Chapter 1
GENERAL

1.1 SCOPE

This standard has been combined from four previous parts identified below, to expedite the approval and release process and to facilitate ease of use.

Previous Parts 1, 2, 3, and 4 of ASCE 21-05 and 21-08 cover a minimum set of requirements for design of an automated people mover (APM) with an acceptable level of safety and performance. The previous numbering system is retained (with additions):

Part 1 of ASCE 21-05 consists of

1. General
2. Operating Environment
3. Safety Requirements
4. System Dependability
5. Automatic Train Control (ATC)
6. Audio and Visual Communications

Part 2 of ASCE 21-08 consists of

7. Vehicles
8. Propulsion and Braking

Part 3 of ASCE 21-08 consists of

9. Electrical Equipment
10. Stations
11. Guideways

Part 4 was a minimum set of requirements for maintaining an acceptable level of safety and performance for an automated people mover in passenger operation.

Part 4 of ASCE 21-08 consists of

12. Security
13. Emergency Preparedness
14. System Verification and Demonstration
15. Operations, Maintenance, and Training
16. Operational Monitoring

Annex A. System Safety Program Requirements

Annex B. Bibliography

Annex C. Recommended Practice for Acceptance of an APM System Application

Annex D. Inspection and Test Guidelines

Annex E. Recommended Practice for Working Safely near APM Systems

1.2 EXISTING APPLICATIONS

Existing installations and projects in progress before the effective date of this standard need not comply with the new or revised requirements of this edition, except where specifically required by the authority having jurisdiction. Existing APMs, when completely removed and reinstalled, shall be classified as new installations.

1.3 NEW APPLICATIONS

New installations begun after the effective date of this standard shall comply with the new or revised requirements of this edition.

1.4 REFERENCE STANDARDS

The following documents or portions thereof are incorporated by reference in this standard:

AASHTO: American Association of State Highway and Transportation Officials, Suite 249, 444 North Capitol Street NW, Washington, D.C. 20001; phone (202) 624-5806.

AASHTO LRFD Bridge Design Specifications, 4th Edition, 2007 (cited in Sections 11.9.1, 11.9.2, and 11.9.3)

AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002 (cited in Sections 11.9.1, 11.9.2, and 11.9.3)

ACGIH: American Conference of Government Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240; phone (513) 742-2020.

ACGIH Publication #7 DOC-648, *Whole Body Vibration: TLV Physical Agents*, 7th Edition, 2001, "Documentation" (cited in Section 7.7.3.2)

NOTE: An equivalent source for the above is ISO 2631-1-1985 (1985), *Evaluation of Human Exposure to Whole-Body Vibration*, which is no longer supported by or available from the ISO but may be purchased from the IHS Standards Store, 15 Inverness Way East, Englewood, Colo. 80112; phone (303) 792-2181 ext. 1950.

ANSI Publications: American National Standards Institute, Attn: Customer Service, 11 West 42nd Street, New York, N.Y. 10036; phone (212) 642-4900.

ANSI S1.4-1983 (1983a), *Specification for Sound Level Meters* (cited in Sections 2.2.1 and 7.7.4)

ANSI S3.29-1983 (1983b), *Guide to the Evaluation of Human Exposure to Vibration in Buildings* (cited in Section 2.2.2)

ANSI/ASME B15.1-2000 (2000), *Safety Standard for Mechanical Power Transmission Apparatus* (cited in Section 8.5)

ANSI B77.1-2006 (2006), *Passenger Ropeways—Aerial Tramways, Aerial Lifts, Surface Lifts, Tows and Conveyors—Safety Requirements* (cited in Sections 8.2.2 and 11.0)

ANSI Z97.1-2004 (2004), *Safety Glazing Materials Used in Buildings—Safety Performance Specifications and Methods of Test* (cited in Sections 10.2.1 and 10.2.2)

ANSI Z26.1-1996 (1996), *American National Standard, Safety Code for Safety Glazing Materials for Glazing Motor Vehicles Operating on Land Highways* (cited in Section 7.9)

ANSI 117.1-2003 (2003), *Guidelines for Accessible and Usable Buildings and Facilities* (cited in Section 11.5)

APTA Publications: American Public Transportation Association, 1666 K Street, NW, Washington, D.C. 20006; phone (202) 496-4800.

