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of Transportation
Federal Railroad Administration

Safety of High Speed Guided Ground Transportation Systems

Office of Research
and Development
Washington, D.C. 20590

Work Breakdown Structure

DOT/FRA/ORD-94/03

Final Report
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13. ABSTRACT (Maximum 200 words)

This report provides a systems approach to the assessment, evaluation, and application of high-speed guided ground transportation (HSGGT) safety criteria and presents one potential methodology by combining a work breakdown structure (WBS) approach with an interface evaluation methodology. By systems approach it is meant that safety considerations and criteria are tied to an HSGGT structural concept and are addressed from the highest level of a system hierarchy downward in a WBS. Safety criteria can then be logically associated with each system structure. This is a departure from the traditional approach of assessing safety issues individually and in isolation of other factors.

The generic work breakdown structure (WBS) developed by The Defense Systems Management College and outlined in its publication, *System Engineering Management Guide*, was selected to structure the complex configurations of a generic maglev system and a generic high speed rail (HSR) system. Both WBS provide a system approach to the assessment of the need for and application of safety regulations in the field of high-speed guided ground transportation (HSGGT). A typical generic WBS is composed of segments, elements, subsystems, and components, but the maglev and HSR WBS presented in this report are defined to the subsystem level only, allowing for further lower level definitions at a later time.

Each WBS is organized on the basis of providing mutually exclusive segments on a technological basis, at least to the maximum extent that is reasonable. A methodology known as n-1 is used to describe a means to create diagrams that depict the interface between segments, elements, and subsystems. A total of 129 subsystems are identified for a generic maglev system and 118 are identified for a generic HSR system.

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PREFACE

This report provides a systems approach to the assessment of high-speed guided ground transportation (HSGGT) safety needs and presents one potential methodology by combining a work breakdown structure (WBS) with an interface evaluation methodology. Through a total system approach, this report ties safety issues to an HSGGT structural concept and presents them from the highest level of a system hierarchy downward in a WBS.

This report was prepared in support of the United States Department of Transportation, Federal Railroad Administration's (FRA) Office of Research and Development. The author wishes to thank Mr. Arne J. Bang of the FRA Office of Research and Development for his thoughtful direction, helpful guidance and input during the preparation of this document.

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METRIC/ENGLISH CONVERSION FACTORS

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

INCHES	0	1	2	3	4	5	6	7	8	9	10															
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

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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INTRODUCTION

The ongoing development and implementation of high-speed guided ground transportation (HSGGT) systems in the United States make it very important that HSGGT safety concerns, as well as existing safety regulations, be examined to determine their adequacy for passenger equipment operating at speeds above 177 km/h (110 mph). Real and conceptual HSGGT systems may have many purposes, usages, concepts, forms, shapes, methods, requirements, and specifications, while incorporating numerous state-of-the-art technologies with operational capabilities significantly higher than rail equipment now in service.

This report provides a system approach to the assessment of high-speed guided ground transportation safety needs and presents one potential methodology by combining a work breakdown structure (WBS) with an interface evaluation methodology. By system approach, it is meant that safety issues are tied to an HSGGT structural concept and are addressed from the highest level of a system hierarchy downward in a WBS. This is a departure from the traditional approach of assessing safety issues individually and in isolation of other factors.

SYSTEMS APPROACH

System is a commonly used word in HSGGT projects and, therefore, must be properly defined. The word occurs often because a typical HSGGT project consists of many systems. Within the scope of HSGGT engineering it becomes evident that the term *system* may mean different things to different people. In this case *system* may be classified as a relative term and it is important to put it in perspective. For example, *system* once had a more absolute morphological relationship of components than it does today. In simplistic cases system decomposition involved only subsystems and components.

Why the need for a systems approach? The answer lies in the fact that proposed HSGGT projects are complex and involve many critical system interactions. The integration, design, and construction of these systems embodies an expensive megaproject whose overall design involves many trade-offs to achieve safe, high system performance levels at reasonable costs. More important, HSGGT projects involve the integration of new technologies to yield substantial improvements in ground transportation productivity, and their incorporation may yield safety concerns.

An HSGGT system, whether rail or maglev, may be described as a system wherein all of the parts must be suitably matched to yield optimal performance. This is important because of the critical manner in which some major units of the system interact. Interactions such as those between high-speed rail (HSR) vehicles and track curvature, running surface smoothness, signal systems, and power supply are apparent. Although disregard of these interactions may seriously degrade operational safety in any rail system, the consequences may be catastrophic at very high speeds. An approach to the assessment of interactions is presented later in Part III, Safety at System Segment, Element, and Subsystem Interfaces.

HSGGT ARCHITECTURE

Before any significant development can begin on a system, it is necessary to organize its functional units for management purposes. A definition of key terms must be established so that a common understanding of the system and its breakdown into lower levels can be developed in order to understand the basis and impact of the system hierarchy. One of the better definitions of a system is found in the U.S. Army field manual, FM-770-78:

> "A composite of equipment, skills and techniques capable of performing and/or supporting an operational role. A complete system includes related facilities, equipment, material, services, software, technical data, procedures, and personnel required for its operation and support to the degree that it can be considered a self-sufficient unit in its intended operational and/or support environment. The system is what is employed operationally and supported logistically."

GENERIC HSGGT ARCHITECTURE

For conceptual clarity, an HSGGT system may be defined as a *system of systems*, and as such a generic system architecture can be structured for it. This architecture is presented in hierarchial form (Figure 1). The overall system structure involves System Segments, System Elements, Subsystems, and perhaps, Components and Piece Parts.[1] To keep the work within scope the subsystem level is the lowest level defined.

In the context of a *system-of-systems* definition, an overview of a generic HSGGT system architecture provides an aid to understanding the system hierarchy/structure issue and the importance of system interface requirements and relationships. From this point forward *System* refers to the HSGGT system architecture and is used in place of the term *system-of-systems*. Understanding the

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[1] *System Engineering Management Guide, Defense Systems Management College, Fort Belvior, VA, October 1983.*

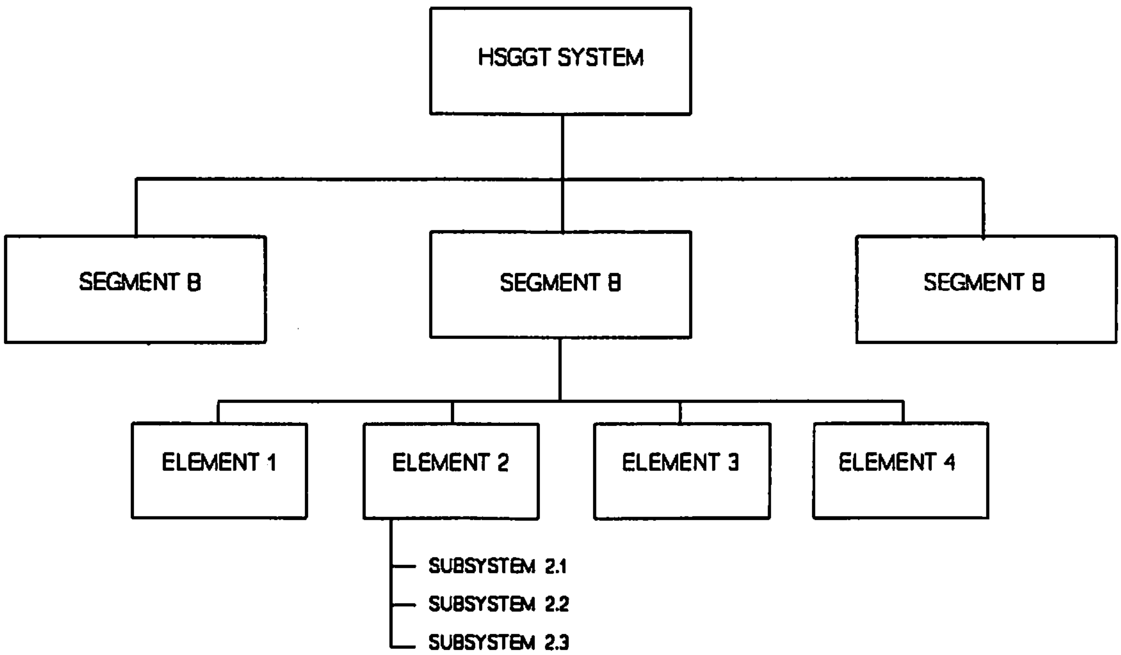

Figure 1. Generic HSGGT Architecture

hierarchial aspects of a complete HSGGT architecture is essential to providing one with the basis for a sound structure of prime interface relationships. This is important so that the interfaces may be assessed.

It is important to refer to the *System*, in the formal context of HSGGT, as the top level of the WBS. It should be recognized that the concept of an architecture or system hierarchy is an evolving, flexible entity initially, but, once it is set, remains in place during the safety evaluation phase permitting orderly documentation to take place throughout the life of the evaluation project. In this report, for purposes of illustration, generic HSGGT hierarchies are examined against a variety of factors and typical interface nodes are identified for a generic maglev system. A generic HSR system WBS has also been developed but interface nodes are not identified. No claim is made that the two postulated architectures are unique--there are many ways to assign technological and operational items to the segments, elements and subsystems.

SYSTEM SEGMENT

In Figure 1 it may be seen that the first level of system decomposition is comprised of *Segments*. The segment is a conceptual grouping of elements that are closely related and often physically interface. The segment consists of logically grouped elements produced by several contractors and integrated by one segment integrator. For example, if Segment A were a right-of-way segment, it could be composed of design criteria, earthwork, guideway, turnouts, special structures, and manufacturing requirements which would appear at the element level.

The segment is a natural first level breakdown for a major system such as is found in HSGGT. Segment designation allows for flexibility when tailoring the segment for a specific system application. This is because it allows a proper management span of control by specialist teams examining the constituent parts of segments. Segments must be as exclusive as possible on a technological and/or operational basis. For example, if Segment A deals primarily with civil engineering issues, Segment B would be oriented towards mechanical engineering issues, and Segment C those of electrical engineering concerns. It should be remembered that HSGGT systems consist of multiple, complex elements that are not always cleanly distributed on a technological basis. The development of safety regulations structured on a WBS also involves interface resolution. As stated earlier, interface issues between segments are dealt with in Part III of this report.

SYSTEM ELEMENT

The second level of system decomposition is the system *element*. An element is defined as a completely integrated set of subsystems capable of accomplishing an operational role or function.

SUBSYSTEMS

The third level of an HSGGT system decomposition is that of *subsystem*. A subsystem is defined as an integrated set of components. It is at the subsystem level that design criteria and subsystem requirements appear for the purpose of safety regulation assessment and/or application.

Unless otherwise entered, all candidate definitions (Section 3 of each of the two WBS Parts) appear at the subsystem level. Loads, codes, criteria, and standards also are associated with each subsystem level. As the WBS user identifies and lists the appropriate components for each subsystem of the specific HSGGT system under consideration, a judgement may be made on the need for a specific safety item regulation, and the appropriate code would be noted at that location.

CODES AND STANDARDS

The two postulated WBS provide a framework against which the *Code of Federal Regulations (CFR)*, and also codes specified, and/or recommended by various organizations, may be applied for appropriateness of coverage for the issues to be studied or investigated. In addition to the CFR, the following organizations, at a minimum, have applicable standards, some of which are found in the CFR.

AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans With Disabilities Act of 1990,
ANSI	American National Standards Institute
AREA	American Railroad Engineering Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing Materials
FCC	Federal Communications Commission
FRA	Federal Railroad Administration
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Organization for Standardization
NEC	National Electrical Code
NFPA	National Fire Prevention Association
UIC	International Union of Railways

Not all safety requirements will necessarily be applied to subsystems or components. In some cases safety requirements are introduced as criteria in place of a subsystem description. Generally, the most appropriate place for the application of criteria is at the subsystem level.

It should be noted that some of the example criteria and safety requirements apply to civil engineering design work. Civil engineering design criteria have not been applied to Federal Railroad Administration safety applications in recent years, if ever, but some such design criteria may be found in the CFR for application to federally funded highway projects.

HSGGT SYSTEM HIERARCHIES

This report provides two safety evaluation oriented system work breakdown structures (WBS), one for maglev (Part I) and one for high-speed rail (HSR) (Part II). Together they define generic HSGGT systems.

There are numerous alternatives for structuring system architecture. Figures I-1 through I-7 (maglev) and II-1 through II-7 (HSR) depict options in which elements are grouped and subtiered as closely related conceptual system elements. It is intended that these two WBS establish a guideline methodology and framework to provide the baseline for future safety related HSGGT documentation, annotations, specifications, discussions, and presentations.

It is important to note that the system hierarchies are not necessarily intended to represent precise subordinate management structures. Rather, especially for a HSGGT project, a hierarchy should provide for flexibility.

For the purpose of this report, only the top three levels are addressed. The tenets of program structuring apply, however, throughout the project from the overall system to the piece part or line of code. Beginning with the system element and subsequent lower levels of each WBS, it should be noted that there is increasing inflexibility in the composition of the structure.

PART I. MAGLEV SYSTEM SAFETY WBS/DEFINITIONS

1.0 MAGLEV SYSTEM SAFETY WORK BREAKDOWN STRUCTURE

Presented below is a safety evaluation oriented system work breakdown structure for a generic high speed magnetic levitation (maglev) guided ground transportation system. It is intended to provide a methodology to facilitate the logical identification and grouping of safety considerations, safety evaluation criteria, and applicable safety standards and codes to specific functional areas of the overall system.

It should be realized that there are numerous alternatives for structuring system architecture. One systems approach was selected based on methodology presented in the *System Engineering Management Guide* developed and published by the Defense Management College. Figures I-1 through I-7 present the hierarchal structure developed from this approach, in which elements are logically grouped and subtiered as closely related conceptual system elements. This WBS establishes a guideline methodology and framework to provide the baseline for future safety related maglev HSGGT documentation, annotations, specifications, discussions, and presentations.

As this WBS is intended to facilitate safety evaluations and considerations of generic maglev HSGGT system, it addresses the top three levels of the system structure only. However, since the tenets of system structuring continue to be applicable downward through ensuing levels of any system to the to the lowest replaceable unit or piece part level, as a specific maglev system is addressed it is intended that this WBS would be expanded to cover all lower levels.

1.1 MAGLEV RIGHT-OF-WAY SEGMENT

This segment is composed of those elements related to the design, specification, and construction of guideways within a given right-of-way. All elements of this segment consist of safety requirements that involve civil engineering work and structures. No electrical elements appear here -- they may be found under the Propulsion Segment which deals with electrical design and construction safety requirements.

1.1.1 ENGINEERING DESIGN ELEMENT

Civil engineering design requirements apply to the initial stages of new construction, or to the reconstruction of an existing maglev alignment.

1.1.1.1 Line & Profile Criteria

This right-of-way related safety issue is important because earthworks are generally in place for a hundred years or more. Earthworks can define the limiting or maximum operational speeds intended for a given system routing in an HSGGT corridor, and by ride quality considerations at very high speeds. Horizontal alignments and vertical profiles make basic contributions to the definition of lateral and horizontal forces on guideways and vehicle structures, as well as on passengers. The point at which ride quality becomes more an issue of safety than comfort must be determined on an individual alignment basis.

1.1.1.2 Guideway Center Line Separation Criteria

These design criteria apply to safe separation distances between guideway centerlines for super-speed maglev operations and are safety related in terms of defining minimum guideway centerline spacings to avoid mutually adverse aerodynamic pressure forces between trains operating in opposite directions.

1.1.1.3 Superelevation Criteria

The amount of guideway superelevation used on curves traditionally has been governed by the practices of railroads to provide a balance of lateral forces on passengers for reasons of assuring comfort and the perception of safety. A limited amount of unbalance (manifested as a lateral force, with the maximum on the order of .05g) generally has been accepted, with the standards for unbalance expressed in inches of superelevation deficiency.

The trend in maglev engineering is to express superelevation in degrees inasmuch as guideway widths for various systems differ from one system to another. As maglev systems are introduced in the U.S., criteria for the maximum superelevation must be determined on the basis of passenger safety and comfort. Especially important is the limiting maximum guideway superelevation that will allow safe footing on the guideway by workers, and safe footing for passengers in the event of evacuation under conditions of rain or ice, and in the absence of guideway access evacuation walkways.

1.1.1.4 Guideway and Turnout Load Criteria

These criteria apply to guideway and turnout components such as piers, pylons, horizontal spans, trusses, beams, and other primary running surfaces and supporting structure. This includes design criteria that govern the application of dead and live loads on guideways resulting from vehicles, wind, earth movement, and other forces.

1.1.1.5 Foundation Load Criteria

Foundation is defined as that earthwork required to provide a firm base upon which guideway supporting piers or pylons rest. Foundations may consist of natural materials such as earth or rock, or man-made materials. These safety criteria apply to above included areas.

1.1.1.6 Survey Criteria (Aerial, Transit, & Geophysical Surveys)

These criteria consist of minimum requirements that would apply in order to select an alignment that will assure safety of operations based on route choice and geophysical (soil, rock, sand, or wetland) conditions.

1.1.1.7 Tunnel Design Criteria

This consists of design criteria that will assure minimum aerodynamic blockage and minimum mutual aerodynamic pressure interference between two trains traveling in opposing directions on adjacent guideways within the confines of a tunnel. It also covers all civil engineering design requirements, including ventilation, lighting, inspection, maintenance, and evacuation routes.

1.1.2 EARTHWORK ELEMENT

This element consists of those principal earthwork operations necessary to establish a very high-speed maglev line. It is comprised of cuts and fills, subgrade, tunnel, and roadbed construction subsystems.

1.1.2.1 Grading

Grading criteria, which also include cuts and fills, are defined as a subsystem. Grading consists of the formation of side wall slopes and compaction of earthwork when cutting through hills, or moving earth to fill in low or depressed areas, wet or dry, upon which guideway piers and foundations will be erected.

1.1.2.2 Foundations & Footings

Because of the critical nature of precise guideway beam height and alignment for certain types of maglev systems, design safety criteria apply to the testing and preparation of earth and rock foundations that are to support guideway structures to avoid settlements.

1.1.2.3 Tunnels

Tunnels are defined as subsystems of the Earthwork Element. This subsystem is comprised of requirements for materials, boring machines, and techniques. Typical safety requirements for tunnel construction materials may be found in codes developed by AASHTO, ASME, ASCE, ASTM, and others that apply to materials used in constructing tunnels. Other safety requirements may apply to the techniques and machinery employed in the boring of tunnels, the construction of tunnel walls and overhead structures, and tunnel appurtenances for ventilation and evacuation.

1.1.3 GUIDEWAY ELEMENT

This element covers all guideway structures and materials. The guideway element is comprised of criteria that govern load applications, superelevation, piers and columns, beams, girders, decks, the anchoring of propulsion related magnets and coils, and construction material codes and standards. There are no present safety requirements for guideways that are comparable to the appropriate subparts of *49 CFR Part 213 Track Safety Standards*.

This element does not apply to electrical equipment, electrical wiring, communications wiring, magnet coils, or stator windings; but it does cover the mechanical supports that mount magnet coils, stator packs and reaction rails, to the guideway for the purpose of transmitting propulsion, and/or braking loads from the magnets to the guideway structure.

1.1.3.1 Piers, Columns, & Abutments

Possible safety regulation could apply to materials and construction techniques for piers, columns, and abutments used to support guideway deck and turnout machinery and other right-of-way structures.

1.1.3.2 Beams, Girders, Decks, & Sidewalls

Structural components and construction techniques for guideway beams, girders, deck and sidewalls, and the construction techniques necessary to construct load carrying operational guideways and turnouts, comprise this category at the next lower level.

1.1.3.3 Reaction Rail, Power, & Magnet Coil Attachments

This grouping is comprised of the safety criteria that apply to reaction rails, electrical insulation, and attachment techniques for mounting the feeder systems for electrical power along the guideway, the mounting of magnet coils to the guideway, and, if used, the installation of reaction rails. Magnet coil attachments or installations must be sufficiently strong to carry vehicle propulsion/brake-thrust, levitation and guidance loads into the guideway or turnout structure.

1.1.3.4 Construction Materials Codes/Standards

This grouping consists of the safety requirements that apply to the use, mixture, and application of guideway and turnout construction materials. These requirements are expressed in various codes and standards (e.g., AASHTO, ASCE, ASTM, ASME, etc.).

1.1.4 TURNOUT ELEMENT

The turnout element consists of turnout structures, mechanisms, and materia-ls. Groupings included under this element are those mechanisms and devices that produce a maglev route change. Turnouts consist of fixed and/or movable guideway elements, switch mechanisms, and electrical, hydraulic, or mechanical switch actuation mechanisms, and/or those magnet arrangements that alter train route by means of magnetic fields. The mechanisms may be laterally movable or bendable beam structures, or magnetic fields that achieve route switching by acting in vertical or horizontal directions.

1.1.4.1 Beams, Girders, Decks, and Sidewalls

The groupings within this subsystem consiss of the materials and/or mechanisms used for movable or bendable guideway turnout beams, girders, deck materials, sidewalls, and construction techniques.

