission of Critical Information		
1. Encode/transmit speed command to point of utilization	Yes—speed commands sent by wayside via modulated signals in fixed-transposition transmission lines.	Yes—best suited to short stator systems.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Yes—train speed and location information generated and used on-board and at wayside respectively; equipment failure status sent via transmission line back to wayside (not in safety critical manner).	Yes—best suited to short stator systems.
C. Decoding/Validation of Critical Information		
1. Decode/validate speed command prior to utilization	Yes—on-board equipment demodulates and validates signals from wayside.	Yes—best suited to short stator systems.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Yes—invalid signal results in initiation of braking.	Yes—best suited to short stator systems.
3. Decode other critical information (e.g., speed, location)	Other critical information generated and used either on-board or at wayside.	Yes—best suited to short stator systems.
II. Safe Speed Enforcement A. Providing Overspeed Protection 1. Determine actual speeds of trains—values determined must not be less than true value	Yes—see response to I.A.2.c.	See response to I.A.2.c.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—on-board equipment checks timing of phase reversals with on-board checks to determine overspeed; tachometer signals and phonic wheels checked against commands at very low speeds.	Yes—basic concept is acceptable (generally from short stator systems), but use of tachometers and phonic wheels is not.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—emergency braking is initiated by on-board equipment if overspeed detected.	Yes—best suited to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is already directly controlled on-board.	Yes—best suited to short stator systems.
B. Responding to Failures/Faults and Abnormal Conditions 1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Such failures/conditions are undetermined.	Undetermined; specific items and failures/conditions to be monitored should be defined.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Specific actions are undetermined, but braking and propulsion can be controlled on-board.	Undetermined.
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is already directly controlled on-board.	Yes—best suited to short stator systems.
C. Encoding/Transmission of Critical Information 1. Transmit actual speed and location information to points of utilization—encode if necessary	Train speed and location information generated and used on-board and at wayside, respectively.	Yes—best suited to short stator systems.
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Yes—emergency braking signal from wayside results if no modulation exists in signal sent to train.	Yes—best suited to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Braking is already directly controlled on-board.	Yes—best suited to short stator systems.