APTA SS-E-010-98 (1998), *Standard for the Development of an Electromagnetic Compatibility Plan* (cited in Section 2.1.8)

ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers, 1791 Tullie Circle NE, Atlanta, Ga. 30329; phone (800) 527-4723.

2005 ASHRAE Handbook Fundamentals Volume, Chapter 28, Table 1 (cited in Section 7.7.1)

2009 ASHRAE Handbook—Fundamentals, Chapter 14, Climatic Design Information (cited in Section 2.1)

ASTM: Formerly the American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, Penn. 19428-2959; phone (610) 832-9585.

ASTM D635-06 (2006a), Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position (cited in Section 9.3.6)

ASTM C1036-06 (2006b), Standard Specification for Flat Glass (cited in Sections 10.2.1 and 10.2.2)

ASTM C1048-04 (2004), Standard Specification for Heat Treated Flat Glass (cited in Sections 10.2.1 and 10.2.2)

Code of Federal Regulations: U.S. Government Printing Office, Superintendent of Documents, 732 North Capitol Street, NW, Washington, D.C. 20401; phone (202) 512-1800.

CFR, Title 47, Chapter I, Part 15, Radio Frequency Devices (cited in Section 2.2.3)

CFR, Title 47, Chapter I, Part 90, Subparts S and T, Private Land Mobile Radio Services (cited in Section 2.2.3)

16 CFR 1201, Consumer Products Safety Commission Standard on Architectural Glazing Materials (cited in Sections 10.2.1 and 10.2.2)

Gale Research Publication: Gale Research Company, P.O. Box 33477, Detroit, Mich. 48232; phone (800) 877-4253, Ext. 5477.

Weather of U.S. Cities, Fifth Edition, Vols. 1 and 2 (1996), by Richard A. Wood (cited in Section 2.1)

IEC Publications: International Electrotechnical Commission (IEC) Central Office, 3, rue de Varembé, CH-1211, Geneva 20, Switzerland; phone +41 22 919 02 11; Website: www.iec.ch.

IEC 62236 Edition 2.0, 2008–12, Parts 1–5, Railway Applications—Electromagnetic Compatibility (cited in Section 2.1.8)

IEEE Publications: Institute of Electrical and Electronic Engineers, 3 Park Avenue, New York, N.Y. 10016-5997; phone (800) 678 4333.

IEEE Standard 1474.1-2004 (2004), IEEE Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements (cited in Sections 3.6 and 5.0)

IEEE Standard 32-1972 (1972, revised 1990), Standard Requirements, Terminology and Test Procedures for Neutral Grounding Devices (cited in Section 7.12.5)

IEEE Standard 242-2001 (2001), Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, Section 1.0, First Principles (cited in Section 9.1.3)

IEEE Standard 519-1992 (1992), IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems (cited in Section 9.2.3)

IEEE Standard 142-1991 (ANSI C114.1-1991) (1991), IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (cited in Section 9.1.4.1)

ISO: See ACGIH.

Military Standards: Defense Printing Service, Building A, 700 Robbins Avenue, Philadelphia, Penn. 19111; phone (215) 697-2179 or 2667.

MIL-STD-810 F (2000), Environmental Test Methods and Engineering Guidelines (cited in Section 2.1.5)

NACE: National Association of Corrosion Engineers, 1440 South Creek Drive, Houston, Tex. 77084; phone (281) 228-6200.

NACE Standard RP0169-2002 (2002), Control of External Corrosion on Underground or Submerged Metallic Piping Systems (cited in Section 9.1.2)

NEMA: National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Arlington, Va. 22209; phone (703) 841-3200.

All NEMA standards (cited in Section 7.12.2.2)

NFPA Publications: National Fire Protection Association, Customer Service Department, 1 Batterymarch Park, P.O. Box 9101, Quincy, Mass. 02269-9101; phone (800) 344-3555.

NFPA 72-2002 (2002), National Fire Alarm Code (cited in Section 6.1.6)

NFPA 70, 2005 edition, National Electrical Code (cited in Sections 7.12.2.2, 9.1.4.2, 9.2.9, and 9.4)

NFPA 101, 2006 edition, Life Safety Code (cited in Section 10.4)

NFPA 130, 2003 and 2007 editions, Fixed Guideway Transit and Passenger Rail Systems (cited in Sections 6.1.2, 7.10, 7.10.1, 7.11.2, 7.12.2.1, 7.12.3, 9.1.1, 9.2.9, 10.4, 10.5.2, 10.5.3, 11.1, 11.3, 11.3.1, 11.3.2, 11.3.3, 11.4, 11.5, 11.6, and 11.7)

NOAA Publications: National Climatic Data Center, 151 Patton Avenue, Room 120, Ashville, N.C. 28801-0900; phone (828) 271-4800.