1.1.4.2 Switch Movement - Power Equipment

The groupings within this subsystem consist of switch machinery (e.g., electrical, hydraulic, mechanical) used to execute diversion (or merging) of vehicles from (to) one route to another at a turnout by means of a deflecting, bendable, or segmented guideway beam.

1.1.4.3 Magnetic Switching

This subsection is comprised of safety requirements that would apply to the application of magnetic fields that would be the principal force mechanism to accomplish route changes.

1.1.4.4 Interlocking Detection/Execution

This subsystem category consists of devices that provide detection and execution of route establishment through proper switching and signal indications for all turnouts and blocks on the new route. This subsystem interfaces with the Safe Train Separation subsystem of the Automatic Train Protection Element.

1.1.5 SPECIAL GUIDEWAY STRUCTURES ELEMENT

This element consists of special guideway structures and subsystems that require special construction techniques. Examples of these structures include: special trusses, long guideway spans, bridges, viaducts and flyovers, protective structures (e.g., for magnetic shielding), passenger evacuation, and station-platform guideways.

1.1.5.1 Special Trusses

Special trusses consist of bridge or guideway components that require unusual design considerations, materials, or fabrication techniques. This subsystem grouping consists of all related safety standards and codes that apply.

1.1.5.2 Long Spans

This subsection applies to the design, materials, and fabrication of extremely long, spans on the order of 60 meters (200 ft) or more that are necessary to make longitudinally diagonal crossings of interstate highway lanes without intermediate piers. Present safety regulations apply to bridge workers.

1.1.5.3 Bridges, Viaducts & Flyovers

This subsection grouping includes the safety criteria that apply to design, material properties, and the fabrication of bridges, viaducts, flyover guideways, as well as, the safety of bridge workers.

1.1.5.4 Protective Structure (Shielding)

The components of this subsystem consist of the materials and installation of shielding to protect passengers and employees from electric and magnetic fields emanating from power systems along the guideway, maintenance areas, and in passenger stations.

1.1.5.5 Passenger Evacuation

This subsection addresses the potential need for safety regulations that apply to the evacuation of passengers from vehicles and guideways. The requirements encompass location, spacing along guideways, and the configuration of passenger evacuation walkways, stairs, or other structures.

1.1.5.6 Station-Platform Guideway

This subsection grouping includes the design, construction, maintenance, and operation of guideway turnouts, gradients and sidings in passenger stations, and passenger platforms within stations.

1.1.6 CONSTRUCTION & MANUFACTURE ELEMENT

This element is comprised of subsystem groupings related to the design, construction, and manufacture of guideway structures, including on-site or field manufacture and assembly.

1.1.6.1 Machining & Special Assembly Regulations

This subsystem grouping includes the safety criteria that apply to the design, casting, forging, extrusion, machining and assembly of materials having critical structural deflection tolerance limits, including fabrication consisting of weldments.

1.1.6.2 Field-Assembly, Stator Windings

This grouping includes the safety criteria that apply to the manufacture, assembly, or installation in the field of stator windings, or, if used, levitation and guidance windings for attachment to guideways and turnouts.

1.1.6.3 Field Manufacture of Guideway Components

This grouping include the criteria that define the application of codes and/or standards for the field manufacture of guideway beams, piers, sidewalls, or other structural components, as deemed necessary.

1.1.6.4 Control and Communications

This grouping includes the criteria that apply to the manufacture, assembly, installation, and maintenance of train and power control and communications equipment including antennas, waveguide, train location tags, and transponders. It also includes compliance with the proper codes and standards of the Federal Communications Commission and other agencies as appropriate.

1.1.6.5 Fabrication, Tunnel Structural Members

This grouping includes the criteria that apply to the manufacture, assembly, installation, and maintenance of fabricated structural members used in the construction of maglev guideway tunnels. The appropriate codes shall apply.

1.2 MAGLEV REVENUE VEHICLE SEGMENT

This segment consists of elements that apply to maglev vehicles utilized for passenger carrying service. The term "revenue" is used to distinguish this class of vehicle from one used for utility or maintenance purposes.

1.2.1 CARBODY ELEMENT

The carbody element is comprised of structure, glazing, electrical wiring, crew and passenger accommodations, and the body-mounted subsystems of a maglev vehicle.

1.2.1.1 Structure

This maglev carbody subsystem is comprised of the primary load carrying car structure, and secondary structural members which may include sheathing (skin), frames, sills, etc. This subsection also pertains to the application of proof loads used to determine the structural integrity of a carbody. (Examples of such regulations are found in *49 CFR Part 229 Railroad Locomotive Safety Standards - Subpart D*). This reference is for illustrative purposes only and not suggested as a specific recommendation for maglev applications.

1.2.1.2 Magnetic Shielding

This grouping includes safety regulations that apply to the design, materials, application, and testing of magnetic shielding to prevent exposure of passengers and employees to harmful electric and magnetic fields.

1.2.1.3 Passenger Accommodations

The subsystem grouping consists of heating, ventilating and air conditioning (HVAC), lighting, glazing, carbody lining materials, crash-protecting passenger seat design, and other crash protection and fire retardation materials and techniques as may be installed. Provisions of the Americans With Disabilities Act of 1990 apply. See *49 CFR Part 223, Safety Glazing Standards* for an example.

1.2.1.4 Cab & Crew Accommodations

This subsystem grouping consists of a cab structure that provides physical protection to the crew, the crew environment, and operating controls. Current regulations for conventional locomotives cover: pilots, snow plows and end plates, head lights, glazing, fire extinguishers, flooring, passageways, cab noise, cab lighting and temperature control, slip/slide alarms, speed indicators, sander controls, and audible warning devices. Other maglev safety regulations apply to forward visibility, seating, HVAC, and accessibility of controls.

1.2.1.5 Doors and Evacuation

This subsystem grouping includes the safety criteria that apply to maglev vehicle doors, and passenger and crew escape means that may be used in the event of "derailment" or an accident which damages the carbody. (*Sample similar requirements exist under 49 CFR Part 223 - Safety Glazing Standards - Locomotives, Passenger Cars and Cabooses.*)

1.2.1.6 Carbody Electrical

This subsystem grouping includes the safety criteria for the head-end power (HEP) generating equipment aboard maglev cars such as motor-alternators or inverters that supply power for cab and passenger car lighting, heating, ventilation, and air conditioning equipment. It includes electric trainlines and wiring aboard the car. Also included in this subsystem are rear train markers.

1.2.1.7 High Voltage Cable

The components within this subsystem grouping consist of, at a minimum, all high voltage cable aboard, under, or upon a maglev vehicle, and the design, installation, markings, and maintenance of high voltage cables.

1.2.1.8 Cryogenic Refrigeration Subsystem: Compressor & Piping

The cryogenic refrigeration subsystem consists of all safety criteria that aply to the condenser, compressor, and electrical controls carried in the confines of the carbody, or the underside of the carbody proper, and associated piping that leads to truck-frame mounted evaporators and cooling units.

1.2.1.9 Fire Safety

The fire safety subsystem safety criteria includes smoke and flame detectors, fire extinguishers, and fire retardation materials in vehicle interiors and doors, emergency hatches, tools such as axes, and other equipment to allow the evacuation of passengers and crew from a burning vehicle.

1.2.2 TRUCK & SUSPENSION ELEMENT

The truck (bogie)[1] and suspension element consist of a truck frame that supports the carbody, and those subsystems and magnets that are mounted on the frame. Failure of any truck or truck-mounted component may cause interference between the carbody and the guideway, thus contributing to collision, "derailment," or adverse contact with other vehicles or station platforms. It should be noted that truck-mounted versus body-mounted subsystems may vary from one maglev vehicle concept design configuration to another.

1.2.2.1 Structure

The structural components of the truck consist of, at a minimum, side and cross frames, bolsters, suspension components (springs and dampers), attach points for mounting magnets, and cryogenic equipment (if so equipped). If body banking is a capability of the vehicle, then the truck frame may have a tilting bolster which is part of this subsystem.

Safety regulations apply to the overall strength of the truck frame, the means of attaching it to the carbody, and the amount of force required before it is separated from the carbody in the event of an accident. Requirements may also apply to the fatigue life of truck-frame materials (e.g., steel, aluminum, composites) that are attached to or in close proximity to cryogenically cooled components.

1.2.2.2 Levitation

The levitation subsystem (i.e., the primary suspension subsystem) consists of magnets and ancillary components attached to the truck frame in a typical case. These components may also interact with guideway components to supply propulsion and guidance in some system configurations. Examples of safety requirement applications are: levitation system components and magnets in terms of electric insulation, magnetic field emissions, sensing components, and control devices. Failure of these components could have an adverse effect on a vehicle's dynamic motions.

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[1] *The term bogie is of foreign origin (Scotland: A small truck under the main vehicle).*

1.2.2.3 Secondary Suspension

Safety criteria may apply to the components of the secondary suspension subsystem. This subsystem may consist of pneumatic, hydraulic, or mechanical springs and dampers, electrical sensors, and control equipment. Failure of these components could have an adverse effect on a vehicle's dynamic motions.

1.2.2.4 Guidance

The guidance subsystem consists of magnets, sensors, and ancillary components. Safety criteria may apply to the guidance subsystem components mounted on the truck frame. Failure of these components may have an adverse effect on a vehicle's dynamic motions.

1.2.2.5 Cryogenic Components

Safety criteria may apply to the truck mounted portion of the cryogenic subsystem used to maintain low superconducting-magnet temperatures. Failure of components may adversely affect safe vehicle operations and controlled responses to divergent dynamic motions. Typical components of the truck-mounted cryogenic refrigeration subsystem are evaporator units, controls, and associated piping that lead to other equipment such as condensers and compressors.

1.2.2.6 Brake Magnet

If independent magnets are used for brake purposes, safety criteria apply to the braking action of an independent or secondary electrical brake subsystem, or the brake action (reverse thrust) of the propulsion subsystem, and its components if such, are truck-frame mounted.

1.2.2.7 Pre-/Post-Levitation Suspension

This subsystem grouping consists of wheels and wheel retraction components. Safety criteria may apply if wheels are used to support the vehicle until such time as it is sufficiently carried by magnetic fields, or during the deceleration (landing) phase.

1.2.2.8 Skid Brake & Actuation

The skid brake and actuation subsystem consist of devices to slow the vehicle by friction when it drops against the guideway if power is lost and/or an emergency stop is required.

1.2.2.9 Derailment Protection

The derailment protection subsystem consists of devices which provide assurance that the vehicle will not leave the guideway in the event of an accident, or that critical guidance or levitation components are in a fail safe mode. The safety criteria of this subsystem must be carefully considered.

1.2.3 ON-BOARD PROPULSION & BRAKING ELEMENT

Maglev vehicle designs vary from one concept to another in terms of equipment type and placement. For example, propulsion subsystems may be located on the trucks for one concept but distributed between carbody and trucks on another. Body-mounted propulsion and braking element equipment in this WBS consist of the principal thrust/brake magnet control subsystems, the linear generator subsystem, power collection devices (for linear-induction-motor-powered vehicles), cryocooler(s), power conditioning equipment, air compressors, reservoirs, auxiliary devices, and other electrical and mechanical subsystems where the components of these subsystems are mounted on or in the carbody rather than on truck frames (e.g., to reduce unsprung mass).

1.2.3.1 Propulsion

The on-board propulsion subsystem consists of body-mounted power collection, conditioning, and distribution components. Safety criteria may be expressed in terms of electrical codes and standards for insulation, and the interaction with other subsystems such as signal, control, and communications subsystems.

1.2.3.2 Brake

The on-board brake subsystem consists of body-mounted brake control components to apply braking action (reverse thrust) of the propulsion subsystem, and other components. Safety criteria may be expressed in terms of electrical codes and standards for insulation, and interaction with other subsystems such as signal, control, and communications and other electrical subsystems. It may also consist of other forms of emergency and/or service brakes, including aerodynamic means of slowing and/or stopping the vehicle.

1.2.3.3 Cryostat & Cryocooler

This subsystem is comprised of those components of the cryocooler subsystem, such as liquid refrigerant storage, that are mounted within or under the carbody. Safety criteria include all refrigerant and "super cold" considerations.

1.2.3.4 Power Supply, Conditioning, and Distribution

This subsystem consists of the safety criteria that apply to those on-board components, such as batteries, power conditioning equipment (inverters, converters, transformers, rectifiers), and propulsion/brake wiring.

1.2.3.5 Power Collection

This subsystem consists of the safety criteria that apply to those contacting or inductive devices used to collect power from wayside sources, such as inductive generators. The wayside sources may include d.c., and single- or three-phase a.c. "third rail" power distribution subsystems, guideway-installed windings, or other devices.

1.2.3.6 Air Compressors, Reservoirs, and Auxiliaries

This subsystem consists of the safety criteria that apply to air compressors, air reservoirs, and auxiliary power devices carried or mounted in the vehicle carbody.

1.2.4 ON-BOARD DIAGNOSTIC ELEMENT

The on-board diagnostic element is comprised of those subsystems used to monitor vehicle equipment operation and those that detect and identify failures. It includes computers, sensors, interlocks, data transmission, and power supplies.

1.2.4.1 Data Transmission

This subsystem consists of the safety criteria that apply to on-board data transmission and communication equipment that connect the computer with individual sensors and equipment monitoring components, as well as components that transmit and receive information with the central system-wide diagnostic and dispatching centers.

1.2.4.2 Computers

This subsystem consists of the safety criteria that apply to on-board central diagnostic computers. These computers interface with all of the other subsystems of this element.

1.2.4.3 Sensors & Interlocks

This subsystem is consists of the safety criteria that apply to individual sensors and devices to monitor interlock components such as those between motion sensors, brake release sensors, and door open/close/lock actuators. These devices connect to the on-board diagnostic computer.

1.2.4.4 Power Supply

This subsystem consists of the safety criteria that apply to sensors and components to allow the on-board diagnostic computer to monitor power supply functioning and uninterruptable power supply components (batteries).

1.2.4.5 Propulsion & Braking

The propulsion and braking diagnostic subsystem consists of the safety criteria that apply to sensors and components to allow the central computer to monitor and diagnose on-board propulsion and braking equipment functioning.

1.2.4.6 Levitation & Guidance

This subsystem consists of the safety criteria that apply to sensors and components that allow the on-board diagnostic computer to perform the monitoring and diagnosis of levitation and guidance subsystem components.

1.2.4.7 HVAC

The heating, ventilating, and air conditioning diagnostic subsystem consists of the safety criteria that apply to components to monitor the functioning of on-board HVAC equipment. This subsystem connects to the on-board diagnostic computer.

1.2.4.8 Pneumatic and/or Hydraulic Equipment Monitoring

This subsystem consists of the the safety criteria that apply to the various devices and sensors that allow the on-board diagnostic computer to monitor the status and functioning of on-board pneumatic and/or hydraulic equipment.

1.2.4.9 Cab Equipment Monitor

This subsystem monitors and diagnoses the functioning of control cab equipment, communications, electrical and lighting subsystems, vehicle position location equipment, and data displays and warning devices. It is connected with the on-board diagnostic computer. This grouping consists of the safety criteria that include the above items.

1.2.4.10 Fire Safety Monitor

This subsystem grouping monitors and diagnoses the functioning of smoke and flame detectors.

1.2.5 CONTROL, INSTRUMENTATION & COMMUNICATIONS ELEMENT

This element consists of vehicle on-board subsystems necessary to control propulsion, braking, levitation, guidance magnets, carbody banking subsystem operations, and provides instrumentation and communications functions.

1.2.5.1 Vehicle Levitation & Guidance Control

The levitation and guidance control subsystem consists of the safety criteria that apply to the equipment, devices, and instrumentation necessary to control levitation and guidance magnets. Failure of these components may catastrophically affect dynamic vehicle motion.

1.2.5.2 Vehicle Propulsion Control

The vehicle propulsion control subsystem consists of the safety criteria that apply to the equipment, devices, and instrumentation necessary to control current flow in propulsion windings. Failure of these components may have an adverse effect on vehicle acceleration and constant thrust action.

1.2.5.3 Vehicle Braking Control

The vehicle braking control subsystem consists of the safety criteria that apply to the equipment, devices, and instrumentation necessary to control primary and secondary brake subsystems. Failure of these components may have an adverse effect on vehicle stopping or slowing actions.

1.2.5.4 Vehicle Banking Control

The banking control subsystem consists of the safety criteria that apply to the equipment and devices to control the vehicle's carbody banking. Failure of these components may have an adverse effect on vehicle lateral motions to such a degree that the carbody collides with vehicles on adjacent guideways, or binds on its guideway.

1.2.5.5 Vehicle Communications

The on-board communications subsystem consists of the safety criteria that apply to equipment and devices to provide voice and data communications with wayside and central traffic control facilities. Examples are two-way radios, car-mounted antennas, transponders, etc.

1.2.5.6 Vehicle Electrical, HVAC, & Lighting Control

This subsystem consists of the safety criteria that apply to the control of vehicle electrical systems, and heating, ventilation, and air conditioning equipment in the event of an on-board fire that may threaten passenger or crew asphyxiation.

1.2.5.7 Vehicle Location

This subsystem consists of the safety criteria that apply to those devices and components that, for example, either provide information to the maglev system operations control center based on a) guideway milepost information, or b) position location information from exterior sources (e.g., GPS data).[2] This subsystem interfaces with the operations center by means of the communications network (1.3.1.5).

1.2.5.8 Door Control and Propulsion/Brake Interlock

This interlock subsystem consists of the safety criteria that apply to the prevention of door opening when the vehicle is in motion, or brake release when doors are open.

1.2.6 CARBODY BANKING ELEMENT

The carbody banking element includes those subsystems that provide for carbody tilting about the longitudinal axis when the vehicle is on a curved guideway. The banking system may also be used to maintain the carbody floor in a horizontal plane if the vehicle stops on superelevated curved guideway. Carbody banking components may be truck frame and/or carbody mounted. Failure of any carbody banking component may cause interference between the carbody and the guideway, thus contributing to collision, "derailment," or other adverse contact with the guideway, other vehicles, or station platforms.

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[2] *Global Positioning Satellite.*

1.2.6.1 Sensor

The carbody banking sensor subsystem consists of the safety criteria that apply to gyros and/or accelerometers, as well as banking controls that call for activation or lock-out of the banking equipment.

1.2.6.2 Power Banking

The power banking subsystem (active suspension) consists of the safety criteria that apply to structural, hydraulic, pneumatic, and/or electrical components that physically support actuators or provide mechanical actuation, damping, and lock-out of powered carbody banking.

1.2.6.3 Passive Banking

The passive banking subsystem (active suspension) consists of the safety criteria that apply to structural, hydraulic, pneumatic, and/or electrical components that physically support, and/or provide damping and lock-out of carbody banking motion by linkages that are activated by gravity and centrifugal forces (pendular motion).

1.2.7 ANCILLARY ELECTRICAL EQUIPMENT

1.2.7.1 HVAC

This subsystem consists of the safety criteria that apply to the heaters, compressors, evaporators, and other heating, ventilating, and air conditioning equipment aboard the vehicle. It interfaces with the HVAC control and diagnostic subsystems.

1.2.7.2 Lighting

This subsystem consists of the safety criteria that apply to exterior lighting such as front and rear markers, and cab and passenger compartment illumination equipment.

1.3 MAGLEV SYSTEM OPERATIONS CONTROL SEGMENT

This segment consists of the following elements and their subsystems: Operations Control Center, Automatic Train Protection, Automatic Train Operation, Automatic Train Supervision, and Automatic Dispatching.

Long stator, linear synchronous motor (LSM) propelled maglev technologies move vehicles on the guideway by means of control of propulsion power dispatched from wayside substations, via a central control center, to individual guideway blocks. Safe train separation within a given block is inherent. On the other hand, short stator systems such as those that utilize on-board linear induction motor (LIM) propulsion may be individually controlled on board (with respect to guideway location) in terms of starting, speed control, stopping, and train separation.

1.3.1 OPERATIONS CONTROL CENTER ELEMENT

The Operations Control Center Element is comprised of the central traffic control center, central computers, personnel, power control, and a voice and data communications network. The operations control center may consist of a computerized central traffic control subsystem which has authority over vehicle movements and the dispatching of power to the guideway. Federal regulations[3] govern conventional railroad operations with respect to the need for automatic cab signals, automatic train stop (ATS), or automatic train control (ATC).

1.3.1.1 Central Traffic Control

The central traffic control (CTC) subsystem integrates the Automatic Train Protection (ATP), Automatic Train Operation (ATO), Automatic Train Supervision (ATS), and Automatic Dispatching (AD) elements. It consists of interfaces between the Operations Control Segment, computer software, and displays covering all routes and interlockings, computer input terminals, and displays used to administer, dispatch, route, and otherwise regulate train movements. See *49 CFR Part 236.* The CTC subsystem has authority over vehicle movements through the Central Computer Subsystem.

1.3.1.2 Central Computer

This subsystem consists of the safety criteria that apply to central processing units, software, and networks that support the Central Traffic Control subsystem. It interfaces with subsystems of the Automatic Train Protection (ATP), Automatic Train Operation (ATO), Automatic Train Supervision (ATS), Automatic Dispatching (AD) elements, and wayside Traction Power Control subsystem. A hierarchial computer installation may be one means of configuring the subsystem and its interface with the ATP, ATO, ATS, AD, and System Power subsystems.