TABLE B-8. VAL SYSTEM (LILLE) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Train speed and location information generated and used on-board.	Yes—best suited to short stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Yes—on-board equipment decodes signal from wayside, looking for presence or absence of modulation.	Yes—best suited to short stator systems.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Yes—emergency braking results in absence of modulation; removal of propulsion most likely occurs, but not confirmed.	Yes—best suited to short stator systems.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. <u>Safe Speed Command Generation</u>		
A. Determination/Production of Command Speed		
1. Civil Speed Restriction		
a. Determine location of train	Yes—determined on-board by VOBC via phase changes in signals due to transpositions in inductive cable (raw position) and signals from digital tachometers.	Partially—inductive cable scheme is applicable while use of tachometers is not; operation at higher speeds may need to be confirmed.
b. Assign/restrict speed command based on train location and associated stored values	Yes—wayside VCC determines maximum permitted speed and safe stopping point with associated target speed; VOBC calculates braking curve.	Yes—best suited to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—wayside VCC determines maximum permitted speed and safe stopping point with associated target speed; VOBC calculates braking curve.	Yes—best suited to short stator systems.
2. Headway Control		
a. Determine locations of, distance between, and direction of trains	Yes—location and direction of train determined on-board, while distance between trains determined in wayside VCC.	Yes—as long as tachometers are not used.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—determined on-board by VCC and digital tachometers.	No—tachometers are unacceptable.
d. Assign/restrict speed command accordingly	Yes—wayside VCC generates speed limit with safe stopping point and associated target speed; VOBC calculates braking curve.	Yes—best suited to short stator systems.
3. Route Integrity a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—wayside VCCs obtain inputs from interlockings and other VCCs.	Yes.
b. Recognize normal braking capabilities/characteristics	Yes—recognized by wayside VCC.	Yes—best suited to short stator systems.
c. Assign/restrict speed command accordingly	Yes—wayside VCC generates speed limit and safe stopping point with target speed.	Yes—best suited to short stator systems.
4. Schedule Control a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests considered by wayside VCC in generation of speed limit and safe stopping point with target speed.	Yes—best suited to short stator systems.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—determined in wayside VCC.	Yes
c. Determine speed of subject train	Yes—see response to I.A.2.c.	See response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—recognized by wayside VCC in generation of speed limit and safe stopping point with target speed.	Yes—best suited to short stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Undetermined, but sensing devices most likely used.	Undetermined
f. Assign/restrict speed command accordingly throughout stopping process	Yes—wayside VCC generates speed limit and safe stopping point with target speed, and VOBC generates braking profile.	Yes—best suited to short stator systems.
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—wayside VCC issues speed limit and safe stopping point with target speed based on applicable considerations, and VOBC releases brakes when ready to depart (e.g. doors closed).	Yes—best suited to short stator systems.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Actual train speed determined on-board and sent to wayside VCC as well.	Yes
7. Siding Utilization a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—considered by wayside VCC in generation of speed limit and safe stopping point will target speed.	Yes—best suited to short stator systems.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—see response to I.A.6.b.	Yes—see response to I.A.6.b.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Undetermined, but most likely considered in cab-signalling mode.	Undetermined
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Status of certain on-board equipment monitored, but specific items/failures/ conditions monitored are undetermined.	Undetermined; specific items/failures/conditions to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Specific responses to abnormal conditions undetermined, but wayside VCC can respond and control speed commands accordingly.	Yes—best suited to short stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—performed by wayside VCC.	Yes—best suited to short stator systems.
B. Encoding/Transmission of Critical Information 1. Encode/transmit speed command to point of utilization	Yes—speed limits and safe stopping points with target speeds are encoded at wayside VCC and sent to train via inductive cable.	Yes—best suited to short stator systems.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Yes—train location, speed, travel direction and failure status information encoded on-board and sent to VCC via inductive cable.	Yes—best suited to short stator systems.
C. Decoding/Validation of Critical Information 1. Decode/validate speed command prior to utilization	Yes—on-board VOBC decodes speed and safe stopping point information from wayside; extent of validation is undetermined.	Yes—best suited to short stator systems.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Specific responsive action is undetermined, but VOBC can inhibit generation of brake hold-off signal.	Yes—best suited to short stator systems.
3. Decode other critical information (e.g., speed, location)	Yes—speed, location and travel direction information from train decoded at wayside VCC.	Yes—best suited to short stator systems.
II. Safe Speed Enforcement		
A. Providing Overspeed Protection		
1. Determine actual speeds of trains—values determined must not be less than true value	Yes—see response to I.A.2.c.	See response to I.A.2.c.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—performed by on-board VOBC.	Yes—best suited to short stator systems.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—if overspeed detected, the VOBC inhibits generation of brake hold-off signal; removal of propulsion is also likely, but undetermined.	Yes—best suited to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is directly controlled only on-board.	Yes—best suited to short stator systems.
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Such failures/conditions are undetermined.	Undetermined; specific items/failures/ conditions to be monitored should be defined.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Specific actions are undetermined, but braking and propulsion can be controlled on-board.	Yes—best suited to short stator systems.
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is directly controlled only on-board.	Yes—best suited to short stator systems.
C. Encoding/Transmission of Critical Information		
1. Transmit actual speed and location information to points of utilization—encode if necessary	Train speed, location, equipment status and travel direction information encoded and sent to wayside VCC.	Yes—best suited to short stator systems.
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Braking and propulsion control signals generated on-board, but wayside can also command braking via inductive cable.	Yes—best suited to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Braking is directly controlled only on-board.	Yes—best suited to short stator systems.

TABLE B-9. VANCOUVER SKYTRAIN SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
D. Decoding/Validation of Critical Information 1. Decode actual speed and location information	Yes—train speed, location, equipment status and travel direction information decoded at wayside VCC.	Yes—best suited to short stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Braking and propulsion control signals generated and used on-board; validation not necessary.	Not applicable.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Validation not performed—responsive action not applicable.	Not applicable.

TABLE B-10. MARTA SYSTEM ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. Safe Speed Command Generation		
A. Determination/Production of Command Speed		
1. Civil Speed Restriction		
a. Determine location of train	Yes—determined on wayside via audio frequency track circuits and wheel/axle shunting.	No—conventional track circuits with wheel/ axle shunting is unacceptable.
b. Assign/restrict speed command based on train location and associated stored values	Yes—performed by wayside equipment in generation of coded speed command.	Yes—best suited to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—performed via wayside equipment in generation of coded speed command.	Yes—best suited to short stator systems.
2. Headway Control		
a. Determine locations of, distance between, and direction of trains	Yes—determined by wayside equipment based on information from track circuits.	No—track circuits with wheel/axle shunting is unacceptable.
b. Recognize normal braking capabilities/characteristics	Yes—recognized on wayside in generation of coded speed command.	Yes—best suited to short stator systems.
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—calculated on-board based on information from reluctance type speed sensor that senses gear motion.	No—sensing of gear motion is unacceptable.