Local Climatologic Data, Annual Summary with Comparative Data, National Oceanic and Atmospheric Administration, updated annually (cited in Section 2.1)

SAE: Society of Automotive Engineers International, SAE World Headquarters, 400 Commonwealth Drive, Warrendale, Penn. 15096-0001; phone (877) 606-7323 (U.S. and Canada), 1-724-776-4970 (outside U.S. and Canada).

SAE J673-2005 (2005), Automotive Safety Glasses (cited in Section 7.9)

TIA, Telecommunications Industry Association Publications: Telecommunications Industry Association, 2500 Wilson Boulevard, Suite 300, Arlington, Va. 22201; phone (703) 907-7700.

Wireless Communications Systems—Performance in Noise and Interference-Limited Situations—Recommended Methods for Technology- Independent Modeling, Simulation, and Verification, Addendum 1, TIA/EIA Telecommunications Systems Bulletin TSB-88-A-1, January 2002 (cited in Section 6.1.6)

UL Publications: Underwriters Laboratories Publications, 333 Pfingsten Road, Northbrook, Ill. 60062; phone (847) 272-8800.

UL 96A, 11th Edition (2001). Installation Requirements for Lightning Protection Systems (cited in Section 2.1.4)

UL 813-1993 (1993), Commercial Audio Equipment (cited in Section 6.1.3)

1.5 DEFINITIONS

Automated People Mover (APM): A guided transit mode with fully automated operation, featuring vehicles that operate on guideways with exclusive right-of-way.

Automatic Train Control (ATC): The system for automatically controlling train movement, enforcing train safety, and directing train operations. ATC includes subsystems for automatic train operation (ATO), automatic train protection (ATP), and automatic train supervision (ATS).

Automatic Train Operation (ATO): The subsystem within the automatic train control system that performs any or all of the functions of speed regulation, programmed stopping, door and dwell time control, and other functions otherwise assigned to the train operator.

Automatic Train Protection (ATP): The subsystem within the automatic train control system that provides the primary protection for passengers, personnel, and equipment against the hazards of operations conducted under automatic control.

Automatic Train Supervision (ATS): The subsystem within the automatic train control system that monitors and manages the overall operation of the APM system and provides the interface between the system and the central control operator.

Automated Transit Network (ATN): A subset of Automated People Mover that has all stations off-line, switching that requires no track-based moving parts and train capacity less than 25 passengers.

Bogie: The bogie consists of the elements that transmit lateral, longitudinal, and vertical loads between the guideway and the carbody. Bogies are also referred to as trucks.

Braking, Emergency: Irrevocable braking to a complete stop at a rate never less than the minimum guaranteed rate.

Braking, Service: Braking of vehicle motion at a rate that is regarded as comfortable for repeated use in service stopping and/or slowing.

Carbody: The structural body shell, enclosing the passenger compartment(s).

Central Control: That location where automatic train supervision is accomplished for the entire transit system; the train command center.

Central Control Operator: Any person authorized to operate the APM system from Central Control.

Consist: The makeup or composition (number and specific identity) of a train of vehicles.

Cosmetic Damage: Damage that does not impair system function, performance, safety, or structural integrity.

Dwell Time: The total time the train services the station measured as the time from door open command to the time the doors are closed and locked.

Dynamic Sign: A sign on which the messages can be changed.

Fail-Safe: A characteristic of a system or its elements whereby any failure or malfunction affecting safety causes the system to revert to a state that is known to be safe.

Failure: An inability to perform an intended function.

Free Field: An isotropic, homogeneous sound field that is free from all bounding surfaces.

Guideway: A track or other riding surface (including supporting structure) that supports and physically guides transit vehicles specially designed to travel exclusively on it.

Hazard: An existing or potential condition that can result in an accident.

Headway: The time separation between two trains, both traveling in the same direction on the same guideway, measured from the time the head end of the leading train passes a given reference point to the time the head end of the train immediately following passes the same reference point.

Interlock: An arrangement of control elements so interconnected that their operations must succeed each other in proper sequence.