[3] *49 CFR Part 236.0.*

1.3.1.3 Operations Control Center Personnel Safety Requirements

This subsystem grouping includes safety criteria that apply to personnel admitted to or working in the operations control center as specified by Federal Code. Federal alcohol and drug abuse provisions would apply.[4] The requirements call for fire safety and preventative measures.

1.3.1.4 System Power Control

This subsystem consists of the safety criteria that apply to equipment within the Operations Control Center to monitor and dispatch wayside propulsion power to the guideway via switchgear at remote locations.

1.3.1.5 RF & Cable Communications Network

This subsystem consists of the safety criteria that apply to the materials, installation, and operation of a radio-frequency (RF) and/or hard-wired cable or a fiber optic communications network used for communications and control of train operations. Safety requirements may apply to the design, configuration, materials, installation, and operation of a network used for communications and control of maglev train operations.

1.3.2 AUTOMATIC TRAIN PROTECTION ELEMENT

This element contains a fail-safe set of capabilities that assures the safe separation between trains, protects against conflicting and improperly lined routes, and provides protection against detected guideway conditions that might present a danger to trains.

1.3.2.1 Safe Train Separation

This subsystem includes safety criteria that apply to the critical capability of the continuous determination of safe separation between trains to avoid collisions. This subsystem consists of guideway circuits, cab signals, and computer software installed in the CTC computer. It interfaces with interlocking, and software for the ATO, ATS, and AD elements. Safety requirements similar to those used in railroad operations are cited for reference.[5]

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[4] *49 CFR 219--Control of Alcohol and Drug Use.*

[5] *49 CFR 236--Rules, Standards and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices and Appliances, Subpart A--Routes & Instructions: All Systems; Subpart B--Automatic Block Signal Systems Standards; Subpart C--Interlocking; and Subpart D--Traffic Control Systems.*

1.3.2.2 Train Identification

Individual trains are monitored on a continuous basis for location, speed, and identity. Safety requirements play a key role in collision avoidance, and proper identification of the train secures it. This subsystem consists of the safety criteria that apply to software for the CTC computer, and on-board equipment to encode and transmit train identification signals.

1.3.2.3 Train Position/Location Detection

This subsystem consists of the safety criteria that apply to the sensors and transducers that detect and transmit secure or redundant data for determining the speed, direction of movement, and position of the train. This subsystem interfaces with the CTC computer(s).

1.3.2.4 Guideway & Turnout Obstruction Detection

This subsystem consists of the safety criteria that apply to the sensors, signal generation circuits, signal converters, transmission components, interface circuitry, and computational capability required to automatically detect, identify, and provide warning signals (of various types) of obstructions, improperly aligned switches, and other safety problems involving guideway and turnouts, to the other subsystems of the Automatic Train Protection Element.

1.3.2.5 Guideway Integrity Monitoring

This subsystem consists of the safety criteria that apply to the sensors, signal generation circuits, signal converters, transmission components, interface circuitry, and computational capability required to automatically detect, identify, and provide warning signals (of various types), that immediately warn of any compromise in the integrity of the guideway(s) to the other subsystems of the Automatic Train Protection Element.

1.3.3 AUTOMATIC TRAIN OPERATION ELEMENT

This element contains a fail-safe set of capabilities that controls the operation of the train (i.e., acceleration, speed, deceleration). Its subsystems include the train speed detection subsystem, the train speed control subsystem, the on-board crew safety requirements, and the train platform-stop position control subsystem.

1.3.3.1 Train Speed Detection

This subsystem consists of the safety criteria that apply to the sensors and transducers that measure and transmit data relative to the velocity of the train at any time. The subsystem interfaces with the CTC computer(s), the train speed control subsystem, and the platform-stop position control subsystem.

1.3.3.2 Train Speed Control

This subsystem is comprised of the safety criteria that apply to the hardware and software used to control the speed of maglev trains. It interfaces with the train speed detection subsystem, and the CTC computer(s).

1.3.3.3 On-board Crew Safety Requirements

Safety criteria apply to all potential failure modes that threaten the structural integrity of the crew compartment and the operational capability of crew members. Requirements include a deboarding plan outlining the requirements for passenger evacuation in emergencies.

1.3.3.4 Train Platform-Stop Position Control

This subsystem consists of the safety criteria that apply to the hardware and software that monitors train position and controls the train's stopping at the correct position at each platform along the route. The subsystem interfaces with the on-board propulsion power control subsystem, the train position/location detection subsystem, and the CTC computer(s).

1.3.4 AUTOMATIC TRAIN SUPERVISION ELEMENT

This element is comprised of the fail-safe set of capabilities that control station dwell times, including door operations, and regulate maximum authorized speed in accordance with both the schedule and dispatching orders. Its subsystems include train station-dwell and door open control, as well as the train speed control to enforce timetable and dispatch requirements.

1.3.4.1 Train Station-Dwell & Door Open Control

The operation of this subsystem is a function of the automatic train supervision and automatic operation subsystems and is capable of revision to accommodate either automatic, or possibly manual, dispatching commands. It consists of on-board electrical interlocks with the vehicle brakes, interfaces with the ATO element, and the CTC computer(s). The safety criteria that are within this grouping include the above items.

1.3.4.2 Train Speed Control to Enforce Timetable & Dispatching Requirements

This subsystem consists of the safety criteria that apply to hardware and software that accommodates either automatic, or possibly manual, dispatching and routing commands. Continuous monitoring is required for minor adjustments to authorized maximum speeds, which minimize schedule variance. The subsystem interfaces with the ATO Element and the CTC computer(s).

1.3.5 AUTOMATIC DISPATCHING ELEMENT

This element is comprised of the fail-safe set of capabilities that adjusts the schedule or operating plan to reflect planned or unplanned changes in service or guideway availability, facilitates changes to automatic train stop (ATS) parameters, and provides human-directed overall control of the system.

1.3.5.1 Consist Adjustment

This automatic subsystem consists of hardware and software that maintain an inventory of cars assigned to a particular train. The subsystem interfaces with the CTC computer, the train identification subsystem, and the train position/location detection subsystem. Safety criteria may apply if the system automatically cuts or adds cars to a train.

1.3.5.2 Subsystem to Add or Cut Trains to or from Timetable

This subsystem consists of the safety criteria that apply to hardware and software that provide for adding and deleting vehicles from the current plan, including unscheduled removals from service. It interfaces with the train identification subsystem and the CTC computer(s).

1.3.5.3 Station Stop/Bypass

This subsystem consists of the safety criteria that apply to the CTC hardware and software that has authority over route designation and the interlocking necessary to direct a train to turn out to an off-line passenger station, stop, dwell, start, and otherwise return to mainline operation. It interfaces with the train identification and position/location detection subsystems.

1.3.5.4 Speed Restriction Administration

This subsystem consists of the safety criteria that apply to hardware and software that monitors and regulates train speed in accordance with established speed restrictions and/or slow orders. It interfaces with subsystems of the CTC, ATP, ATO, and ATS elements.

1.3.5.5 Guideway Blocking & Unblocking (for reason)

This subsystem consists of the safety criteria that apply to the hardware and software that has authority over route designation and the interlocking necessary to direct a train to cross over to a parallel track in the event that the primary route is blocked off during maintenance, in the event of a wreck, or for other operational reasons. It interfaces with subsystems of the CTC, ATP, ATO, and ATS elements.

1.4 MAGLEV PROPULSION POWER SEGMENT

This segment consists of those elements of a maglev system's wayside guideway propulsion power installation, including substations, such transmission lines and distribution equipment that are installed in or near the guideways, and provide for security of power installations.

1.4.1 SUBSTATION ELEMENT

The substation element consists of subsystems that are used to receive electric power from high-voltage transmission feeder lines, and to step down, rectify, or otherwise convert, invert, and/or distribute that power for train operations. The substation element includes health and safety criteria for personnel working at the substation.

1.4.1.1 Transformers

This subsystem is comprised of the safety criteria that apply to transformers and their auxiliary equipment and coolants.

1.4.1.2 AC Bus

This subsystem consists of the safety criteria that apply to the specifications, construction, and the maintenance of electrical bus equipment designed to carry alternating current used in substations, and to the personnel working in close proximity to this equipment.

1.4.1.3 Switch Gear & Circuit Breakers

This subsystem consists of the safety criteria that apply to high-voltage electrical switch gear and high-current circuit breakers and other electrical and mechanical equipment used in substations. The subsystem interfaces with the System Power Control subsystem of the Operations Center Control Element.

1.4.1.4 Rectifiers

This subsystem consists of the safety criteria that apply to high-power rectifier systems used in substations, and to the personnel working in close proximity to this equipment.

1.4.2 BLOCK CONTROL SYSTEM ELEMENT

The block control system element is composed of, at a minimum, the substation control subsystem and the block power dispatching control subsystem. This element interfaces with and is located in the Maglev System Operations Control Center (Element 1.3.1)

1.4.2.1 Substation Control

This subsystem consists of the safety criteria that apply to electrical control equipment located at wayside, and the equipment used to control substation operations. It interfaces with the Substation Element (1.4.1).

1.4.2.2 Block Power Control

This subsystem consists of the safety criteria that apply to guideway-block power control or dispatching equipment at wayside.

1.4.3 MOTOR SECTION SWITCHING ELEMENT

The motor section switching element is composed of the direct current (dc) power bus subsystem, the inverter subsystem, the guideway linear synchronous motor (LSM) switching subsystem, and the guideway LSM propulsion winding subsystem.

1.4.3.1 DC Power Bus

This subsystem consists of the safety criteria that apply to the direct current (dc) power bus and its components that feed inverters, and to the personnel working in close proximity to it.

1.4.3.2 Inverter Subsystem

This subsystem consists of the safety criteria that apply to the inverter (converter) subsystem used to convert direct current power to three-phase electric current, and to the safety regulations pertaining to the personnel working in close proximity to the inverters (converters).

1.4.3.3 Guideway LSM Stator Switching

This subsystem consists of the safety criteria that apply to the guideway linear synchronous motor (LSM) stator switching subsystem, and the safety regulations pertaining to personnel working in close proximity to the equipment.

1.4.3.4 Guideway LSM Propulsion Winding

This subsystem consists of the safety criteria that apply to the linear synchronous motor (LSM) propulsion winding components in the guideway, and to personnel working in close proximity to these components.

1.4.4 SECURITY ELEMENT

The security element consists of those subsystems and components that are used to prevent unrestricted entrance to the substation by unauthorized personnel.

1.4.4.1 Substation Security

This subsystem consists of the safety criteria that apply to fencing and intrusion detection security equipment used to prevent and monitor entrance to the substation by unauthorized personnel. The subsystem interfaces with the Operations Control Center (1.3.1).

1.5 MAGLEV FACILITIES SEGMENT

The maglev facilities segment includes those elements that provide maintenance of vehicles, guideways, and electrification. They consist of special purpose rescue or work vehicles, along with the diagnostic center and passenger stations.

1.5.1 MAINTENANCE SHOP ELEMENT

The maintenance shop element consists of the following subsystems: buildings, shop power, and yards.

1.5.1.1 Building Safety

The building subsystem consists of the safety criteria that apply to the maintenance and parts shops, tools, personnel therein for vehicle maintenance and overhaul work, maintenance-of-way, and electrical and communications maintenance work. These criteria include applicable codes such as those of ADA, OSHA, NEC. etc.[6]

1.5.1.2 Vehicle Shop Power

Safety criteria within this subsystem grouping may apply to the provision and application of high voltage power used within maintenance shops, and for the movement or testing of vehicle equipment within the building.

1.5.1.3 Yards

Safety requirements within this subsystem grouping may apply to vehicle storage, service and inspection, maintenance yard guideways, and are applicable to personnel working in the yards.

Yard safety includes the following areas: vehicle storage, service, inspection, and maintenance. The subsystem also includes personnel working in the yards. Existing railroad regulations serve as an example.[7] In addition to safety requirements, noise standards are imposed on yard operations. Existing railroad noise regulations serve as an example.[8]

1.5.2 SPECIAL PURPOSE VEHICLE ELEMENT

The special purpose vehicle element consists of the various self-propelled and towed vehicles that are required for guideway and electrical wire inspection and maintenance.

1.5.2.1 Maintenance-of-Way & Power Vehicles

This subsystem consists of the safety criteria that apply to vehicles employed for inspection, maintenance-of-way work, and for maintenance of wayside

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[6] *49 CFR 214 Railroad Workplace Safety.*

[7] *49 CFR 218 Railroad Operating Practices.*

[8] *49 CFR 210 Railroad Noise Emission Compliance Regulations.*

electrification subsystems and components. Examples are cranes, inspection cars, and surface grinders.

1.5.2.2 Rescue Vehicle

This Rescue Vehicle subsystem consists of the safety criteria that apply to special purpose vehicles used to retrieve disabled trains, or to rescue passengers and crew from disabled or wrecked maglev trains.

1.5.2.3 Fire Safety Vehicle

The fire safety subsystem consists of the safety criteria that apply to special purpose vehicles used to engage in fighting fires involving maglev vehicles, especially those involved in accidents in tunnels.

1.5.3 DIAGNOSTIC CONTROL CENTER ELEMENT

This element is comprised of those subsystems that form part of a maglev system's diagnostic control center (DCC). The center contains equipment to monitor, communicate, and analyze information from train-based and wayside diagnostic equipment, including signals, and power dispatching.

1.5.3.1 Building Subsystems

The building subsystem houses the diagnostic control center (DCC), and the DCC's supporting equipment.[9] Safety criteria and regulations are imposed by OSHA, NEC, ADA, and others.

1.5.3.2 Operations Control, Central Diagnostic Computer

The Central Diagnostic Computer subsystem consists of the safety criteria that apply to software and hardware components, including transmission modes to on-board and wayside transducers or computers, data input devices, and displays. It interfaces with the Central Computer of the Operations Control Center and may be colocated with other computers in the Operations Control Center.

1.5.4 PASSENGER STATION ELEMENT

This element consists of those subsystems which facilitate passenger and crew safety in passenger stations and their administrative offices.

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[9] *49 CFR 214 Railroad Workplace Safety.*

1.5.4.1 Building Subsystems

The Building subsystem consists of those spaces within a building meant for passenger or employee use. Applicable safety criteria and regulations are specified by the ADA, OSHA, NEC, etc.

1.5.4.2 Passenger Security & Access Safety

The Passenger Security and Platform Access Safety subsystem consists of the safety criteria that apply to measures to provide security to passengers and employees using the building and its station platforms for the purpose of entering or exiting railway vehicles.

1.6 MAGLEV SYSTEM OPERATIONS SEGMENT

The Operations Segment is comprised of two elements: Operating Rules and Practices and Personnel Safety Requirements.

1.6.1 OPERATING RULES AND PRACTICES ELEMENT

This element consists of safety requirements related to maglev operations including noise emissions, workplace safety, emergency repairs, operating rules and practices, and the reporting of accidents and incidents.

1.6.1.1 Noise Emission Avoidance Requirements

This subsystem consists of safety regulations for the enforcement of maglev system noise emission standards. One such regulation is in place for railroad operations.[10]

1.6.1.2 Workplace Safety Requirements

This subsystem consists of the safety criteria applicable to workplace safety. Examples of potential applicable workplace regulations are those in place for railroads. The regulations cover the responsibility for compliance and bridge worker safety standards.[11]

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[10] *49 CFR 210 Railroad Noise Emission Compliance Regulations.*

[11] *See 49 CFR 214 Railroad Workplace Safety.*

1.6.1.3 Emergency Repair Requirements

This subsystem consists of the safety criteria applicable to the emerging repairs. Examples of applicable safety regulations are those which authorize the Federal Railroad Administration (FRA) or State Motive Power or Track Inspectors to order a locomotive out of service, or to lower track in class, upon finding that the item in question is not in conformity with FRA safety regulations.[12]

1.6.1.4 Maglev Operating Rules

This subsystem consists of the safety criteria applicable to the development of operating rules for maglev systems. An example of applicable safety regulations is that for railroads to report to the Federal Railroad Administration, the condition of operating rules and practices with respect to trains and other rolling equipment.[13]

1.6.1.5 Maglev Operating Practices

This subsystem consists of the safety criteria applicable to maglev operator practices. Examples of applicable safety regulations are those for railroads concerning operating rules, timetables, timetable special instructions, and other special instructions.[14]

1.6.1.6 Accident Reporting Requirements

This subsection consists of the criteria applicable to accident report practices. An example of possible safety regulations are those requireing railroads to provide the FRA with information concerning hazardous conditions on the Nation's railroads.[15]

1.6.1.7 Maintenance Requirements

This subsection consists of the criteria applicable to maintenance requirements. Examples of areas that could be covered under this heading are maintenance requirements for guideways, turnouts, vehicles, system operations and control, and wayside propulsion power equipment.

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[12] *See 49 CFR 216 Special Notice and Emergency Order Procedures: Railroad Track, Locomotive and Equipment.*

[13] *See 49 CFR 217 Railroad Operating Rules.*

[14] *See 49 CFR 218 Railroad Operating Practices.*

[15] *See 49 CFR 225 Railroad Accidents/Incidents: Reports, Classification, and Investigations.*

1.6.2 PERSONNEL SAFETY ELEMENT

This element is comprised of a minimum of three subsystems concerning maglev employee safety, service hours, and training.

1.6.2.1 Employee Training Requirements

This subsystem consists of the safety criteria to be considered when developing instructions for its employees in maglev system operating practices. With respect to railroad operations, the CFR prescribes minimum Federal requirements for the eligibility, training, testing, certification, and monitoring of all locomotive engineers. Its purpose is to ensure that only qualified persons operate a locomotive or train.[16]

1.6.2.2 Employee Service Hours

This subsystem consists of the safety criteria for a maglev system mandating the recording and reporting of hours of service of certain operating employees, and, it may cover the standards and procedures concerning the construction or reconstruction of employee sleeping quarters. For example, see 49 CFR 228.[17]

1.6.2.3 Control of Alcohol and Drug Use

This subsystem consists of the safety criteria to be considered to insure the prevention of accidents and casualties in maglev operations that result from impairment of employees by alcohol or drugs. For example, see 49 CFR 219. (See footnote 4.)