TABLE B-10. MARTA SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
d. Assign/restrict speed command accordingly	Yes—wayside equipment generates coded speed command accordingly.	Yes—best suited to short stator systems.
3. Route Integrity		
a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—wayside track circuit equipment obtains inputs from interlocking equipment.	Yes
b. Recognize normal braking capabilities/characteristics	Yes—recognized by wayside equipment.	Yes—best suited to short stator systems.
c. Assign/restrict speed command accordingly	Yes—wayside equipment generates coded speed command accordingly.	Yes—best suited to short stator systems.
4. Schedule Control		
a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests verified by wayside equipment.	Yes—best suited to short stator systems.

TABLE B-10. MARTA SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.; however, information not used directly in station stopping routine.	See response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—on-board ATO equipment calculates such information based on data from markers (tuned coils) between rails.	Yes—best suited to short stator systems.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	See response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—recognized by on-board ATO equipment in generation of stopping profile.	Yes—best suited to short stator systems.
e. May need to determine accurate location in station area—obtain input from sensing devices	Yes—accurate location conveyed to train via markers between rails.	Yes—best suited to short stator systems.
f. Assign/restrict speed command accordingly throughout stopping process	Yes—performed by on-board ATO equipment in generation of stopping profile.	Yes—best suited to short stator systems.

TABLE B-10. MARTA SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Yes—train operator initiates departure when ready (e.g. doors closed; wayside issues coded speed command based on all applicable considerations.	Yes—best suited to short stator systems.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Train speed determined and used on-board, but not available at wayside.	No—speed sensors based on gear motion is unacceptable.
7. Siding Utilization		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—taken into account by wayside equipment in generation of coded speed command.	Yes—best suited to short stator systems.

TABLE B-10. MARTA SYSTEM ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—see response to I.A.6.b.	Yes—see response to I.A.6.b.
8. Manual Train Operation		
a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Yes—taken into account by wayside equipment in generation of coded speed commands; also, built into system via block lengths.	Yes—best suited to short stator systems.
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Yes—certain on-board equipment that affects safety is monitored; specific items/ conditions/failures monitored are not defined.	Yes—best suited to short stator systems; specific items/conditions/failures to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Yes—on-board equipment initiates braking in response to detected safety-related failure; other equipment status sent to wayside/central.	Yes—best suited to short stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.

TABLE B-10. MARTA SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—performed by wayside equipment in generation of speed command, based on all applicable considerations.	Yes—best suited to short stator systems.
B. Encoding/Transmission of Critical Information		
1. Encode/transmit speed command to point of utilization	Yes—coded speed command sent to train via rails and on-board antenna.	No—use of rails is unacceptable.
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Yes—train speed and equipment failure status information generated and used directly on-board; location information generated and used on wayside.	Yes—best suited to short stator systems.
C. Decoding/Validation of Critical Information		
1. Decode/validate speed command prior to utilization	Yes—on-board equipment decodes/validates speed command from wayside.	Yes—best suited to short stator systems.
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Yes—braking initiated and propulsion removed via on-board equipment in presence of invalid command or absence of command.	Yes—best suited to short stator systems.

TABLE B-10. MARTA SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
3. Decode other critical information (e.g., speed, location)	Other critical information used directly either on-board or at wayside.	Yes—best suited to short stator systems.
II. Safe Speed Enforcement		
A. Providing Overspeed Protection		
1. Determine actual speeds of trains—values determined must not be less than true value	Yes—see response to I.A.2.c.	See response to I.A.2.c.
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—on-board equipment compares actual speed with coded speed command from wayside.	Yes—best suited to short stator systems.
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—on-board equipment removes propulsion and initiates braking.	Yes—best suited to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is directly controlled on-board.	Yes—best suited to short stator systems.

TABLE B-10. MARTA SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Such failures/conditions are undetermined.	Undetermined; specific items/failures/ conditions to be monitored should be defined.
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Specific actions are undetermined, but braking and propulsion can be controlled on-board.	Yes—best suited to short stator systems (if function exists).
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Braking is directly controlled on-board.	Yes—best suited to short stator systems.
C. Encoding/Transmission of Critical Information		
1. Transmit actual speed and location information to points of utilization—encode if necessary	Train speed and location information used directly on-board and at wayside, respectively.	Yes—best suited to short stator systems.