Jerk: The time rate of change of acceleration or deceleration.

MTBHE: Mean time between hazardous events (Table 3-1).

Off-Line Station: A station in which loading/unloading platforms are in juxtaposition to a siding off the through guideway, so that trains may bypass the station and thus avoid waiting for predecessor trains making a station stop.

Operating Loads: Definitions of operating loads are presented in Section 7.4.4.1.1 as lateral loads, vertical loads, and longitudinal loads.

Overspeed: Train speed that is in excess of the speed limit as defined for the relevant point on the guideway.

Overtravel: Continued movement of a train beyond a specified stopping point.

Passenger Compartment: If a vehicle is divided into separate areas between which passengers are either unable or not permitted to move, each such area is defined as a passenger compartment. If the vehicle is not so divided, then the entire vehicle is the passenger compartment.

Permissive Decision: Granting permission or authority for the system or a part of the system to enter any state other than the safe state.

Risk: A measure of the severity and likelihood of an accident.

Safe State: System state that is deemed acceptable by the hazard resolution process (see Section 3.1.2).

Safety-Critical: A designation placed on a system, subsystem, element, component, device, or function denoting that satisfactory operation of such is mandatory to mitigation of unacceptable and undesirable hazards as defined in Table 3-1.

Separation: The distance between the adjacent ends of two trains traveling along the same guideway as measured along the guideway centerline.

Separation Assurance Zone (SAZ): A distance between the rear of a leading train and the front of a following train that continuously ensures the following train can stop without colliding with the leading train, even in the event of any failure occurring to the leading train.

Shall: In this standard, the word “shall” denotes a mandatory requirement.

Should: In this standard, the word "should" denotes a recommendation.

Slow-Speed People Movers: Site applications in which all vehicles travel no more than 32 km/h (20 mph) at any location on their routes during normal operation.

Subsystem: A major functional subassembly or grouping of items or equipment that is essential to operational completeness of a system.

System: A composite of people, procedures, facilities, and/or equipment that are integrated to perform a specific operational task or function within a specific environment.

System Dependability: The overall set of criteria used to measure the performance of an operating system in terms of reliability, maintainability, and availability.

System Safety: The application of engineering and management principles, criteria, and techniques to optimize all aspects of safety within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle.

Tabletop Drill: A simulated or theoretical drill in which personnel carry out their functions by discussion.

Through Guideway: The main-line guideway, including merges and diverges, whereby trains bypass offline stations, maintenance/storage facilities, etc.

Train: A train consist of one or more contiguous vehicles combined into an operating unit.

Vehicle: The smallest unit that can operate alone or that comprises one of the basic building blocks of a train.

Zero Speed: A specified speed below which automatic train control considers a train to be stopped.

Chapter 5
AUTOMATIC TRAIN CONTROL

The ATC subsystem shall provide automatic train protection (ATP), automatic train operation (ATO), and automatic train supervision (ATS) functions. ATP shall provide the primary protection for passengers, personnel, and equipment against the hazards of operations conducted under automatic control. ATP functions shall have precedence over both the ATO and ATS functions. ATO shall control basic operations that would otherwise be performed by an operator and does so within the protection limits imposed by ATP. The ATS shall provide system status information and the means for the central control operator to monitor and override the automatic control for various functions of the system.

For automated people mover (APM) systems that use communications-based train control (CBTC) for ATC, the requirements of IEEE 1474.1-2004 (2004) shall apply in lieu of the requirements provided in Sections 5.1 and 5.2. Compliance with IEEE 1474.1-2004 (2004) is not required by this Standard for ATN systems subject to section 5.1.2.2.

5.1 AUTOMATIC TRAIN PROTECTION (ATP) FUNCTIONS

All ATP functions shall be designed and implemented in accordance with Sections 3.2, Safety Principles, and 3.3, ATC System Fail-Safe Design.

5.1.1 Presence Detection

Presence detection shall be an ATP function if it is required to ensure the protection aspects of other ATP functions, such as train separation assurance and/or guideway switch interlocks.

As an ATP function, presence detection shall be continuous in accordance with Section 5.1.7 in any and all automated areas of the guideway. All trains and any other vehicles that operate on the system in the presence of trains running in automatic operation shall be detected, regardless of whether they are being operated in automatic or manual control.