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[16] *See 49 CFR 240 Qualifications and Certification of Locomotive Engineers.*

[17] *See 49 CFR 228 Hours of Service of Railroad Employees.*

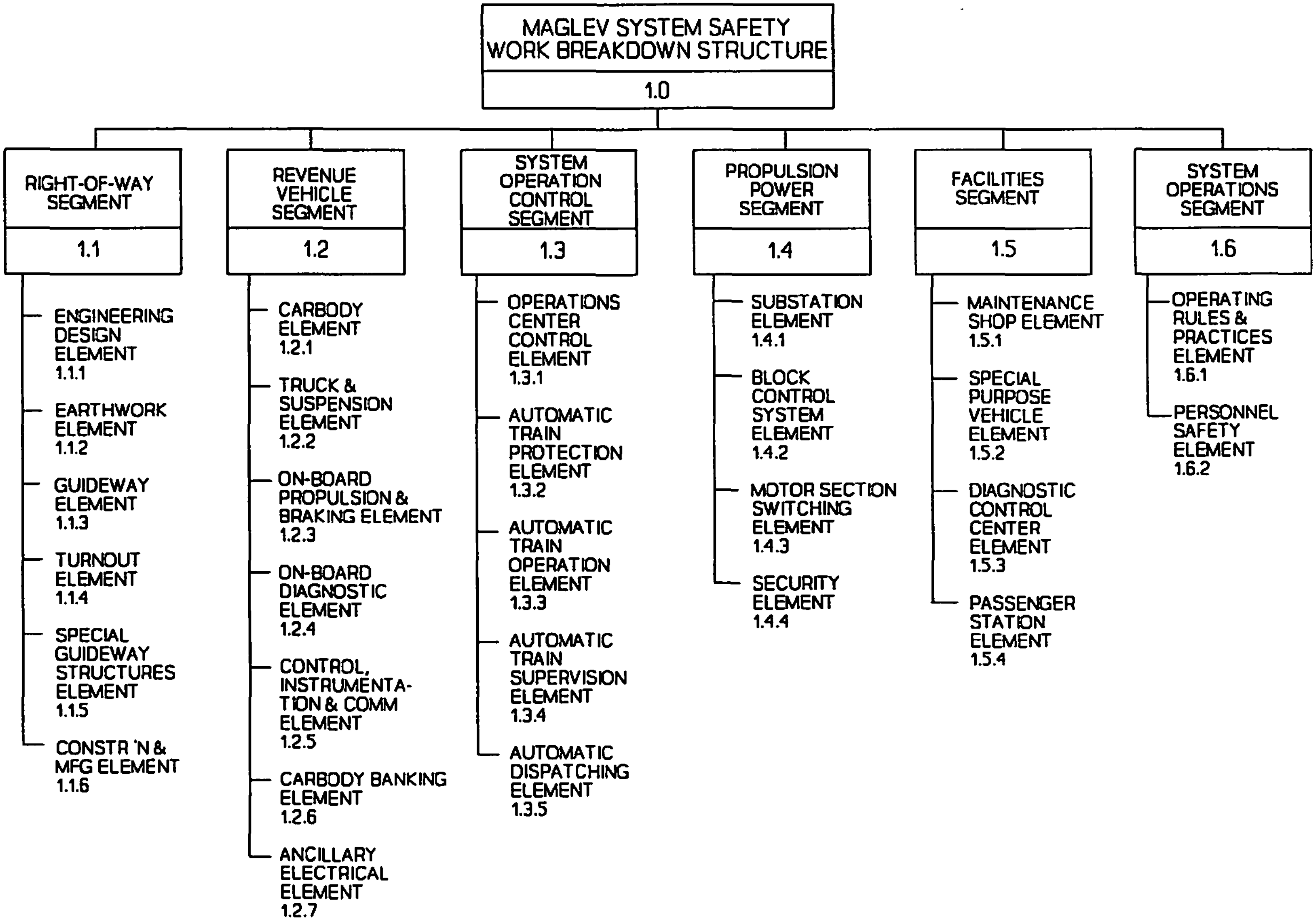

Figure I-1. Maglev System Segments and Elements

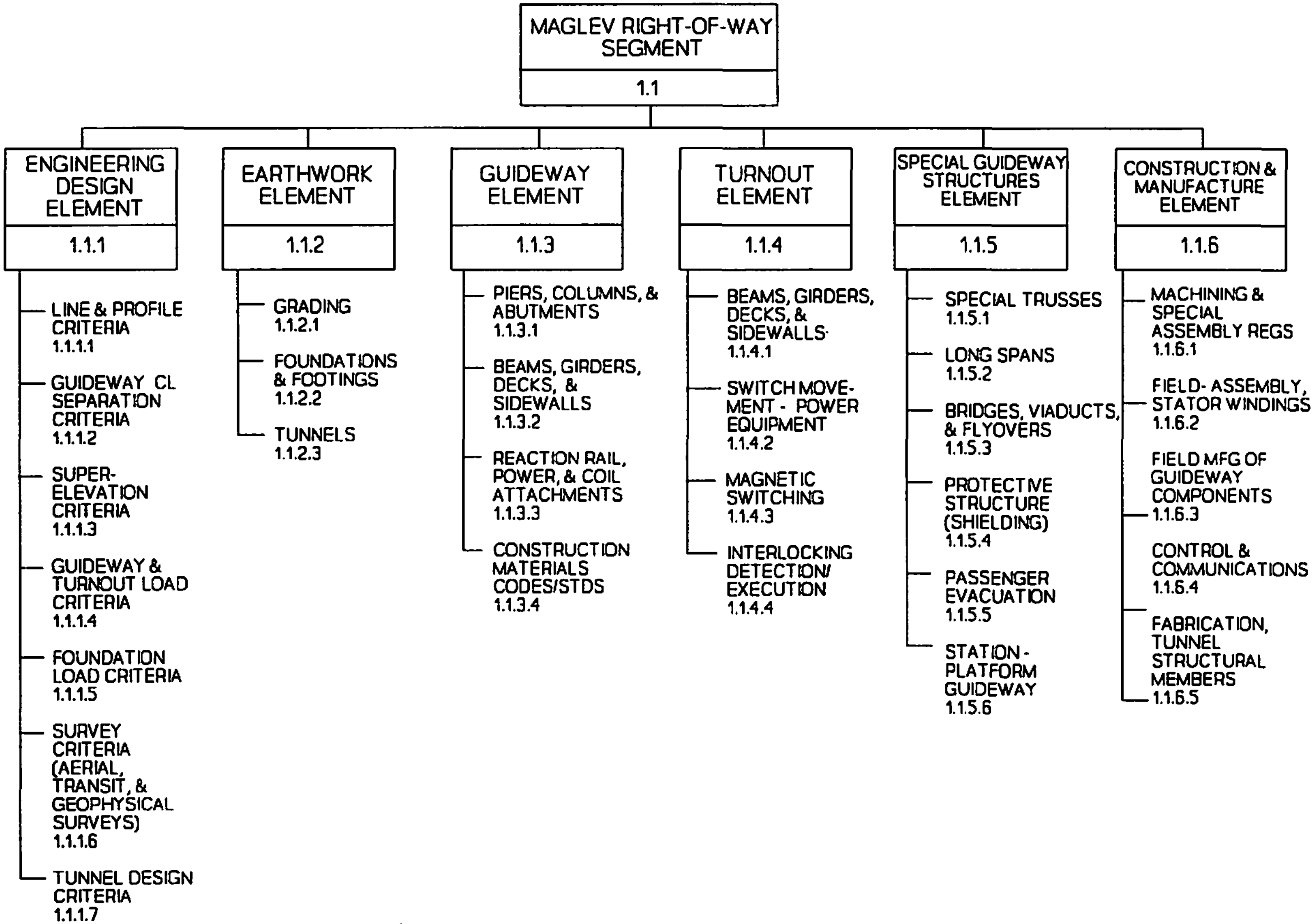

Figure I-2. Maglev Right-of-Way Subsystems

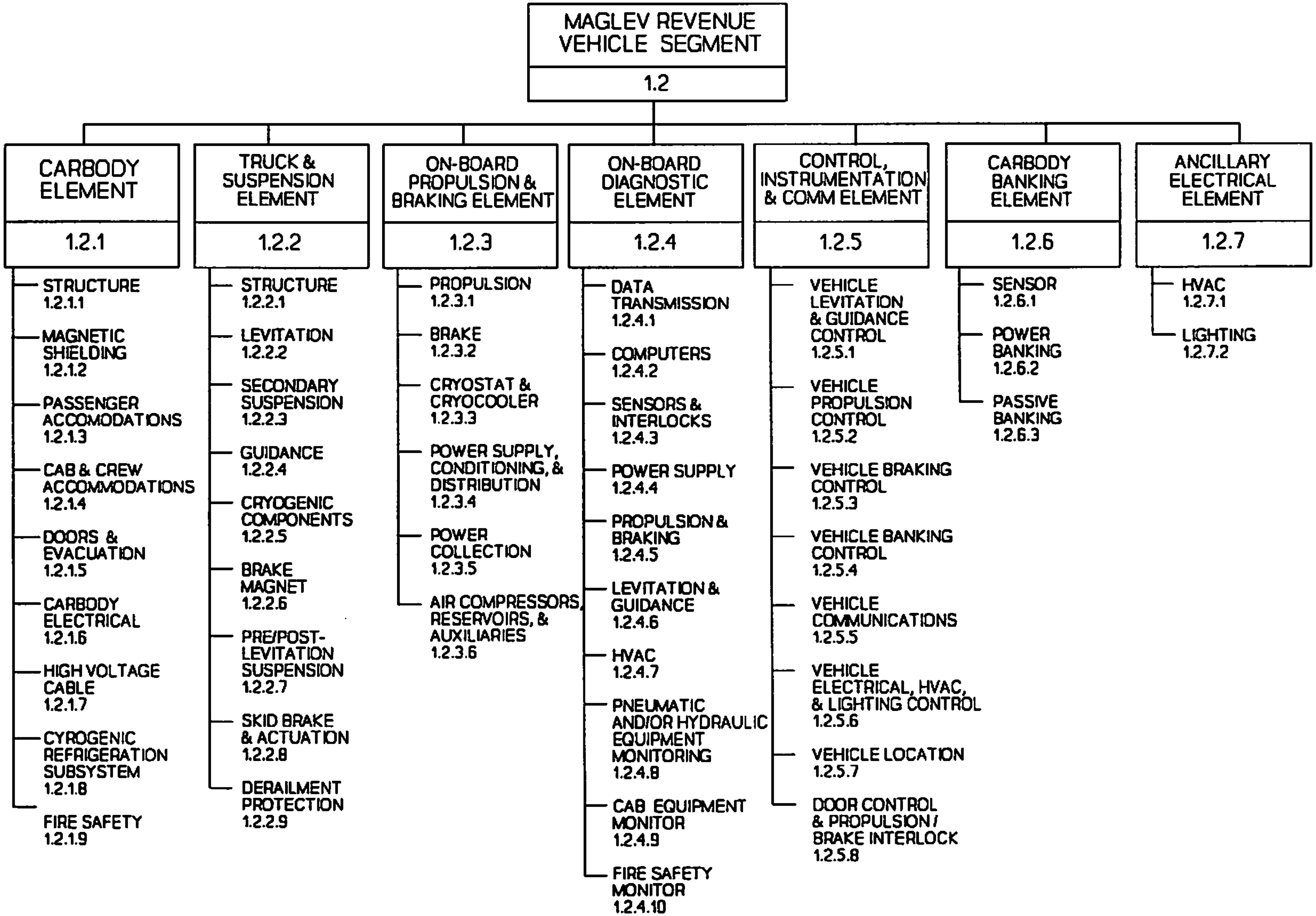

Figure I-3. Maglev Vehicle Subsystems

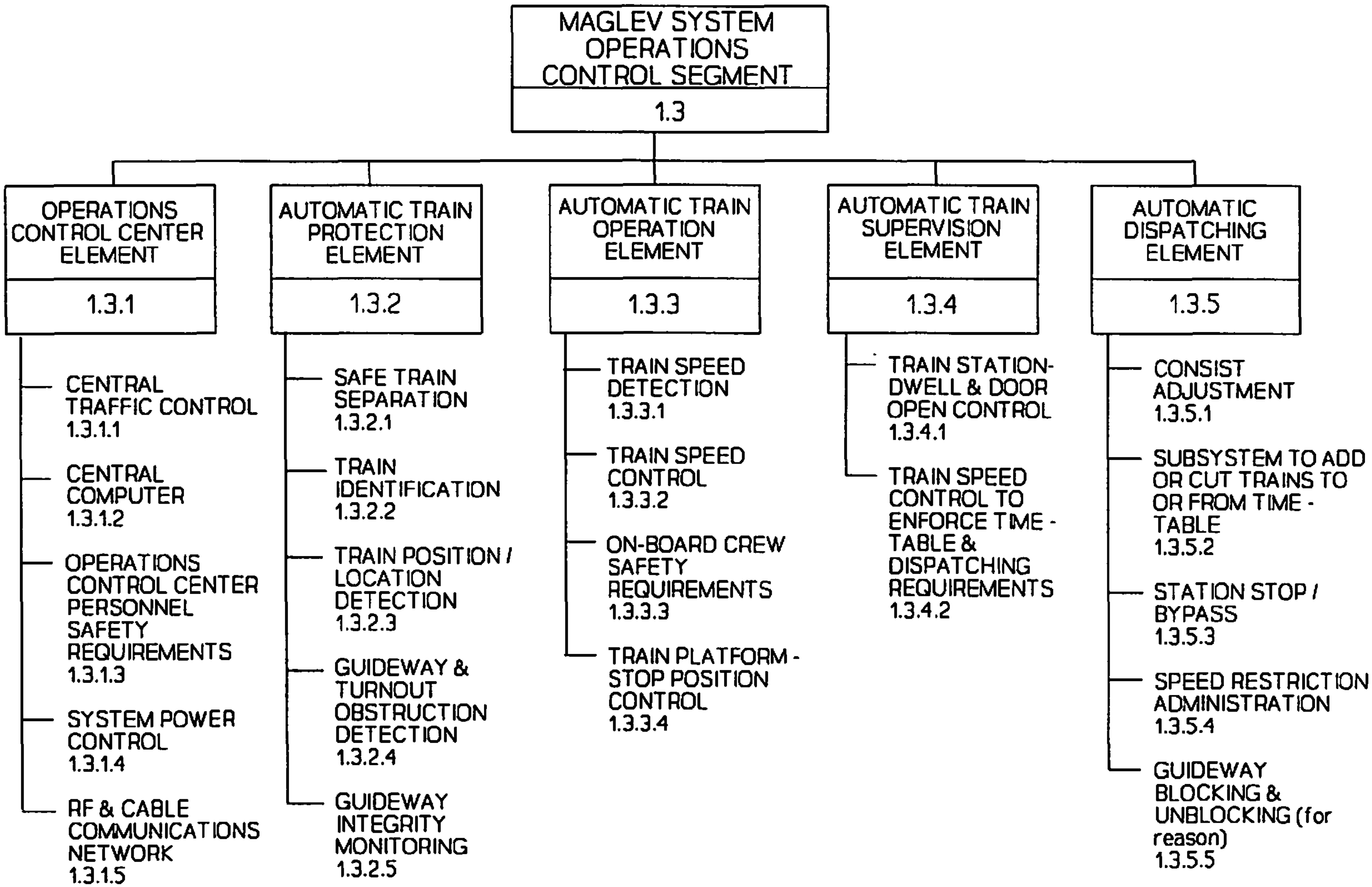

Figure I-4. Maglev Operation Control Subsystems

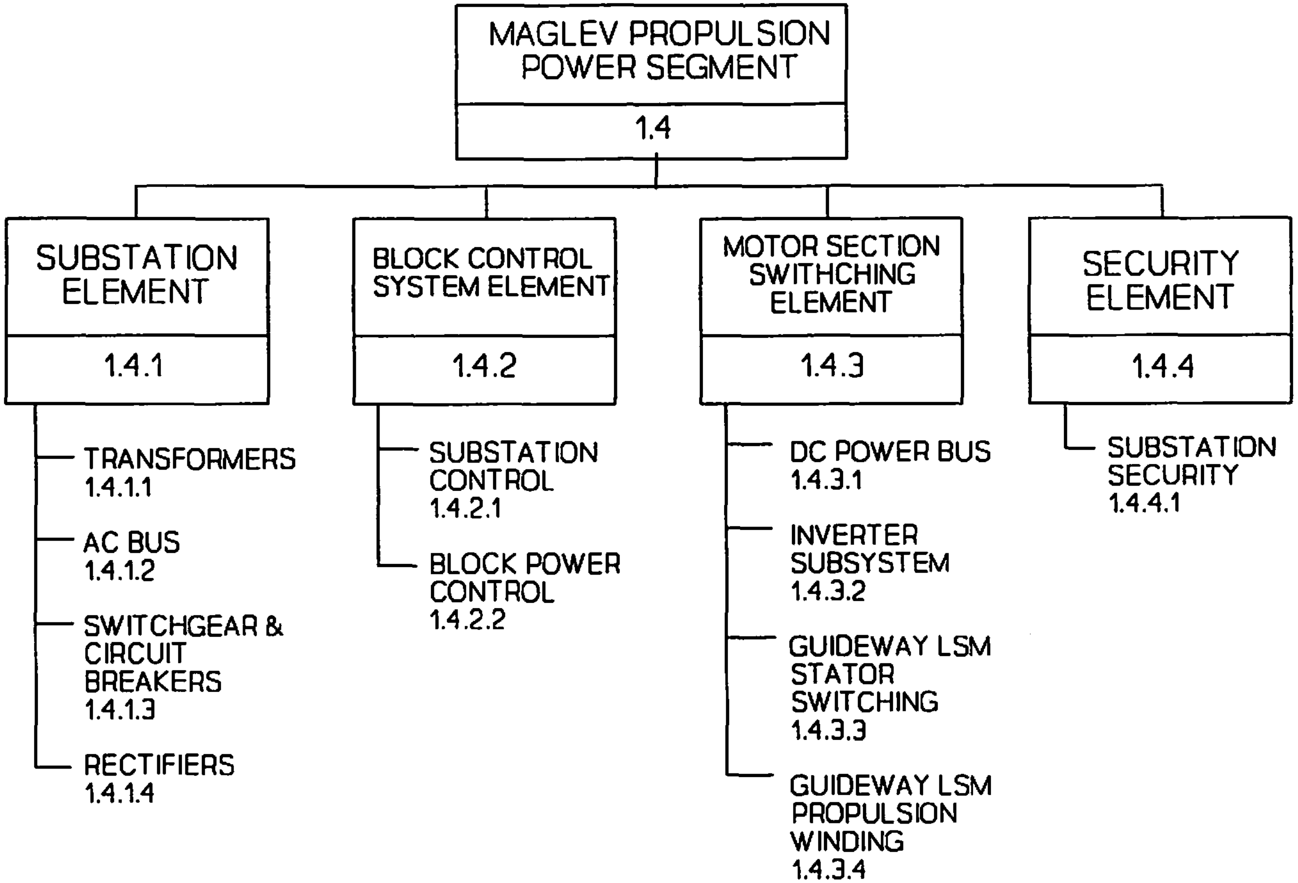

Figure I-5. Maglev Propulsion Power Subsystems

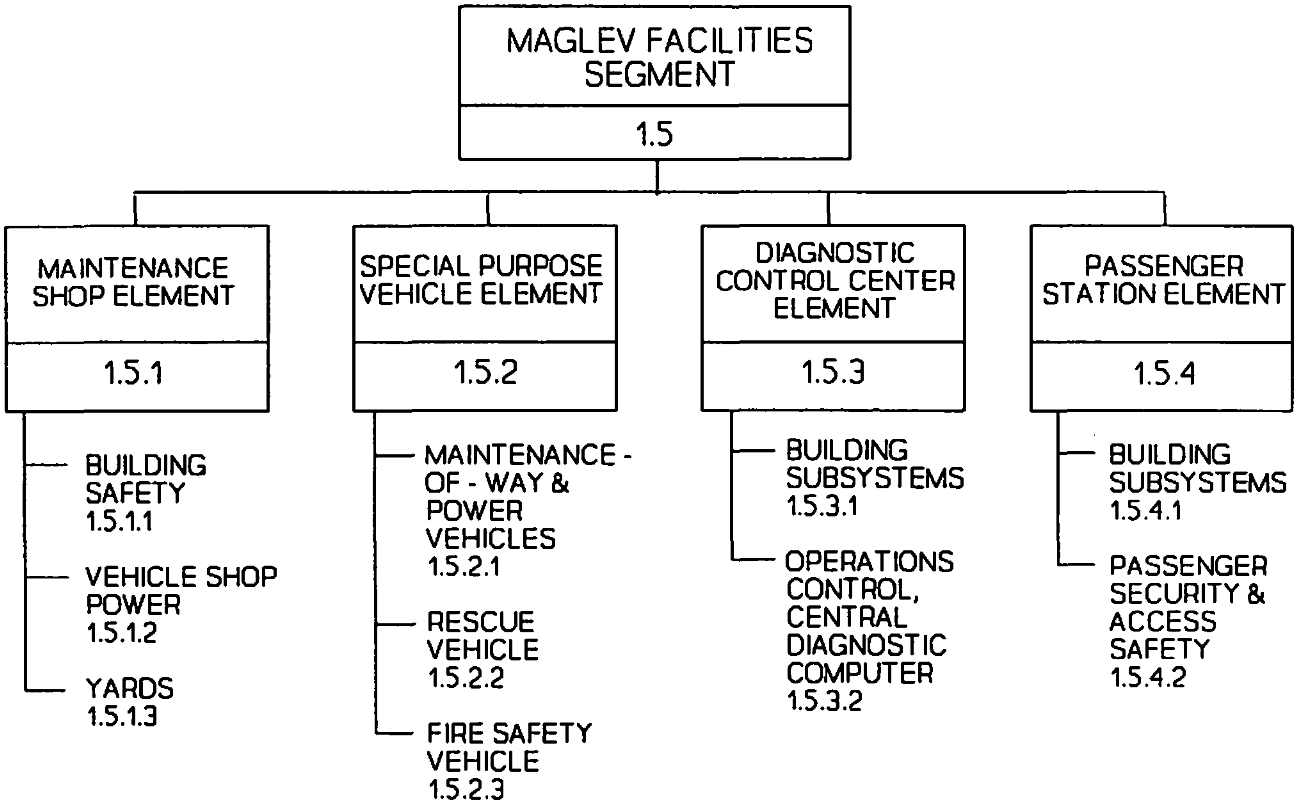

Figure I-6. Maglev Facility Subsystems

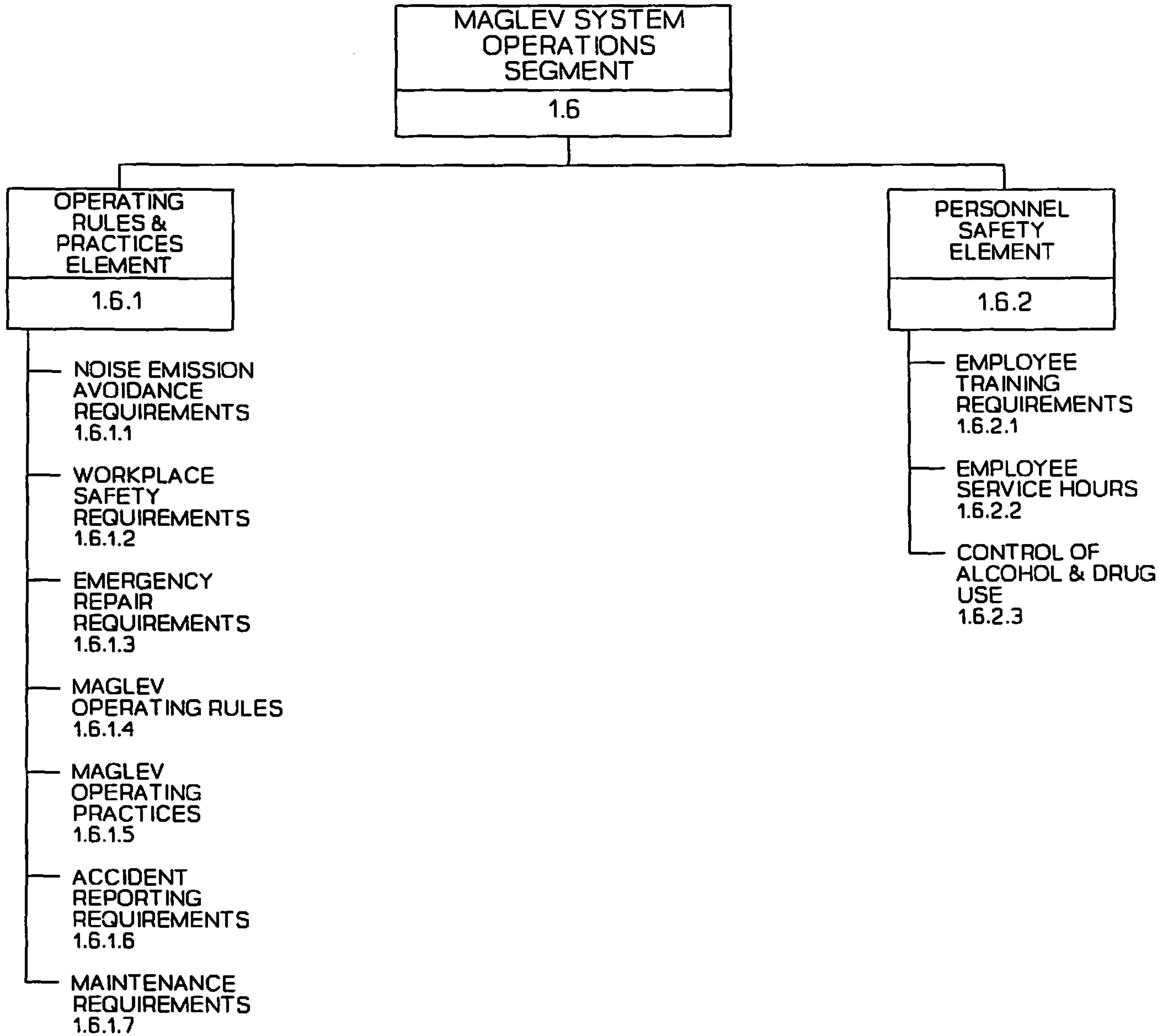

Figure I-7. Maglev System Operations Requirements

PART II. HIGH SPEED RAIL SYSTEM SAFETY WBS/DEFINITIONS

2.0 HIGH SPEED RAIL SYSTEM SAFETY WORK BREAKDOWN STRUCTURE

Presented below is a safety evaluation oriented system work breakdown structure for a generic high speed RAIL (HSR) guided ground transportation system. It is intended to provide a methodology to facilitate the logical identification and grouping of safety considerations, safety evaluation criteria, and applicable safety standards and codes to specific functional areas of the overall system.