TABLE B-10. MARTA SYSTEM ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Braking and propulsion control signals generated and used directly on-board.	Yes—best suited to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Braking is directly controlled on-board.	Yes—best suited to short stator systems.
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Train speed and location information used directly on-board and at wayside, respectively.	Yes—best suited to short stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Braking/propulsion control signals generated directly on-board in response to speed commands.	Not applicable.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Validation not performed—responsive action not applicable.	Not applicable.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
I. <u>Safe Speed Command Generation</u>		
A. Determination/Production of Command Speed		
1. Civil Speed Restriction		
a. Determine location of train	Yes—determined on-board via interrogators and track-bed transponders (for raw position) and axle generators (for fine position).	Partially—interrogators and transponders are applicable, but axle generators are not.
b. Assign/restrict speed command based on train location and associated stored values	Yes—central computer generates speed limit commands and movement authorities for sections of track.	Yes—best suited to short stator systems.
c. Impose temporary speed restriction (e.g., slow order) as necessary—specific location or system-wide	Yes—temporary restrictions requested at central and/or via track forces terminals; central computer converts to proper speed limit commands and movement authorities.	Yes—best suited to short stator systems.
2. Headway Control		
a. Determine locations of, distance between, and direction of trains	Yes—location and direction of trains determined on-board via interrogators, transponders and axle generators; distance between trains determined at central computer.	Partially—interrogators and transponders are applicable, but axle generators are not.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
b. Recognize normal braking capabilities/characteristics	Yes—recognized by central computer in generation of speed limit commands and movement authority, and by on-board equipment in calculation of desired speed and braking distance.	Yes—best suited to short stator systems.
c. May need to determine current speeds of trains (depends upon headway and closure policy)	Yes—calculated on-board via signals from dual axle generators.	No—use of axle generators is unacceptable.
d. Assign/restrict speed command accordingly	Yes—central computer generates speed limit command and movement authority for section of track.	Yes—best suited to short stator systems.
3. Route Integrity		
a. Obtain input on limit of route authority (intermittent or continual basis) from route integrity system	Yes—central computer obtains inputs on route integrity from wayside equipment.	Yes
b. Recognize normal braking capabilities/characteristics	Yes—recognized by central computer in generation of speed limit command and movement authority, and by on-board equipment in generation of speed and braking distance.	Yes—best suited to short stator systems.
c. Assign/restrict speed command accordingly	Yes—central computer generates speed limit command and movement authority for section of track.	Yes—best suited to short stator systems.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
4. Schedule Control		
a. Incorporate schedule considerations into speed command without producing less restrictive command than otherwise permitted	Yes—schedule related speed requests verified by central computer.	Yes—best suited to short stator systems.
5. Station Stopping (Note: May not be safety critical function—depends upon system operating philosophy including door control interface considerations)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. Determine stopping location of train and distance to go	Yes—stopping location inherent in movement authority sent to train from central computer; distance-to-go calculated on-board.	Yes—best suited to short stator systems.
c. Determine speed of subject train	Yes—see response to I.A.2.c.	See response to I.A.2.c.
d. Recognize normal braking capabilities/characteristics and maximum allowable deceleration limit	Yes—recognized by both central and on-board computer.	Yes—best suited to short stator systems.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
e. May need to determine accurate location in station area—obtain input from sensing devices	Can be done via additional transponders.	Yes (if function exists).
f. Assign/restrict speed command accordingly throughout stopping process	Yes—on-board computer calculates speed command and braking distance based on information (i.e. speed limit and movement authority) from central computer.	Yes—best suited to short stator systems.
6. Station Departing (and start-up)		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. Assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway and route integrity clearances; hold train until ready to depart	Central computer issues speed limit command and movement authority when conditions warrant; (door closure not applicable).	Yes—but interface needed with door control.
c. May need to determine adequate train speed is reached shortly after station departure—information may be needed both on-board and at wayside as part of performance check	Train speed information available both on-board and at central.	No—use of axle generators in determining train speed is unacceptable.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
7. Siding Utilization a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. When approaching, entering, and operating within siding, assign/restrict speed command based on all applicable considerations (e.g., headway, route integrity, civil speed)	Yes—performed by central computer in generation of speed limit commands and movement authority.	Yes—best suited to short stator systems.
c. When departing siding, assign/restrict speed command based upon readiness to proceed—e.g., doors closed, headway, and route integrity; hold train until ready to depart	Yes—performed by central computer in generation of speed limit commands and movement authority; (door closure not applicable).	Yes—best suited to short stator systems.