The presence-detection function shall be reinitialized and all trains shall be located and identified by positive detection before the resumption of automatic operation. In no case shall automatic operation be allowed based on manual input of position data.

5.1.2 Separation Assurance

Section 5.1.2.1 provides separation assurance standards for automated people movers. Section 5.1.2.2 replaces section 5.1.2.1 for those APM systems which meet the requirements for ATN systems and intend to operate at closer headways than is permitted by section 5.1.2.1.

5.1.2.1 Separation Assurance for Automated People Movers (APM)

Separation assurance shall be a required ATP function for any APM system configuration that operates trains in following moves around the guideway.

Separation assurance shall provide protection against rear-end collisions for following trains by maintaining a zone at the rear of each train that continuously provides sufficient stopping distance for the following train assuming that the train ahead can stop instantaneously.

Stopping distance shall be calculated analytically using the cumulative worst-case characteristics of relevant elements, where worst case pertains to the characteristic of the element that results in maximum stopping distance. This requirement includes, but is not limited to,

1. Maximum runaway acceleration,
2. Minimum emergency braking condition,
3. Maximum cumulative time delays,
4. Maximum attainable overspeed,
5. Grade,
6. Worst-case load,
7. Minimum adhesion and traction, and
8. Maximum design tailwind.

For stopping distance calculation purposes, minimum emergency braking condition shall be based on the single worst-case failure conditions of the braking system elements as determined by an appropriate analysis conducted in accordance with the requirements of Section 3.1.2.1, Hazard Analyses.

For APM systems that permit the automated operation of trains in opposing directions on the same track, separation assurance using calculated stopping distances for both trains shall apply for the prevention of head-on collisions.

For APM systems that use automatic coupling, the coupling maneuver shall be permitted, provided the entire maneuver is conducted under the protection of ATP and can be verified and validated to be in accordance with Section 3.3, ATC System Fail-Safe Design.

For APM systems where the separation between successive trains is physically maintained, as it is in a cable-propelled system, and where it can be shown by analysis according to Section 3.1.2.1, that slippage and/or detachment from the physical mechanism is possible, then such slippage or detachment

shall be detected and emergency braking shall be initiated to stop the slipping or detached train and all other trains connected to that mechanism.

Comparable separation assurance protection shall be required for APM systems that use other means to maintain separation between successive trains.

5.1.2.2 Separation Assurance for Automated Transit Network (ATN) Systems

This section replaces section 5.1.2.1 for ATN systems that can be shown to be free from failure modes that can result in Unacceptable hazards as defined in Section 3.2 according to Risk Assessment for lead train stops conducted in accordance with Section 3.1.2, including all supplemental provisions added by this Section 5.1.2.2.

The automated operation of trains in opposing directions at the same time on the same through guideway shall be prohibited.

Separation assurance shall be a required ATP function meeting the fail-safe design requirements of Section 3.3 for any ATN system configuration that operates trains in following moves around the guideway. More specifically the ATP shall vitally assure that trains do not exceed their movement authority limits or the safe speed limit.

Separation assurance shall provide protection against following trains colliding with leading trains by maintaining a separation assurance zone (SAZ).

Separation assurance requirements, design, calculations, hazard analyses and mitigation measures shall be independently reviewed by an independent safety assessor (ISA). The ISA shall be approved by the authority having jurisdiction (AHJ).

In calculating the SAZ, the following train's use of the lead train's position and velocity information shall include all instrument measurement tolerances, data latencies and communication delays from the time the location and speed were transmitted by the lead train. It shall also account for deterioration in performance related to poor visibility, inadequate lighting, or EMI conditions or emergency shutdown or other failure of positioning system equipment

Stopping distance for the following train shall be calculated analytically using the worst-case characteristics of relevant elements, where worst case pertains to the characteristic of the element that results in maximum stopping distance. This requirement includes, but is not limited to:

1. Maximum runaway acceleration,
2. Minimum emergency braking condition,
3. Maximum cumulative time delays,
4. Maximum attainable overspeed,
5. Track geometry including grade,
6. Worst-case load,

7. Minimum or variable adhesion and traction,

8. Maximum design tailwind.

For following train stopping distance calculation purposes, minimum emergency braking condition shall be based on the single worst-case failure conditions of the braking system elements as determined by an appropriate analysis conducted in accordance with the requirements of Section 3.1.2.1, Hazard Analyses.