It should be realized that there are numerous alternatives for structuring system architecture. One systems approach was selected based on methodology presented in the *System Engineering Management Guide* developed and published by the Defense Management College. Figures II-1 through II-7 present the hierarchal structure developed from this approach, in which elements are logically grouped and subtiered as closely related conceptual system elements. This WBS establishes a guideline methodology and framework to provide the baseline for future safety related HSR documentation, annotations, specifications, discussions, and presentations.

As this WBS is intended to facilitate safety evaluations and considerations of a generic HSR system, it addresses the top three levels of the system structure only. However, since the tenets of system structuring continue to be applicable downward through ensuing levels of any system to the to the lowest replaceable unit or piece part level, as a specific maglev system is addressed it is intended that this WBS would be expanded to cover all lower levels.

2.1 HSR RIGHT-OF-WAY SEGMENT

This segment is composed of those elements related to profile and alignment selection, and to the design, specification, and construction of track structures within a given right-of-way.

2.1.1 ENGINEERING DESIGN ELEMENT

Civil engineering design requirements apply equally to the initial stages of new construction, or to the reconstruction of an existing railway alignment.

2.1.1.1 Line & Profile Criteria

This right-of-way subsystem consists of safety criteria that is important because earthworks are generally in place for a hundred years or more. Earthworks can define the maximum operational speeds intended for a given system routing in an HSGGT corridor, and by ride quality considerations at very high speeds.

Horizontal alignments and vertical profiles make basic contributions to the definition of lateral and horizontal forces on track and vehicle structures as well as passengers. The point at which ride quality becomes more an issue of safety than comfort must be determined on an individual alignment basis.

2.1.1.2 Track Center Line Separation Criteria

Design criteria for safe separation distances between track center-lines for high-speed rail operations are safety related in terms of defining minimum spacings to avoid the mutually adverse aerodynamic forces between trains operating in opposite directions.

2.1.1.3 Superelevation Criteria

The amount of track superelevation used on curves has been governed by the practices of individual railroads to provide a balance of lateral forces on passengers for reasons of assuring comfort. A limited amount of unbalance (manifested as a lateral force) is generally accepted with the standards varying from 3 to 6 inches in the U.S., to 6 (or more) inches on some European railways. As high-speed railway systems are introduced in the U.S. the maximum superelevation must be determined on the basis of mixed traffic use or dedicated passenger service use.[1]

2.1.1.4 Track Load Criteria

The criteria apply to the track structure. This section includes design criteria that govern the application of static and dynamic loads on track resulting from vehicles, earth movement, and other forces. The criteria may be expressed as the ratio of lateral-to-vertical wheel loads on the rail, limits to prevent rail rollover, lateral track shift, etc.

2.1.1.5 Bridge & Trestle Foundation Load Criteria

Foundation is defined as that earthwork required to provide a firm base upon which supporting piers rest. It may consist of natural materials such as earth or rock, or man made materials.

2.1.1.6 Survey Criteria (Aerial, Transit, & Geophysical Survey)

These criteria consist of the minimum requirements that would apply in order to select an alignment selection and to assure safety of operations based on route selection and soil or rock foundation conditions.

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[1] *See 49 CFR 213--Track Safety Standards, §213.57--Curves.*

2.1.1.7 Tunnel Design Criteria

This grouping consists of the design criteria that will assure minimum aerodynamic blockage and minimum mutual interference between two trains traveling within the confines of a tunnel. It also includes all civil engineering design requirements, including ventilation and evacuation.

2.1.2 EARTHWORK ELEMENT

The Earthwork Element consists of those principal construction operations necessary to establish a high-speed or very high-speed railway line. It is comprised of cuts and fills, subgrade, tunnel, and roadbed construction subsystems.

2.1.2.1 Cut & Fill

Cut and fill work is defined as a subsystem. It consists of the formation of side wall slopes and compaction of earthwork involved when cutting through hills, or moving earth to fill in low or depressed areas.

2.1.2.2 Subgrade

Track subgrade is a subsystem of the Earthwork Element. Subgrade consists of the formation of earthwork and the use of geotextile treatments immediately under the ballast or slab, on which rails are applied, to assure stability to the track.

2.1.2.3 Tunnel

Tunnels are defined as subsystems of the Earthwork Element. Tunnel construction involves the use of specialized tunnel boring machines and construction techniques, and the need for tunnel ventilation.

2.1.2.4 Roadbed

Construction of track roadbed is defined as a subsystem under the Earthwork Element. The subsystem is comprised of the roadbed and areas immediately adjacent to the roadbed. Current safety requirements cover drainage and vegetation.[2]

2.1.3 TRACK ELEMENT

Track standards appearing under the heading of Track Elements include, among other requirements, the appropriate subparts of *49 CFR Part 213 Track Safety*

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[2] *See 49 CFR 213--Track Safety Standards, Subpart B--Roadbed.*

Standards. The track element is comprised of ballast or slab foundation, rails, ties, and fixation devices.

2.1.3.1 Ballast or Slab

The ballast or slab subsystem consists of the type and application of materials used to construct the track support components and to specify the amount of allowable track rail deflection or stability per unit length.[3]

2.1.3.2 Rail, Tie, & Fixation

This subsystem consists of rails, ties, and rail fixation components. Safety requirements apply to materials, and installation and maintenance standards for track geometric quality, including traditional measures such as gage, cross level, twist, and alignment for curved and tangent track.[4]

2.1.4 TURNOUT & CROSSING ELEMENT

Subsystems that are included under the Turnout and Crossing Element include turnouts, and both highway-railroad and railroad-railroad crossings at grade.

2.1.4.1 Turnout Panel

The turnout panel subsystem consists of switch machines, frogs, guard rails, wing rails, stock rails, closure rails, crossties, insulating joints, and fasteners.[5]

2.1.4.2 Track Crossing Panel

The track crossing panels are comprised of those track components needed where one railway track crosses another at-grade. Such panels consist of the following principal components: rails, frogs, crossties, insulating joints, and fasteners.

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[3] *See 49 CFR 213 Track Safety Standards, Subpart D--Track Structure, §213.103 Ballast.*

[4] *See 49 CFR 213--Track Safety Standards, Subpart C--Track Geometry, and Subpart D--Track Structure.*

[5] *See 49 CFR 213--Track Safety Standards, Subpart D--Track Structure, §213.133 through §213.143.*

2.1.5 SPECIAL STRUCTURES ELEMENT

The Special Structures Element consists of, but is not limited to, bridges, viaducts, and tunnels.

2.1.5.1 Bridge & Viaduct

On the basis of safety requirements analysis, the bridge and viaduct subsystem is comprised of design, material properties, the fabrication of bridges and viaducts, maintenance and inspection, and the safety of workmen.[6]

2.1.5.2 Tunnel

At the tunnel subsystem level, the primary concern is with safety standards that govern the use of specialized tunnel boring machines and tunnel construction techniques, inspections and maintenance, and the need for tunnel ventilation.

2.1.6 HIGHWAY-RAILROAD AT-GRADE CROSSING ELEMENT

This element is comprised of warning and protection devices installed at highway-railroad at-grade crossings. The upper limit of train speed across at-grade crossings is 200 km/h (125 mph). Crossings are grade separated for all train speeds in excess of 200 km/h.

Another at-grade crossing subsystem, one that provides surveillance and obstacle warning, appears as Subsystem 2.3.2.5 under the Automatic Train Protection Element.

2.1.6.1 Passive Warning Devices

This subsystem consists of the design, installation, usage, and maintenance of passive warning devices at highway-railroad crossings at-grade. It includes components such as illumination, crossbucks, signs, markings on highway surfaces, advance warning signs, reflectorized surfaces, etc. (See footnote 7.)

2.1.6.2 Active Warning Devices

This subsystem grouping consists of the design, installation, usage, and maintenance of active warning devices at highway-railroad crossings at-grade. Such requirements apply to train-speed measuring devices intended to provide constant warning time, track signal circuits, colored aspect warning lights, flashing lights,

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[6] *See 49 CFR 214--Railroad Workplace Safety, Subpart B--Bridge Worker Safety Standards.*

strobe lights, traffic control gates, pedestrian control gates, and other forms of active advance warning devices. (See footnote 7.)

2.1.6.3 Crossing Area Illumination

This subsystem grouping consists of the design, installation, usage, and maintenance of crossing and crossing approach illumination devices installed at highway-railroad at-grade crossing locations. (See footnote 7.)

2.1.6.4 Crossing Area Barriers

This subsystem consists of the design, installation, usage, and maintenance of barriers emplaced along streets or highway lanes to provide lane separation at railroad-highway crossing locations, and those across highways or streets designed to prevent the travel of highway vehicles onto railway tracks approaching at-grade highway-railroad crossing locations. (See footnote 7.)

2.2 HSR VEHICLE SEGMENT

This segment is comprised of rolling stock elements and subsystems for locomotives and passenger cars.

2.2.1 LOCOMOTIVE ELEMENT

This element applies to high-speed railway locomotives and "power cars" (i.e., units containing no passenger accommodations and used to supply motive power to a train). Present requirements are specified in *49 CFR 229, Railroad Locomotive Safety Standards*.

2.2.1.1 Body Structure

This subsystem grouping for high-speed and very-high-speed locomotives consists of the primary structure, including the main sills or platforms. The subsystem also consists of secondary structural members which may include sheathing, frames, and sills. Current safety regulations cover such things as buff strength, locomotive-end anti-climb structure, coupler carriers, collision protection posts at locomotive ends, and truck attachment strength. (See footnote 7.)

2.2.1.2 Truck Assembly

The truck subsystem for high-speed and very-high-speed locomotives consists of truck frames, wheel sets, suspension components (springs and dampers), and traction motor and gearbox attachments if truck-frame mounted.[7] Current safety requirements cover lateral motion, bearings, spring rigging, trucks, clearance above top of rail, wheel sets, and wheel and tire defects.

2.2.1.3 Cab Space

The cab subsystem consists of the cab structure that provides physical protection to the crew, the crew environment, and operating controls. Current safety regulations cover such things as pilots, snowplows, and end plates, flooring, passageways, cab noise, cab lighting and temperature control, headlights, glazing, and fire extinguishers, slip/slide alarms, speed indicators, sander controls, and audible warning devices.[8]

2.2.1.4 Traction Power Auxiliaries

This subsystem grouping consists of the auxiliary equipment of the locomotive (power car) such as motor-alternator sets, fans, pumps, filters, traction motor blowers, and air compressors.

2.2.1.5 Traction Power

The traction power subsystem grouping is comprised of prime movers, vents, fuel tank grounds, and safety hangers if internal combustion engines are being used for electric locomotives, transformers, rectifiers, smoothing reactors, inverters, traction motors, insulation, and other components of the traction power system aboard a high-speed locomotive.[9]

2.2.1.6 Braking

The subsystem grouping consists of high-speed locomotive braking equipment, involving control stands, reservoirs, brake pipes, operating valves, tread brakes and friction materials, dynamic braking systems (e.g., electric, mechanical, hydraulic, aerodynamic), and various forms of track brakes. In addition, brake schedules and air brake tests are included.[10]

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[7] *See 49 CFR 229--Locomotive Safety Standards, Subpart C--Suspension System, §229.63--§229.75.*

[8] *49 CFR 229--Railroad Locomotive Safety Standards, Subpart C--Cabs and Cab Equipment, §229.115--§229.131.*

[9] *See 49 CFR 229--Railroad Locomotive Safety Standards, Subpart C--Safety Requirements.*

[10] *49 CFR 232--Railroad Power Brakes and Drawbars.*

2.2.1.7 Draft Gear & Couplers

The draft and coupler subsystem consists of knuckles, yokes, and drawbars as currently specified by Federal Code.[11] The subsystem should contain components that keep cars coupled to the locomotive upright in the event of derailment. Unconventional locomotive-to-car connecting equipment may include articulation joints, and automatic couplers that incorporate air and electric trainline connections.

2.2.1.8 On-Board Diagnostic Subsystem

The on-board diagnostic subsystem consists of, at a minimum, central processing units, transducers, audible and visual alarms, data displays, crew input devices, and the interface with radio transmitters and receivers for voice and data transmission. The subsystem monitors block signals, traction and braking equipment, electrical systems, vital passenger car equipment, fire safety devices and other items as necessary.

2.2.1.9 HEP, HVAC, Lighting, and Electrical

This subsystem includes head-end power (HEP) generating equipment aboard locomotives (power cars), such as motor-alternators or inverters to supply power for cab and passenger car lighting, heating, ventilation, and air conditioning equipment. It includes electric trainlines and wiring aboard the locomotive. There are no current CFR regulations governing HEP and HVAC beyond those for steam generators. Also included in this subsystem are rear train markers.[12]

2.2.1.10 On-Board Communications and Control

This subsystem includes train radios and other data transmission and reception devices for communications and train control, cab signals, and automatic train stop equipment aboard the locomotive.[13]

2.2.2 SELF-PROPELLED CAR (EMU) ELEMENT

This element covers the safety requirements of self-propelled electric multiple-unit (EMU) passenger vehicles.

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[11] *49 CFR 229--Railroad Locomotive Safety Standards, Subpart C--Safety Requirements §229.61--Draft System.*

[12] *49 CFR 221 Rear End Marking Device.*

[13] *49 CFR 220 Radio Standards and Procedures, and 49 CFR 236 Subpart E--ATS, Train Control, and Cab Signal Systems.*

2.2.2.1 Body Structure

This subsystem for high-speed and very-high-speed EMU cars is comprised of the primary load carrying car structure, including safety criteria that pertain to buff strength, car-end anticlimb structure, coupler carriers, collision protection at car ends, car-side intrusion protection, and truck attachment strength. The subsystem also consists of secondary structural members which may include sheathing, frames, and sills. Current regulations are specified in *49 CFR Part 229* for multiple-unit (MU) locomotives.

2.2.2.2 Truck Assembly

The truck subsystem for a high-speed and very-high-speed EMU car is comprised of truck frames, wheel sets, suspension components (springs and dampers),[14] and traction motor and gearbox attachments if truck-frame mounted.

2.2.2.3 Cab Space

The cab subsystem consists of the cab structure that provides physical protection to the crew, the crew environment, and operating controls. Current safety regulations cover such things as pilots, snow plows and end plates, head lights, glazing, fire extinguishers, flooring, passageways, cab noise, cab lighting, and temperature control, slip/slide alarms, speed indicators, sander controls, and audible warning devices.[15]

2.2.2.4 Passenger Space

The car interior subsystem consists of glazing, carbody lining materials, crash-protecting passenger seat design, and crash protection and fire retardation materials and techniques.

2.2.2.5 Traction Power

The traction power subsystem consists of transformers, rectifiers, inverters, traction motors, motor wiring insulation and other components of the traction power system aboard a high-speed EMU passenger car.[16]

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[14] *49 CFR 229--Railroad Locomotive Safety Standards, Subpart C--Safety Requirements, Suspension System §229.63--§229.75.*

[15] *49 CFR 229--Railroad Locomotive Safety Standards, Subpart C--Safety Requirements, Cabs and Cab Equipment §229.115--§229.131.*

[16] *49 CFR 229--Railroad Locomotive Safety Standards, Subpart C--Safety Requirements, §229.77 - §229.91 Electrical System.*

2.2.2.6 Braking

The subsystem grouping is comprised of high-speed EMU car braking equipment, including: control stands, reservoirs, brake pipes, operating valves, tread or disc brakes and friction materials, dynamic braking systems (e.g., electric, mechanical, hydraulic, or aerodynamic), and various forms of track brakes. Brake schedules and air brake tests such as those specified by Federal Code[17] are also appropriate.

2.2.2.7 Draft Gear & Couplers

This subsystem consists of draft and coupler equipment, including knuckles, yokes, and drawbars as currently specified by Federal Code[18], and components that keep cars upright in the event of derailment. Unconventional car connecting devices may include articulation joints, and automatic couplers that incorporate air and electric trainline connections.

2.2.2.8 On-Board Diagnostic Subsystem

The on-board diagnostic subsystem consists of, at a minimum, central processing units, transducers and sensors, audible and visual alarms, data displays, crew data-input devices, and the interface with radio transmitters and receivers for voice and data transmission. The subsystem monitors block signals, traction and braking equipment, electrical systems, vital passenger car equipment, fire safety devices and other items as necessary.

2.2.2.9 HEP, HVAC, Lighting, & Electrical

This subsystem includes head-end power (HEP) generating equipment aboard self-propelled (EMU) cars such as motor-alternators or inverters to supply power for cab and passenger car lighting, heating, ventilation, and air conditioning equipment. It includes electric trainlines and wiring aboard the car. Also included in this subsystem are rear train markers.[19]

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[17] *49 CFR 232--Railroad Power Brakes and Drawbars.*

[18] *49 CFR 229--Railroad Locomotive Safety Standards, Subpart C--Safety Requirements, Draft System §229.61.*

[19] *49 CFR 221--Rear End Marking Device.*

2.2.2.10 On-Board Communications and Control

This subsystem includes train radios and other data transmission and reception devices for communications and train control, cab signals, and automatic train stop equipment aboard the car.[20]

2.2.3 CAB CAR ELEMENT

The subsystems and components that appear in this section apply to a cab car (i.e., a passenger car without a self-propelled capability but with a locomotive control cab at one (or more) end of the car for the purpose of providing remote control to a locomotive within the consist).

2.2.3.1 Body Structure

This subsystem grouping for high-speed and very-high-speed cab cars consists of the primary load carrying structure, including requirements that cover such things as buff strength, car-end anticlimb protection, coupler carriers, car-end collision protection, car-side intrusion protection, and truck attachment strength. The subsystem also consists of secondary structural members which may include sheathing, frames, and sills.

2.2.3.2 Truck Assembly

The truck subsystem for high-speed and very-high-speed cab cars consists of truck frames, bolsters (if used), wheel sets, and suspension components (springs and dampers).

2.2.3.3 Cab Space

The cab subsystem consists of the cab structure that provides physical protection to the crew, the crew environment, and operating controls. Current safety regulations cover such things as pilots, snow plows, and end plates, flooring, passageways, cab noise, cab lighting and temperature control, slip/slide alarms, speed indicators, sander controls, and audible warning devices.