8. Manual Train Operation a. Consider human factor limitations of train operator (e.g., range of vision, response time) when assigning speed command	Yes—considered by central computer in generation of speed limit commands and movement authorities.	Yes—best suited to short stator systems.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
9. Failure/Fault Conditions		
a. Obtain input on status of critical equipment (e.g., braking, propulsion, and levitation)	Yes—status of certain on-board equipment can be sent to central computer; specific items/conditions/failures to be monitored are undetermined.	Yes—best suited to short stator systems; specific items/conditions/failures to be monitored should be defined.
b. Assign/restrict speed command based on abnormal condition	Central computer can issue speed limit command and movement authority as appropriate to train in response to abnormal condition.	Yes—best suited to short stator systems.
10. Yard Operations		
a. Determine train location	Yes—see response to I.A.1.a.	See response to I.A.1.a.
b. Assign/restrict speed command according to all applicable requirements (e.g., headway, route integrity, civil speed)	Yes—performed by central computer.	Yes—best suited to short stator systems.
B. Encoding/Transmission of Critical Information		
1. Encode/transmit speed command to point of utilization	Yes—speed limit commands and movement authority encoded and sent via radio from central computer to trains.	Yes—best suited to short stator systems.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Encode/transmit other critical information (e.g., actual speed, train location, equipment failure status) to points of utilization	Yes—other critical information encoded and sent via radio from trains to central computer.	Yes—best suited to short stator systems.
C. Decoding/Validation of Critical Information 1. Decode/validate speed command prior to utilization	Yes—speed limit commands and movement authority decoded on-board; degree of validation is undetermined.	Yes—best suited to short stator systems.
2. If invalid speed command detected, initiate appropriate responsive action by applying braking and removing propulsion—will be necessary to override normal commands, and may need to be irrevocable (system specific)	Validation undetermined, but braking and propulsion can be controlled on-board as appropriate.	Yes—best suited to short stator systems.
3. Decode other critical information (e.g., speed, location)	Yes—train speed, location and failure status information decoded at central.	Yes—best suited to short stator systems.
II. <u>Safe Speed Enforcement</u> A. Providing Overspeed Protection 1. Determine actual speeds of trains—values determined must not be less than true value	Yes—train speed calculated by on-board computer via signals from dual axle generators.	No—use of axle generators is unacceptable.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Detect overspeed conditions (within allowable tolerances) by comparing actual and command speeds	Yes—performed in on-board computer.	Yes—best suited to short stator systems.
3. If overspeed detected, initiate response action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Yes—if operator does not reduce speed, propulsion is reduced (removed) and braking is initiated.	Yes—best suited to short stator systems.
4. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Such information is already available on-board and at central.	Yes—best suited to short stator systems.
B. Responding to Failures/Faults and Abnormal Conditions		
1. Detect failures or abnormal conditions (e.g., improper direction of travel if not otherwise detected) that do not affect command speed or overspeed detection functions, but still could be unsafe	Such failures/conditions are undetermined.	Undetermined; specific items/failures/ conditions to be monitored should be defined.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT
(Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
2. Initiate appropriate responsive action by applying braking (service, emergency, or combination) within safe deceleration limit and removing propulsion—will need to override normal commands, and may be irrevocable	Specific actions are undetermined, but braking and propulsion can be controlled on-board or central.	Undetermined; but actions would be best suited to short stator systems.
3. May need train speed, location, and other information on-board if braking is controlled on-board as well as wayside/central	Such information is already available on-board and at central.	Yes—best suited to short stator systems.
C. Encoding/Transmission of Critical Information 1. Transmit actual speed and location information to points of utilization—encode if necessary	Yes—train speed, location and certain equipment status information encoded and sent to central from trains.	Yes—best suited to short stator systems.
2. Transmit overriding braking/propulsion control signals to points of utilization—encode if necessary	Braking and propulsion control signals generated and used directly on-board.	Yes—best suited to short stator systems.
3. May need speed and location information on-board as well as at wayside/central from controlled braking	Such information is already available on-board and at central.	Yes—best suited to short stator systems.

TABLE B-11. ADVANCED TRAIN CONTROL SYSTEM (ATCS) ASSESSMENT (Continued)

Requirement/Need	Capability Exists in Present Application	Applicable to U.S. Maglev System
D. Decoding/Validation of Critical Information		
1. Decode actual speed and location information	Yes—such information decoded at central.	Yes—best suited to short stator systems.
2. Decode overriding braking/propulsion control signals—validate if necessary	Braking/propulsion control signals generated and used directly on-board; validation not performed.	Not applicable.
3. If invalid signals detected, initiate responsive action by applying braking and removing propulsion—both are to override normal commands, and may be irrevocable (system specific)	Validation not performed—responsive action not applicable.	Not applicable.

APPENDIX C

GLOSSARY

Evaluation of Concepts for Safe Speed
Enforcement, US DOT, NMI, JF Luedeke, 1992 -11-
Advanced Systems