In lieu of assuming the train ahead can stop instantaneously, the lead train deceleration rate shall be analyzed in accordance with the requirements of Section 3.1.2.1 Hazard Analyses and Table 3-1 Risk Assessment. As a minimum, the list of potential hazards or hazardous events shall include:

1. Collision with loose obstacles on the guideway weighing more than 10% over the AWO weight of the vehicle

2. Collision with an undetected train stopped on the guideway involving more than one following train. The definition of an “undetected train” shall be a train no longer being tracked by the vehicle location technology due to detection or communication failure and which is assumed to have previously been commanded to stop immediately upon loss of detection at the maximum deceleration rate used in determining the SAZ.

3. Switch failure that results in trains losing guidance through a diverging or merging point on the track

4. Lateral guidance or derailment capture mechanism failure that exposes the train to the possibility of undesigned contact with power rails, guidance surfaces, guideway or external element.

5. Wheel or suspension system failures that can lead to undesigned contact of the train with power rails, guidance surfaces, guideway or external elements

6. Rollover

7. Train hitting fixed obstacle alongside the guideway due to there being inadequate clearance around the guideway

8. Train hitting fixed obstacle alongside the guideway due to there being inadequate clearance around the guideway where the obstacle is designed to be crashworthy and not cause lead train deceleration exceeding that used in determination of the SAZ.

9. Collision with loose obstacles on the guideway weighing less than 10% of the AW0 weight of the vehicle

10. Accidental thrust reversal by the train propulsion equipment

11. Unexpected application of braking systems (service, emergency and parking if provided) on AW0 train at maximum rate

12. Wheel bearing seizes

13. Drive train lockup

14. Lead train hits overtravel protection device at end of guideway

Events 1 through 7 shall be subjected to a risk analysis per Table 3-1 and not incorporated in the SAZ. Note: Decelerations cannot be accurately estimated for events 1 through 7.

All other hazards shall either be eliminated by incorporating their worst-case deceleration rate directly into the SAZ calculation or be subjected to a risk analysis per Table 3-1.

In calculating worst case deceleration, train weight shall be chosen to produce the worst-case deceleration rate. Any relevant effects of grade, minimum passenger load, maximum headwinds, maximum adhesion/traction limits and minimum initial velocity shall be considered in the analysis.

In using Table 3-1 the frequency of occurrence shall be calculated for the entire ATN system with annual train operating hours per build-out design parameters. Severity of events 1 through 7 shall be "I – Catastrophic". Severity of events 8 through 14 shall be at least "II – Critical". Frequency of occurrence shall be mitigated to an "acceptable with notification to the authority having jurisdiction" level per Section 3.2 of the APM Standard.

Any of the above events involving more than one train and an external object, or more than two trains, shall be considered "I – Catastrophic". Unacceptable hazards shall be eliminated by design.

Provision of all of the following three crash mitigation measures shall permit changing severity of failures from "I – Catastrophic" to "II – Critical".

1. All passengers shall be provided with seats and seat belts. There shall be an audible and visual warning to fasten seat belts prior to departure.

2. All trains shall be provided with collision survivability against a head-on impact at half of the maximum cruise speed (including any tolerance) with a rigid immovable wall.

3. Occupant protection from interior impact shall be required including head restraints for fore and aft facing seats and use of impact absorbing materials.

Note: In addition, obstacle removal and detection systems may be employed to reduce the risk of foreign objects on the guideway. Other mitigation measures including robustness of design, hardware, software, maintenance methods and operating procedures may be proposed and implemented to control risk in accordance with Section 3.2 Safety Principles.

5.1.3 Unintentional Motion Detection

Detection of unintentional motion shall be a required ATP function for all APM systems.

The ATP shall initiate emergency braking in the event that a train is detected to be moving when it has not been commanded to move. Emergency braking shall also be initiated whenever a train is detected to be moving against the permitted travel direction (rollback).

5.1.4 Overspeed Protection

Overspeed protection shall be a required ATP function for all APM systems.

Guideway alignment, civil constraints, and train traffic conditions as determined by ATP shall define the speed limits that represent the maximum allowable train speed at any point on the guideway.

The overspeed protection function shall provide speed enforcement, ensuring that the speed of a train never exceeds the defined speed limit anywhere along the entire route. The overspeed protection equipment shall include speed-measuring devices that furnish signals that are a measure of the actual speed of the train. If ever the actual speed of the train exceeds the speed limit, the overspeed protection equipment shall immediately command emergency braking.