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[20] *See 49 CFR 220--Radio Standards and Procedures, and 49 CFR 236 Subpart E--ATS, Train Control, and Cab Signal Systems for current regulations.*

2.2.3.4 Passenger Space

The car interior subsystem is comprised of glazing, carbody lining materials, crash-protection passenger seat design, and crash protection and fire retardation materials and techniques.

2.2.3.5 BLANK

This item left blank intentionally.

2.2.3.6 Braking

This subsystem grouping consists of high-speed cab car brake equipment, including control stand, reservoirs, tread or disc brakes, friction materials, brake pipes, rigging, operating valves, and inspection and test procedures and schedules.

2.2.3.7 Draft Gear & Couplers

This subsystem grouping consists of draft and coupler equipment, including knuckles, yokes, and drawbars if so equipped, and components that keep cars upright in the event of derailment. Unconventional car connecting systems may include articulation joints, and automatic couplers that incorporate air and electric train line connections.

2.2.3.8 On-Board Diagnostic Subsystem

This subsystem may consist of, at a minimum, central processing units, sensors and transducers, audible and visual alarms, data displays, crew data-input devices, and the interface with locomotive (power car) radio transmitters and receivers for voice and data transmission. The subsystem monitors block signals, traction and braking equipment, electrical systems, vital passenger car equipment, fire safety devices and other items as necessary.

2.2.3.9 HVAC, Lighting, & Electrical

This subsystem includes equipment aboard cab cars for regulating cab and passenger space lighting, heating, ventilation, and air conditioning. It includes electric trainlines and electrical wiring aboard the car. Also included in this subsystem are rear train markers.[21]

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[21] *49 CFR 221 Rear End Marking Device.*

2.2.3.10 On-Board Communications and Control

This subsystem includes, train radios and other data transmission and reception devices for communications and train control, cab signals, and automatic train stop equipment aboard the cab car.[22]

2.2.4 TRAILER CAR ELEMENT

The subsystems and components that appear in this section apply to an unpowered passenger car.

2.2.4.1 Body Structure

This subsystem consists of the primary load carrying car structure safety criteria that covers such things as buff strength, car-end anticlimb structure, coupler carriers, car-end collision protection, car side-intrusion protection, and truck attachment strength. The subsystem also consists of secondary structural members which may include sheathing, frames, and sills.

2.2.4.2 Truck Assembly

The truck subsystem for high-speed passenger cars consists of truck frames, bolsters (if used), wheel sets, and suspension components (springs and dampers). Safety requirements include the strength of attachment of a truck to a carbody.

2.2.4.3 BLANK

This item left blank intentionally.

2.2.4.4 Passenger Space

The car interior subsystem consists of glazing, carbody lining materials, crash-protection passenger seat design, and crash protection and fire retardation materials and techniques.

2.2.4.5 BLANK

This item left blank intentionally.

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[22] *See 49 CFR 220--Radio Standards and Procedures, and 49 CFR 236--Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal, and Train Control systems, Devices and Appliances, Subpart E--ATS, Train Control, and Cab Signal Systems for current regulations.*

2.2.4.6 Braking

The subsystem consists of high-speed passenger car brake equipment, including reservoirs, brake pipes, operating valves, tread and disk brakes, friction materials, rigging, and inspection and test procedures and schedules.

2.2.4.7 Draft Gear & Couplers

This subsystem consists of draft and coupler equipment, including knuckles, yokes, and drawbars (if so equipped), and components that keep cars upright in the event of a derailment. Unconventional car connecting systems may include articulation joints, and automatic couplers that incorporate air and electric train line connections.

2.2.4.8 On-Board Diagnostic Subsystem

This subsystem may consist of, at a minimum, sensors and transducers, audible and visible alarms, data displays, crew input devices, and the interface with locomotive radio transmitters and receivers for voice and data transmission. The subsystem monitors car electrical and mechanical equipment, fire safety devices, and other items as necessary.

2.2.4.9 HVAC, Lighting, & Electrical

This subsystem includes equipment aboard high-speed cars for regulating lighting, heating, ventilation, and air conditioning equipment. It includes electric trainlines and electrical equipment aboard the car. Also included in this subsystem are rear train markers.[23]

2.2.4.10 On-Board Communications and Control

This subsystem includes: train telephones and other data transmission and reception devices aboard a passenger car. (See footnote 24.)

2.2.5 BANKING CAR ELEMENT

The carbody banking elements include those subsystems that provide for carbody tilting about the longitudinal axis when the vehicle is on curved track. Carbody banking components may be either truck frame or carbody mounted. Failure of any carbody banking component may make a car exceed railway line clearances sufficient to cause interference between the carbody and trains on an adjacent track,

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[23] *See 49 CFR 221 Rear End Marking Device.*

thus contributing to collision, derailment, or other adverse contacts with other trains, wayside structures, or station platforms.

2.2.5.1 Body Structure

This subsystem consists of the primary load carrying car structure, including requirements that cover buff strength, car-end anticlimb structure, coupler carriers, car-end collision protection, car side-intrusion protection, and truck attachment strength. The subsystem also consists of secondary structural members which may include sheathing, frames, and sills.

2.2.5.2 Truck Assembly

The truck subsystem for cars with tilting carbodies consists of truck frames, tilting bolsters (if so equipped) wheel sets, and suspension components (springs and dampers). Safety requirements include the strength of attachment of a truck to a carbody.

2.2.5.3 BLANK

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2.2.5.4 Passenger Space

The car interior subsystem consists of glazing, carbody lining materials, crash-protection passenger seat design, and crash protection and fire retardation materials and techniques.

2.2.5.5 BLANK

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2.2.5.6 Braking

The subsystem consists of high-speed passenger car brake equipment, including reservoirs, brake pipes, operating valves, tread and disk brakes, friction materials, rigging, and inspection and test procedures and schedules.

2.2.5.7 Draft Gear & Couplers

This subsystem grouping consists of draft and coupler equipment, including knuckles, yokes, and drawbars (if so equipped), and components that keep cars upright in the event of a derailment. Unconventional car connecting systems may include articulation joints, and automatic couplers that incorporate air and electric train line connections.

2.2.5.8 On-Board Diagnostic Subsystem

This subsystem may consist of, at a minimum, sensors and transducers, audible and visible alarms, data displays, crew input devices, and the interface with locomotive radio transmitters and receivers for voice and data transmission. The subsystem monitors car electrical and mechanical equipment, carbody tilting mechanisms, fire safety devices, and other items as necessary.

2.2.5.9 HVAC, Lighting, & Electrical

This subsystem includes equipment aboard high-speed cars for regulating lighting, heating, ventilation, and air conditioning equipment. It includes electric trainlines and electrical equipment aboard the car. Also included in this subsystem are rear train markers.[24]

2.2.5.10 Active Tilting Subsystem

This subsystem is comprised of the various structural, hydraulic, pneumatic, and electrical components that physically support actuators or provide mechanical actuation, damping, and lock-out of powered carbody banking. Other components include those that sense track curvature and compute the amount of body banking necessary to provide an acceptable level of lateral balance for passenger comfort, and components to provide tilt information to adjacent cars in advance of the receiving cars entrance to the curve. Other components may include tilting carbody bolsters, swing hangers, or other pivot mechanisms.

2.2.5.11 Passive Tilting Subsystem

The subsystem grouping consists of structural, hydraulic, pneumatic, or electrical components that physically support, and/or provide damping and lock-out of passive carbody banking (gravity and centrifugal force powered pendular motion). These components may include tilting carbody bolsters, swing hangers, or other pivot mechanisms.

2.2.5.12 On-Board Communications and Control

This subsystem includes train telephones and other data transmission and reception devices aboard a passenger car. (See footnote 24.)

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[24] *49 CFR 221 Rear End Marking Device.*

2.3 HSR OPERATIONS CONTROL SEGMENT

The Operations Control Segment consists of: the Operations Center Control Element, Automatic Train Protection Element, Automatic Train Operation Element, Automatic Train Supervision Element, and an Automatic Dispatching Element.

Federal regulations govern conventional railroad operations with respect to the need for automatic cab signals, automatic train stop (ATS), or automatic train control (ATC).[25]

2.3.1 OPERATIONS CENTER CONTROL ELEMENT

The Operations Control Center element consists of a Central Traffic Control Subsystem equipped with one or more central computers, the HSR System Power Control Subsystem, an RF and Cable Communications Network, and Operations Control Center Personnel Safety Requirements.

2.3.1.1 Central Traffic Control

The central traffic control (CTC) subsystem integrates the Automatic Train Protection (ATP), Automatic Train Operation (ATO), Automatic Train Supervision (ATS), and Automatic Dispatching (AD) elements. It consists of element interfaces for the Operations Control Segment, computer software, and displays covering all routes and interlockings, computer input terminals, and displays used to administer, dispatch, route, and otherwise regulate train movements. See *49 CFR 236*. The CTC subsystem has authority over vehicle movements through the Central Computer Subsystem.

2.3.1.2 Central Computer

This subsystem consists of central processing units, software, and networks that support the Central Traffic Control subsystem. It interfaces with subsystems of the Automatic Train Protection (ATP), Automatic Train Operation (ATO), Automatic Train Supervision (ATS), Automatic Dispatching (AD) elements, and wayside Traction Power Control subsystem. A hierarchial computer installation may be one means of configuring the subsystem and its interface with the ATP, ATO, ATS, AD, and System Power subsystems. See *49 CFR 236.*

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[25] *49 CFR 236--Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices and Appliances for current regulations.*

2.3.1.3 Operations Control Center Personnel Safety Requirements

Safety requirements apply to personnel admitted to or working in the operations control center as specified by Federal Code.[26] The requirements call for fire safety and preventative measures.

2.3.1.4 System Power Control

This subsystem is comprised of equipment within the Operations Control Center that monitors and dispatches wayside traction power to the railroad via switchgear at remote locations.

2.3.1.5 RF & Cable Communication Network

This subsystem consist of the materials, installation, and operation of a radio-frequency (RF) and/or hard-wired cable communications network used for communications and control of train operations.

2.3.2 AUTOMATIC TRAIN PROTECTION ELEMENT

This element contains the set of capabilities that assures safe separation between trains, protects against conflicting and improperly lined routes, and provides protection against detected track conditions that might present a danger to trains.

2.3.2.1 Safe Train Separation

Safety requirements apply to the critical capability of the continuous determination of safe separation between trains to avoid collisions. This subsystem grouping consists of track circuits and wayside or cab signals, and computer software installed in the CTC computer. It interfaces with interlocking, and software for the ATO, ATS, and AD elements.[27]

2.3.2.2 Train Identification

Individual trains are monitored on a continuous basis for location, speed, and identity. Safety requirements play a key role in collision avoidance. Proper identification of the train secures it. This subsystem consists of software for the CTC

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[26] *49 CFR 219--Control of Alcohol and Drug Use.*

[27] *49 CFR 236--Rules, Standards and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices and Appliances, Subpart A--Routes & Instructions: All Systems; Subpart B--Automatic Block Signal Systems Standards; Subpart C--Interlocking; and Subpart D--Traffic Control Systems.*

computer, and on-board equipment to encode and transmit train identification signals.

2.3.2.3 Train Position/Location Detection

This subsystem includes the sensors and transducers that detect and transmit secure or redundant data for determining the speed, direction of movement and position of the train. This subsystem interfaces with the CTC computer(s).

2.3.2.4 Interlocking

The interlocking subsystem consists of an arrangement of signals and signal appliances operated from an interlocking machine and so interconnected by means of electric locking that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication. This subsystem interfaces with the CTC computer(s).[28]

2.3.2.5 Highway-Railroad At-Grade Crossing Obstruction Detection

The subsystem consists of surveillance and detection equipment. The surveillance equipment provides visual and electronic surveillance of highway-railroad at-grade crossings through the railroad's central traffic control system. The upper limit of train speed across at-grade crossings is 200 km/h (125 mph), and crossings are grade separated for all train speeds in excess of 200 km/h. The obstruction detection equipment displays advance warning indicators to the enginemen in the locomotive cab of obstacles that are in place on railway tracks at highway-railroad at-grade crossings. The subsystem's safety requirements apply to the design, installation, usage, and maintenance of the subsystem's components. (See footnote 7.)

2.3.2.6 Dragging Equipment, Hot Box, and Slide Detectors

This subsystem consists of wayside devices that detect dragging equipment, hot boxes, and slides of rock or earth that are hazardous to train travel. The wayside devices control signals to provide warning against unusual contingencies.[29] The subsystem interfaces with subsystems of the Operations Center.

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[28] *See 49 CFR 236--Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices and Appliances, Subpart C--Interlocking, and Subpart D--Traffic Control Systems for current regulations.*

[29] *49 CFR 236--Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices and Appliances, Subpart F--Dragging Equipment and Slide Detectors and Other Similar Protective Devices.*

2.3.3 AUTOMATIC TRAIN OPERATION ELEMENT

This element contains the set of capabilities that controls the operation of the train (i.e., acceleration, speed, deceleration). Its subsystems include the train speed detection subsystem, the train speed control subsystem, the on-board crew safety requirements, and the train platform-stop position control subsystem.[30]

2.3.3.1 Train Speed Detection

This subsystem grouping is comprised of the sensors and transducers that measure and transmit data relative to the velocity of the train at any time. The subsystem interfaces with the CTC computer(s), the train speed control subsystem, and the platform-stop position control subsystem.

2.3.3.2 Train Speed Control

This subsystem is comprised of hardware and software used to control the speed of high-speed trains. It interfaces with the train speed detection subsystem, and the CTC computer(s).

2.3.3.3 Train Platform-Stop Position Control

This subsystem consists of hardware and software that monitors train position, and controls the train's stopping at the correct position at each platform along the route. The subsystem interfaces with the on-board traction power control subsystem, the train position/location detection subsystem, and the CTC computer(s).

2.3.4 AUTOMATIC TRAIN SUPERVISION ELEMENT

This element contains the set of capabilities that control station dwell times, including door operations, and regulate maximum authorized speed in accordance with both the schedule and dispatching orders. Its subsystems include train station-dwell and door open control as well as the train speed control to enforce timetable and dispatch requirements. (See footnote 32.)

2.3.4.1 Train Station-Dwell & Door Open Control

The operation of this subsystem is a function of the automatic train supervision and automatic operation subsystems and is capable of revision to accommodate either automatic or manual dispatching commands. It consists of on-board electrical inter

[30] *49 CFR 214 Railroad Workplace Safety.*

locks with the train brakes, and interfaces with the ATO element, and the CTC computer(s).

2.3.4.2 Train Speed Control to Enforce Timetable & Dispatching Requirements

This subsystem consists of hardware and software that accommodates either automatic or manual dispatching and routing commands. Continuous monitoring is required for minor adjustments to authorized maximum speeds to minimize schedule variance. The subsystem interfaces with the ATO Element and the CTC computer(s).

2.3.5 AUTOMATIC DISPATCHING ELEMENT

This element includes the set of capabilities that adjusts the schedule or operating plan to reflect planned or unplanned changes in service or track availability, facilitate changes to automatic train stop (ATS) parameters, and provide human-directed overall control of the system.[31]

2.3.5.1 Consist Adjustment

This automatic subsystem consists of hardware and software that maintains an inventory of cars assigned to a particular train. The subsystem interfaces with the CTC computer, the train identification subsystem, and the train position/location detection subsystem. Safety requirements may apply if the system automatically cuts or adds cars to a train.

2.3.5.2 Subsystem to Add or Cut Trains to or from Timetable

This subsystem consists of hardware and software that provide for adding and deleting vehicles from the current plan, including unscheduled removals from service. It interfaces with the train identification subsystem and the CTC computer(s).

2.3.5.3 Station Stop/Bypass

This subsystem consists of the CTC hardware and software that has authority over route designation and the interlocking necessary to direct a train to turn out to an off-line passenger station, stop, dwell, start, and otherwise return to mainline operation. It interfaces with the train identification and position/location detection subsystems.

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[31] *49 CFR 218 Railroad Operationg Practices.*

2.3.5.4 Speed Restriction Administration

This subsystem consists of hardware and software that monitors and regulates train speed in accordance with established speed restrictions and/or slow orders. It interfaces with subsystems of the CTC, ATP, ATO, and ATS elements.

2.3.5.5 Track Blocking & Unblocking (for reason)

This subsystem consists of hardware and software that has authority over route designation and the interlocking necessary to direct a train to cross over to a parallel track in the event that the primary route is blocked off during maintenance, in the event of a wreck, or for other operational reasons. It interfaces with subsystems of the CTC, ATP, ATO, and ATS elements.

2.4 HSR TRACTION POWER SUPPLY SEGMENT

This segment consists of those elements of a high-speed rail system's wayside traction power installation, including substations, such transmission lines and catenary distribution equipment that is installed in or near the tracks, and security of traction power installations.

2.4.1 SUBSTATION ELEMENT

The substation element consists of subsystems that are used to receive electric power from high-voltage transmission feeder lines, and to step down, rectify, or otherwise convert, invert, and/or distribute that power for train operations, and high-voltage switchgear and circuit breakers. The substation element includes health and safety regulations for personnel working at the substation.

2.4.1.1 Transformers

This subsystem is comprised of transformers and their auxiliary equipment and coolants.

2.4.1.2 Switchgear & Circuit Breaker

This subsystem consists of high-voltage electrical switch gear and high-current circuit breaker and other electrical and mechanical equipment used in substations. The subsystem interfaces with the System Power Control subsystem of the Operations Center Control Element.

2.4.1.3 Personnel Safety

This subsystem includes personnel operations, maintenance and repair of substations, switchgear, and circuit breakers. (See footnote 32.)

2.4.2 WAYSIDE SUPPLY & CATENARY ELEMENT

The wayside power supply element is composed of, at a minimum, the phase break subsystem, the wayside feeder subsystem, and catenary subsystem.

2.4.2.1 Phase Breaks

The phase break subsystem consists of phase switching circuit breakers in the substations, switching transducers, on-board detectors, and overlapping catenary wires.

2.4.2.2 Wayside Feeders

The wayside feeder subsystem includes high-voltage electric lines, insulators, and support poles.

2.4.2.3 Catenary

The catenary subsystem consists of support poles, support pipes, registration arms, hangers, insulators, and messenger and contact wires used to supply electric power to trains.

2.4.3 TRACTION POWER SECURITY ELEMENT

The security element consists of those subsystems and components that are used to prevent unauthorized entrance to the traction power substation by unauthorized personnel.

2.4.3.1 Substation Security

This subsystem consists of fencing and intrusion detection security equipment used to prevent and monitor entrance to the substation by unauthorized personnel. The subsystem interfaces with the Operations Control Center.

2.5 HSR FACILITIES SEGMENT

The HSR train facilities segment includes those elements that provide maintenance of vehicles, track, and electrification. It also consists of special purpose rescue or work vehicles, the diagnostic center, and passenger stations.

2.5.1 MAINTENANCE SHOP ELEMENT

The maintenance shop element consists of the following subsystems: buildings, shop power, and yards.

2.5.1.1 Building

The building subsystem consists of the maintenance and parts shops, tools, personnel therein for vehicle maintenance and overhaul work, maintenance-of-way, and electrical and communications maintenance work. These requirements include applicable codes such as those of ADA, OSHA, NEC. etc. (See footnote 32.)

2.5.1.2 Vehicle Shop Stinger Power

The vehicle shop stinger power subsystem consists of electrical cables that provide high voltage power for the movement or testing of vehicle equipment within the building area.

2.5.1.3 Yard Safety and Noise

Yard safety includes the following areas: vehicle storage, service, inspection, and maintenance. The subsystem also includes personnel working in the yards.[32] In addition to safety requirements, noise standards are imposed on yard operations.[33]

2.5.2 SPECIAL PURPOSE VEHICLE ELEMENT

The special purpose vehicle elements consist of those self-propelled and towed vehicles that are required for track and overhead electrical wire inspection and maintenance.

[32] *49 CFR 218 Railroad Operating Practices.*

[33] *49 CFR 210 Railroad Noise Emission Compliance Regulations.*

2.5.2.1 Maintenance-of-Way & Power Vehicle

This subsystem consists of vehicles employed for inspection, maintenance-of-way work, and for maintenance of wayside electrification subsystems and components. They consist of cranes, track inspection cars, rail grinders, track laying machines, tampers, spike pullers, cars with raised platforms for catenary work, etc.

2.5.2.2 Rescue Vehicle

This subsystem consists of special purpose vehicles used to retrieve disabled trains, or to rescue passengers and crew from disabled or wrecked high-speed trains.

2.5.3 DIAGNOSTIC CONTROL CENTER ELEMENT

This element consists of those subsystems that form a part of a high-speed rail system's diagnostic control center (DCC). The center contains equipment to monitor, communicate, and analyze information from train-based and wayside diagnostic equipment, including signals, and power dispatching.

2.5.3.1 Building

The building subsystem houses the diagnostic control center (DCC), and the DCC's supporting equipment.[34] Safety requirements are imposed by OSHA, NEC, ADA, etc.

2.5.3.2 Central Diagnostic Computer

The Central Diagnostic Computer subsystem consists of software and hardware components, including transmission modes to on-board and wayside transducers or computers, data input devices, and displays. It interfaces with the Central Computer of the Operations Control Center and may be co-located with other computers in the Operations Control Center.

2.5.4 PASSENGER STATION ELEMENT

This element consists of those subsystems which involve passenger and crew safety in passenger stations and their administrative offices.

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[34] *49 CFR 214 Railroad Workplace Safety.*

2.5.4.1 Building

The Building subsystem consists of those spaces within a building meant for passenger or employee use. Applicable safety requirements are specified by the ADA, OSHA, the NEC, etc.

2.5.4.2 Passenger Security & Platform Access Safety

The Passenger Security and Platform Access Safety subsystem consists of measures to provide security to passengers and employees using the building and its station platforms for the purpose of entering or leaving railway vehicles.

2.6 OPERATIONS SEGMENT

The Operations Segment is comprised of two elements: Operating Rules and Practices, and Personnel Safety Requirements.

2.6.1 OPERATING RULES AND PRACTICES ELEMENT

This element covers safety requirements related to those railroad operations having to do with noise emissions, workplace safety, emergency repairs, operating rules and practices, and the reporting of accidents and incidents.

2.6.1.1 Noise Emission Avoidance Requirements

This subsystem consists of regulations for the enforcement of railroad noise emission standards. (See footnote 35.)

2.6.1.2 Railroad Workplace Safety Requirements

This subsystem consists of regulations for railroads that operate rolling stock that is included as part of the general railroad system of transportation. Safety regulations cover the responsibility for compliance, and bridge worker safety standards.[35]

2.6.1.3 Emergency Repair Requirements

This subsystem consists of regulations which authorize the Federal Railroad Administration (FRA) Inspectors, or the State Motive Power or the Track Inspectors

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[35] *See 49 CFR 214 Railroad Workplace Safety.*

to order a locomotive out of service, or to lower track in class, upon finding that the item in question is not in conformity with FRA safety regulations.[36]

2.6.1.4 Railroad Operating Rules

This subsystem consists of requirements for railroads to report to the Federal Railroad Administration, the condition of operating rules and practices with respect to trains and other rolling equipment.[37]

2.6.1.5 Railroad Operating Practices

This subsystem consists of prescribed minimum requirements for railroad operating rules and practices concerning operating rules, timetables, timetable special instructions, and other special instructions.[38]

2.6.1.6 Railroad Accident Reporting

This subsystem consists of the means to provide the FRA with information concerning hazardous conditions on the Nation's railroads.[39]

2.6.1.7 Railroad Maintenance Requirements

Covered under this heading are maintenance requirements for track, turnouts, vehicles, signals, system operations and control, and wayside electrification.

2.6.2 PERSONNEL SAFETY ELEMENT

This element is comprised of a minimum of three subsystems concerning railway employee safety, service hours, and training.

2.6.2.1 Employee Training Requirements

This subsystem consists of requirements for each railroad to instruct its employees in operating practices.[40] It also prescribes minimum Federal requirements for the eligibility, training, testing, certification, and monitoring of all locomotive

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[36] *See 49 CFR 216 Special Notice and Emergency Order Procedures: Railroad Track, Locomotive and Equipment.*

[37] *See 49 CFR 217 Railroad Operating Rules.*

[38] *See 49 CFR 218 Railroad Operating Practices.*

[39] *See 49 CFR 225 Railroad Accidents/Incidents: Reports, Classification, and Investigations.*

engineers. Its purpose is to ensure that only qualified persons operate a locomotive or train.[40]

2.6.2.2 Employee Service Hours

This subsystem consists of Federal requirements for railroads to record and report the hours of service of certain railroad employees, and covers standards and procedures concerning the construction or reconstruction of employee sleeping quarters. [41]

2.6.2.3 Control of Alcohol and Drug Use

This subsystem consists of regulations to prevent accidents and casualties in railway operations that result from impairment of employees by alcohol or drugs. (See footnote 28.)

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[40] *See 49 CFR 240 Qualifications and Certification of Locomotive Engineers.*

[41] *See 49 CFR 228 Hours of Service of Railroad Employees.*

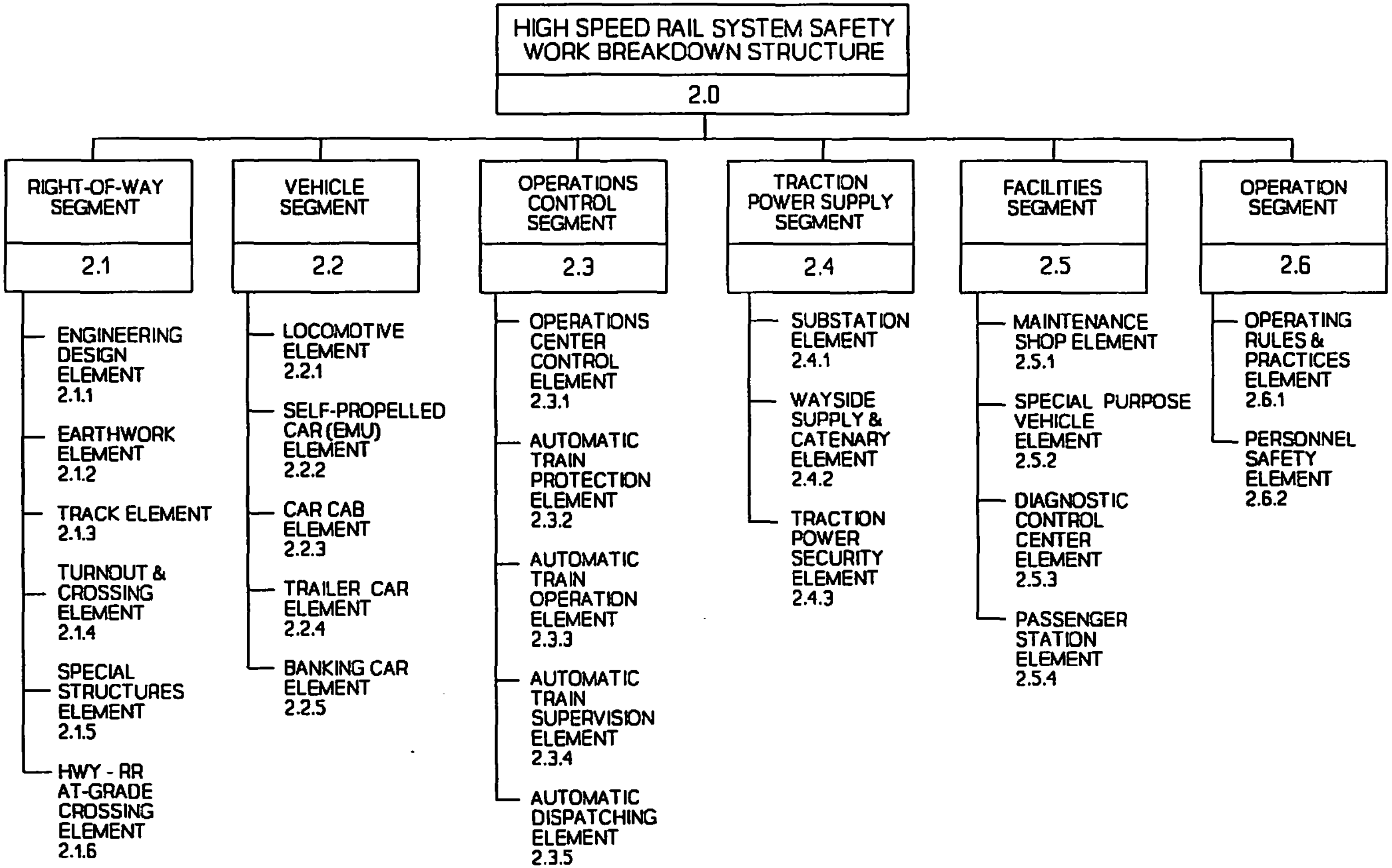

Figure II-1. High Speed Rail System Segments and Elements

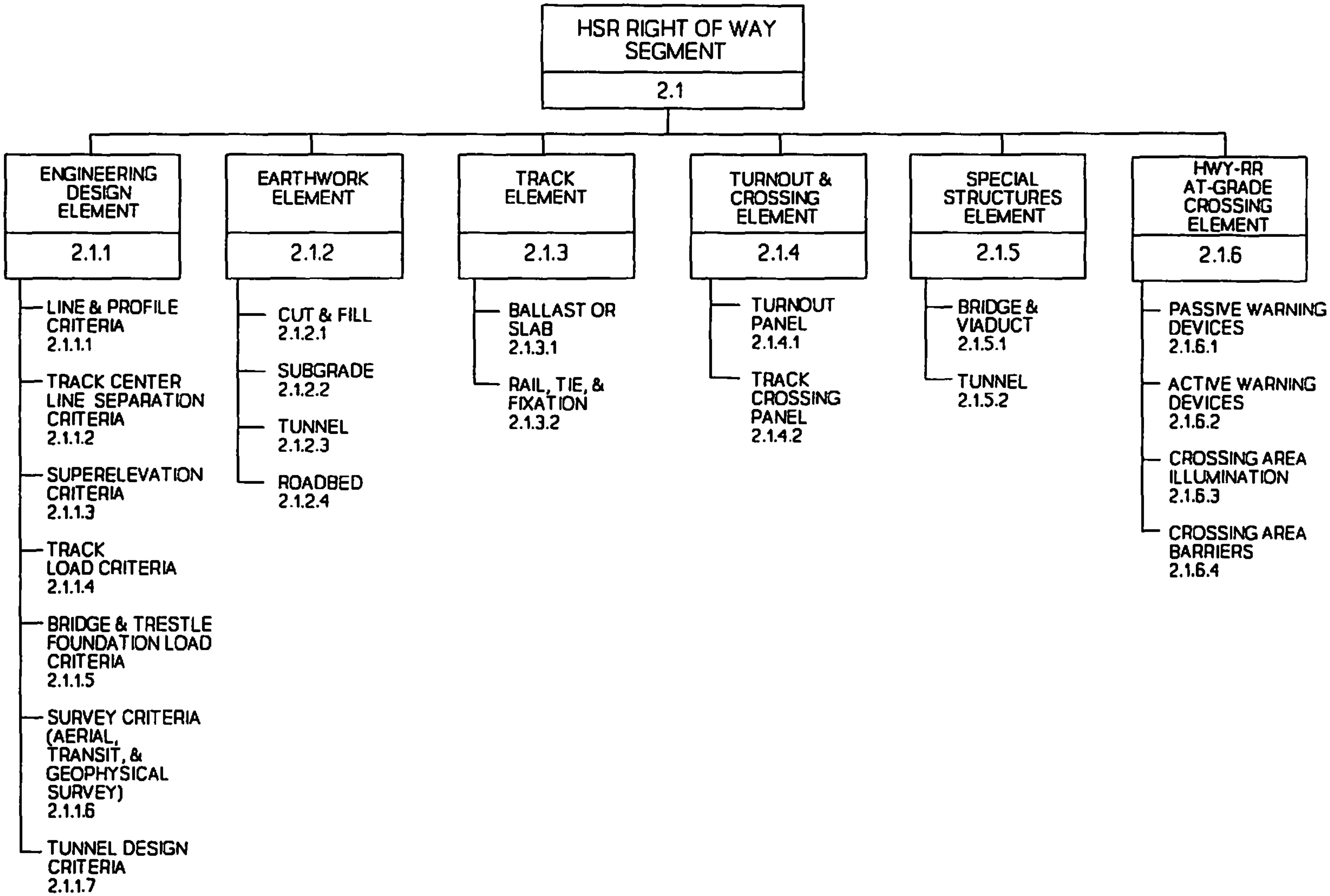

Figure II-2. High Speed Rail Right-of-Way Subsystems

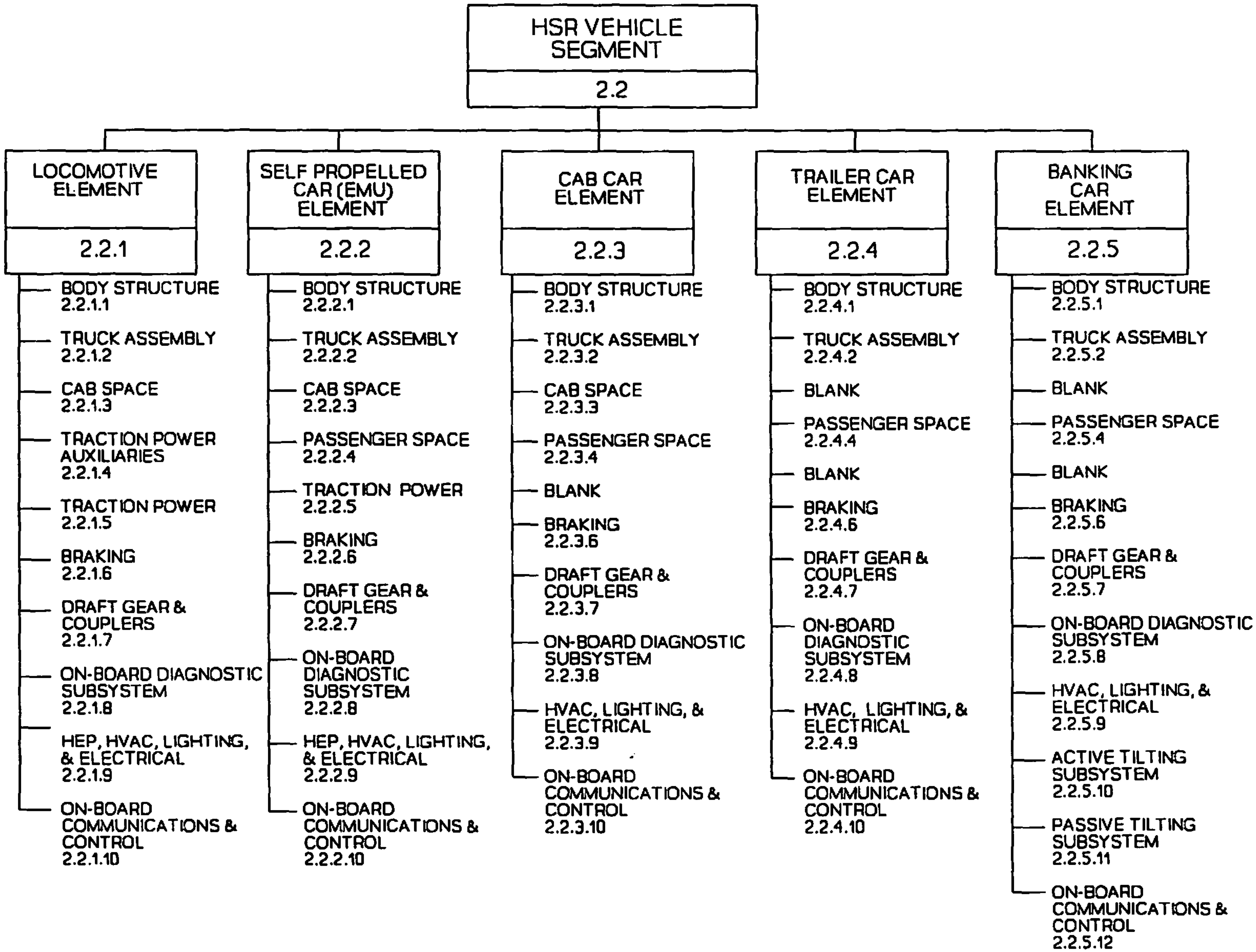

Figure II-3. High Speed Rail Vehicle Subsystems

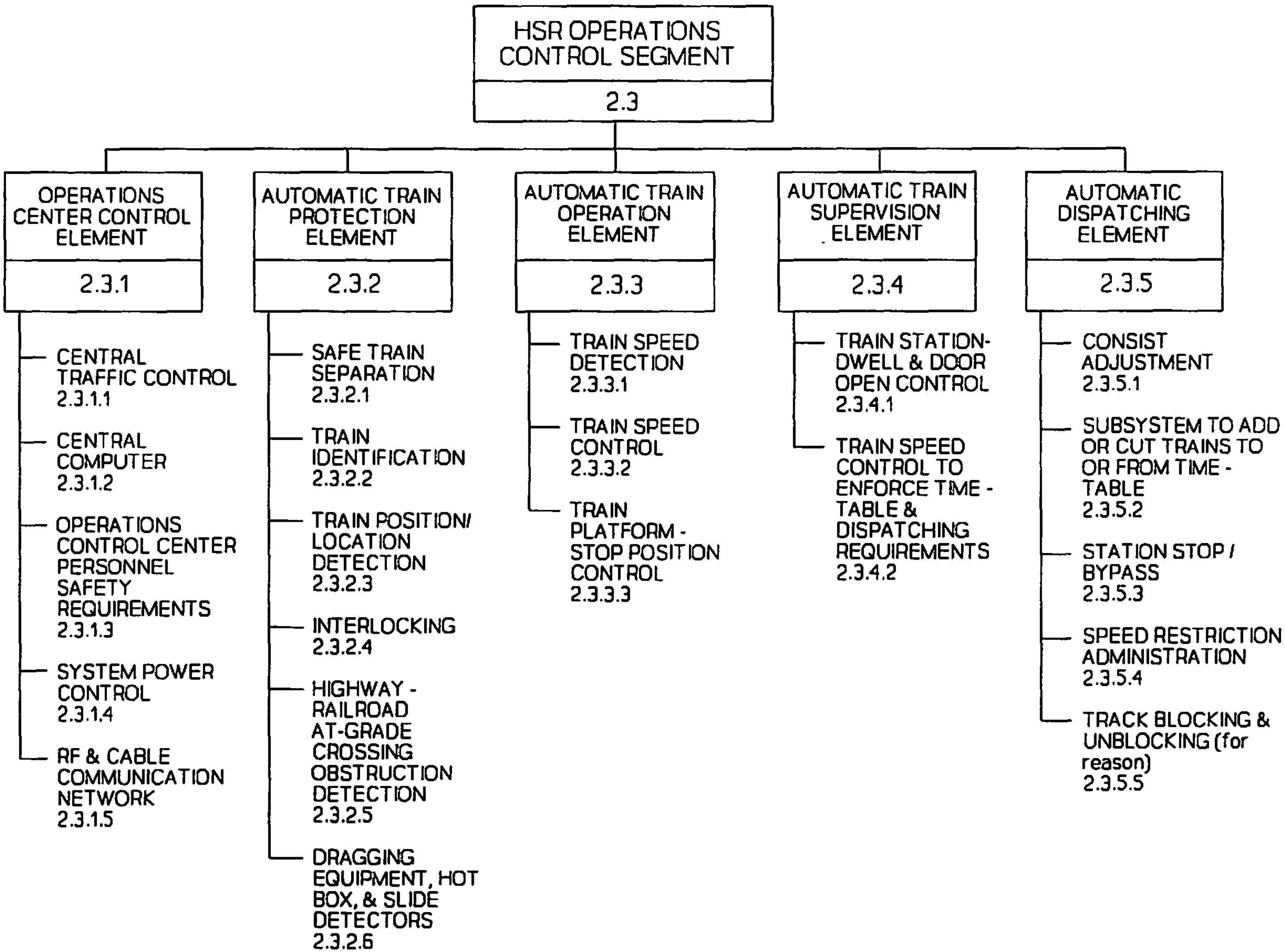

Figure II-4. High Speed Rail Operation Control Subsystems

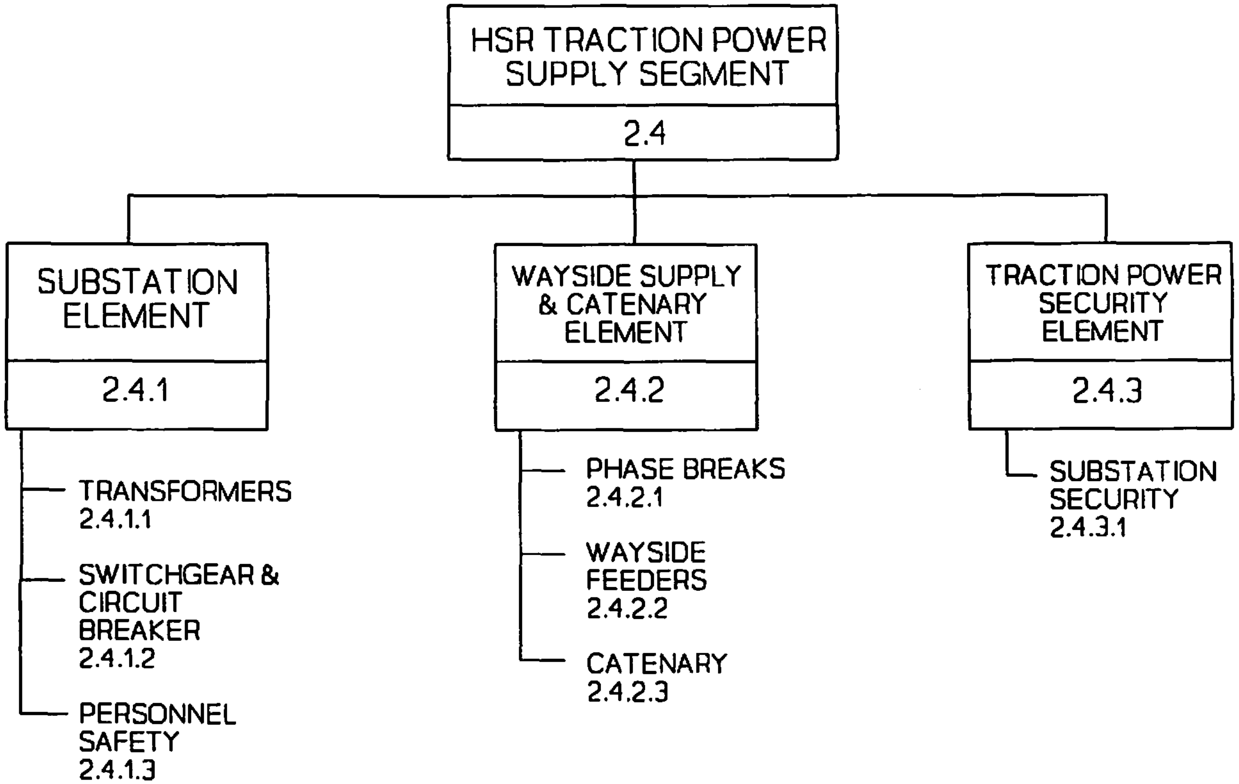

Figure II-5. High Speed Rail Traction Power Supply Subsystems

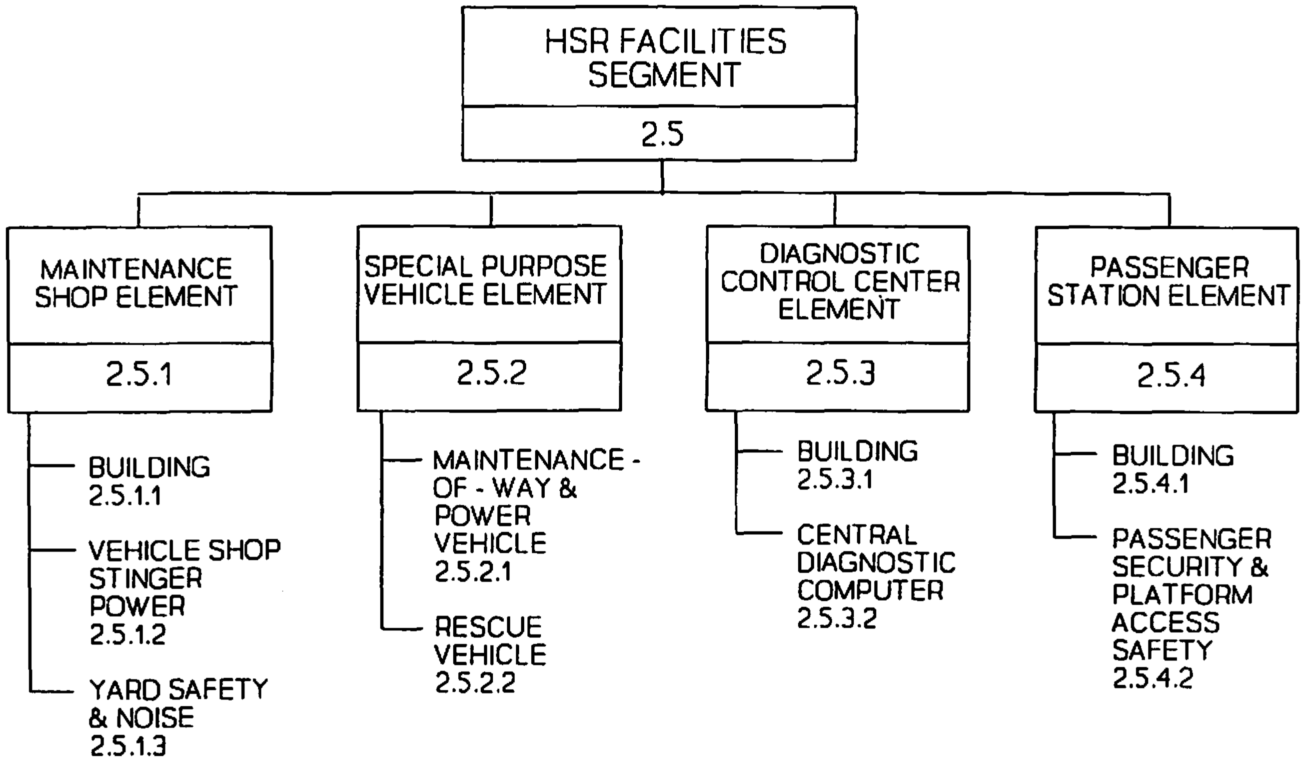

Figure II-6. High Speed Rail Facility Subsystems

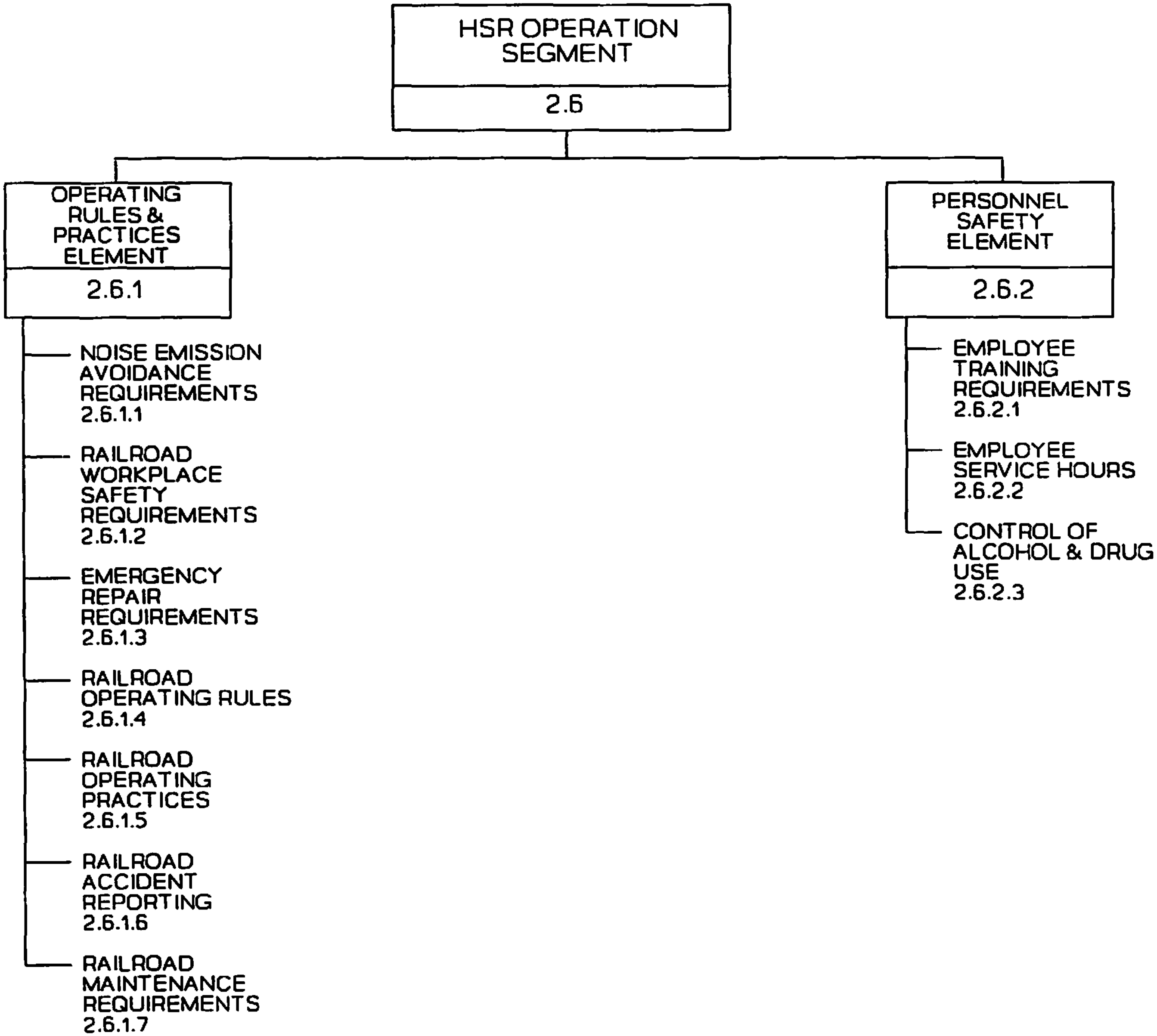

Figure II-7. High Speed Rail System Operations Requirements

PART III. HSGGT SYSTEM SAFETY WBS/ SAFETY AT SYSTEM SEGMENT, ELEMENT, AND SUBSYSTEM INTERFACES

Parts I and II of this report establish and define HSGGT work breakdown structures (WBS) at the segment element, and subsystem levels. This part of the report addresses the methodology of developing the safety considerations and requirements at the interfaces of the functional nodes.

An interface is defined as "...the place at which independent systems meet and act on or communicate with each other; or area where diverse things interact; the means by which interaction or communication is effected at an interface."[1] Specific HSGGT interfaces may be diagrammed to show the relationships between segments or elements.

INTERFACE DIAGRAMS

An important part of the approach to the assessment of safety from the top down is the means of identification of intra- and inter-segment interfaces. A simple graphical technique of diagramming interfaces exists. The basic tenet is that the maximum number of potential interfaces can not exceed n(n-1), where n is the number of segments, elements, or subsystems considered for a specific interface analysis. An example of an interface diagram at the system segment level may be seen in Figure III-1, the six segments of Figure I-1. With six HSGGT system segments (i.e., n=6) the maximum number of potential interfaces is 30 (i.e, n[n-1]), not 36 (i.e., n^2). However, upon investigation it may be seen in Figure III-1 that only 18 are relevant in this case. Relevant safety interfaces are depicted by a circle (-o-) that marks appropriate nodes.

An interface diagram is constructed and read, in a clockwise direction. A safety assessment team (e.g., an Interface Control Working Group) identifies potential interface requirements. The next step is to diagram them and their inter-relationships. Once this is done, a list of potential safety regulations may be drawn up for the specific interface. To construct the diagram, begin at the upper left hand corner, for example, and identify requirements imposed on each of the other segments so that the requirements flow in a clockwise direction.

In Figure III-1 the relevant flow of segment level safety requirements, if any, includes the interfaces between the Vehicle and the Right-of-Way, between the vehicle and the Operations Control Segment, between the Vehicle and the Propulsion Power Segment, between the Vehicle and certain Supporting Facilities (e.g.,

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[1] *Webster's New Collegiate Dictionary*, The G. & C. Merriam Company, Springfield, MA, 1981.

inspection, service, and maintenance shops), and between the Vehicle and the System Operations Segment.

In turn, there are safety interface requirements imposed on the Vehicle by the Right-of-Way Segment, the Operations Control Segment, the Propulsion Power Segment, the Supporting Facilities Segment, and the System Operations Segment. In a similar manner, it may be seen in Figure III-1 that the Right-of-Way Segment imposes safety requirements on both the Operations Control and the Propulsion Power Segments.

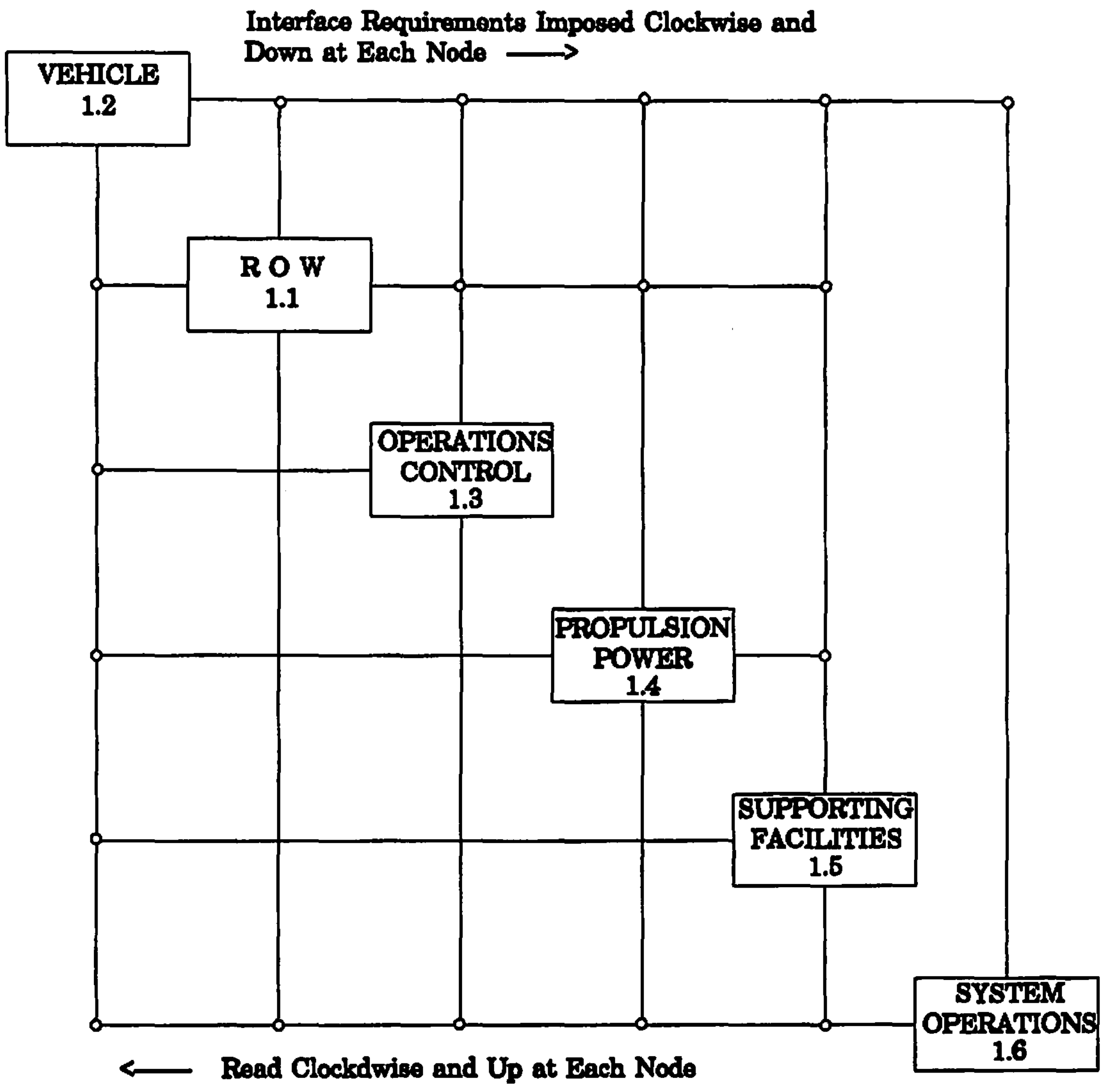

Figure III-1. Safety Interface Diagram At Segment Level for Segments of Figure I-1 (With Vehicle Orientation)

A sample element level interface diagram is presented as Figure III-2. This diagram typifies a sketch of the relationships between the guideway which is in Segment 1.1 and other elements that are in Segments 1.4, 1.2, and 1.6, namely: Motor Section, Vehicle Banking, On-board Propulsion and Braking, Vehicle Truck and Suspension, and Operating Rules and Practices. At the 1.1.3-to-1.4.3 node, one would assess requirements imposed on stator coils by the guideway configuration, if any. At the 1.4.3-to-1.1.3 node, one would assess requirements imposed on the guideway by stator coils.

Similarly, the node between 1.1.3 and 1.2.6 is the place where an assessment of vehicle motion within a clearance diagram would be made.

A similar form of interface diagram between selected subsystems may be seen in the example shown as Figure III-3.

FORMULATION OF SYSTEM SAFETY STANDARDS

Based on safety objectives for the overall HSGGT system, it is necessary to establish objectives at the system segment level for each area of operations and equipment utilization. Existing standards must be considered in terms of their applicability to overall HSGGT system performance in terms of the potential maximum contribution each segment makes to achieving system safety objectives. Such standards should be based on a knowledge of the previously established safety objectives, and on desired operational procedures.

INTERFACE CONTROL

The connectivity of the system is assured by developing and managing interface safety requirements through the use of functional, physical, and environmental interface control documents (ICD). Interface control may be maintained through the management of intersegment ICD's by a System Safety Integrator utilizing an Interface Control Working Group (ICWG) which is chaired by the System Safety Integrator, and supported by subtier system segment integrators. In addition to the system level intersegment ICD, each System Segment Integrator manages an intrasegment ICWG supported by members of the ICWG subtiered to that segment. As an example, the overall Systems Operations Control Segment Integrator should take the lead role in ensuring the successful implementation of automatic traffic control functions throughout the HSGGT system.

A number of items appear in this structure that may not have an obvious safety implication in terms of conventional railroad practice. Indeed, some may have no safety implication whatsoever, but are included to complete a meaningful system profile. The objective being to form a comprehensive safety framework and check list.

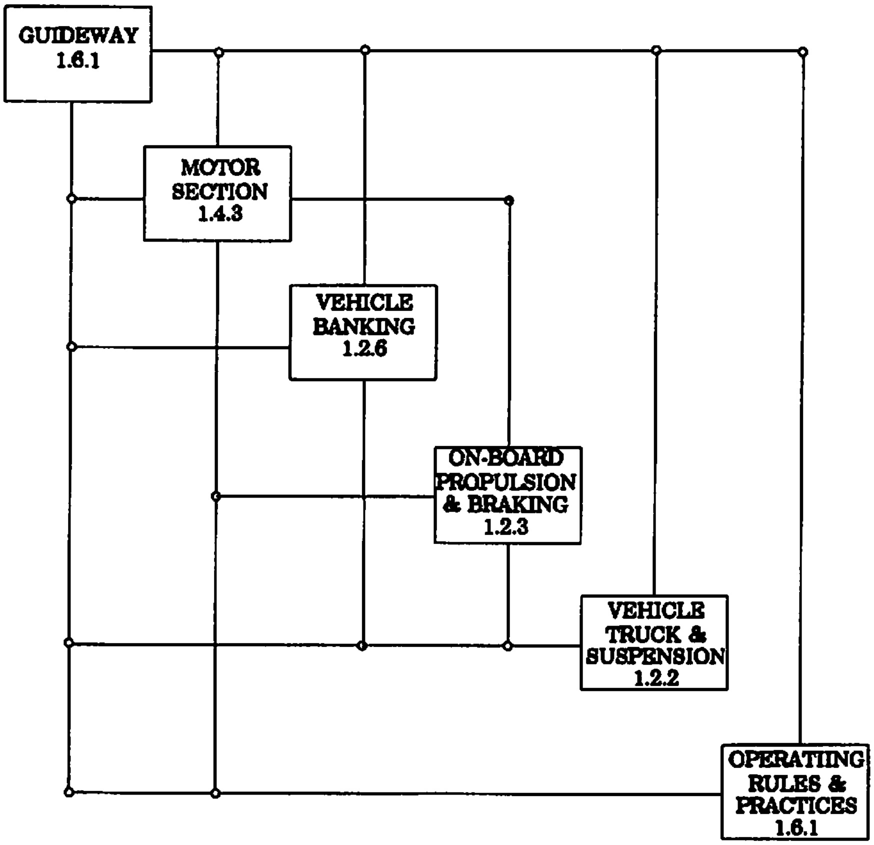

Figure III-2. Safety Interface Diagram At Element Level
for Three Segments (Guideway Orientation)

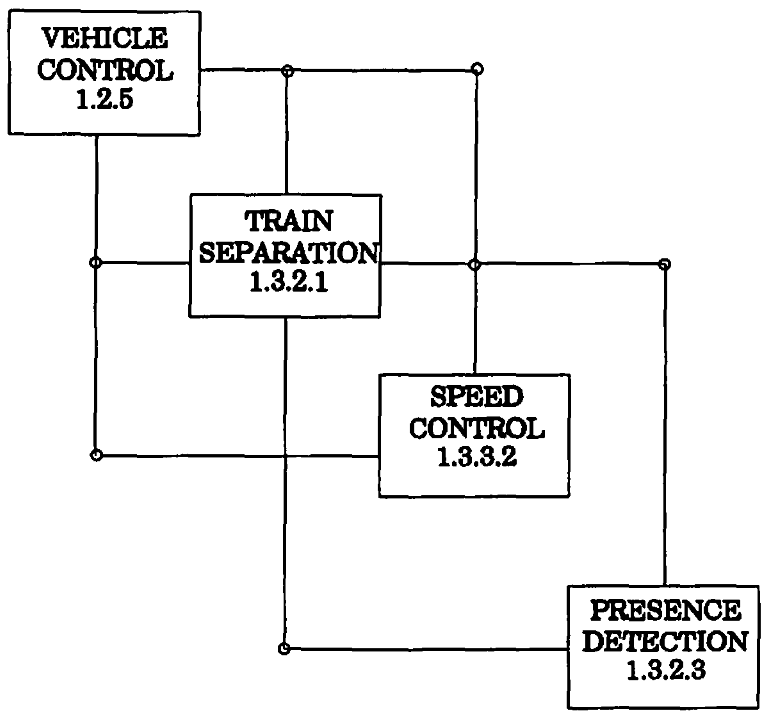

Figure III-3. Safety Interface Diagram At Subsystem Level for Two Segments and Two Elements (Vehicle Control Orientation)

*U.S. G.P.O.:1994-301-717:80488