5.1.5 Overtravel Protection

Overtravel protection shall be a required ATP function for any APM system configuration that permits the automatic operation of trains up to or close to an end-of-guideway terminus.

Overtravel protection shall be incorporated into, or function in conjunction with, overspeed protection to prevent trains from overtraveling the end of the guideway or, if buffers are specified, to prevent trains from exceeding the design limits for impact with an end-of-guideway buffer. Overtravel protection design shall be based on stopping distance calculations using cumulative worst-case characteristics of relevant elements, as in Section 5.1.2.

5.1.6 Parted Consist Protection

Parted consist protection shall be an ATP function for APM systems that use separate vehicles coupled together in a consist of two or more vehicles to form a train. Parted consist protection shall be required regardless of whether the individual vehicles are considered to be permanently coupled or whether they are routinely uncoupled for maintenance or operational purposes.

Parted consist protection shall detect the uncoupling, detachment, and/or separation of vehicles in a consist and shall thereupon immediately cause all vehicles of the previously connected train to brake to a full stop.

Presence detection, if applicable under the requirements of Section 5.1.1, shall detect the individual presence and precise location of each separated entity to the extent possible within the limits of the presence detection segmentation.

5.1.7 Lost Signal Protection

For all APM systems, all signals that are critical to the functions of ATP shall be continuous or be of such a repetitive nature that signal interruption is detected. Detection of signal interruption shall result in emergency braking by ATP in sufficient time so as not to compromise any safety aspect of the ATP functional design.

5.1.8 Zero Speed Detection

On APM systems where the trains are required to stop, zero speed detection shall be a required ATP function.

Zero speed shall not be registered until a speed of 0.30 m/s (0.95 ft/s) or less is attained and braking is commanded.

5.1.9 Unscheduled Door Opening Protection

Unscheduled door opening protection shall be a required ATP function for all APM systems.

If any automatic door or emergency exit door on a train unlocks for any reason while the train is in motion (above zero speed as defined in Section 5.1.8), that train shall be caused to brake to a full stop.

For systems that include train–platform separation walls and automatic station doors, unscheduled door opening protection by ATP shall also apply. If any automatic station door is unlocked for any reason, trains shall be prohibited from entering or leaving that station platform. If any of these doors are unlocked for any reason as a train is entering or leaving the station platform area, the process of braking the train to a full stop shall be immediately initiated.

In the event of any unscheduled door opening (of a train or station), a local manual reset by authorized personnel shall be required before the restoration of automated train operation.

5.1.10 Door Control Protection Interlocks

Door control protection interlocks shall be provided by ATP on all APM systems.

These interlocks shall ensure that the following conditions are satisfied before enabling the automatic unlocking and opening of the train doors and, if provided, the station platform doors:

1. The train is properly aligned at a station platform per the criteria in Section 5.2.2,
2. Zero speed is detected,
3. Propulsion power is removed from the motors, and
4. The train is positively constrained against motion.

For APM systems where trains do not achieve a complete stop for boarding and discharging passengers, the following conditions shall be satisfied for automatic unlocking and opening of train doors and station platform doors (if provided):

1. Speed shall not exceed 0.35 m/s (1.1 ft/s).
2. Acceleration and jerk rates shall be limited to values determined to be acceptable by analysis according to the requirements of Section 3.1.2.1, Hazard Analyses.
3. The entire door opening and door closing sequence shall occur within the designated zones as determined by an analysis conducted in accordance with Section 3.1.2.1.

5.1.11 Departure Interlocks

Departure interlocks shall be provided by ATP on all APM systems.

Any train stopped in a station shall not be permitted to move until all doors (train and station platform, if provided) are properly closed and locked. Only then shall the constraint against motion be removed and the power be applied to the propulsion motors.

For APM systems where trains do not achieve a complete stop for boarding and discharging passengers, departure interlocks shall be provided to stop the train from departing the station if all doors are not closed and locked.

5.1.12 Direction Reversal Interlocks

Travel direction reversal interlocks shall be provided by ATP on all APM systems requiring bidirectional operation on any segment of the automated guideway.

Any reversal of train travel direction shall occur only after zero speed has been registered (see Section 5.1.8). Reversing of train direction shall occur automatically at stations or terminal zones as required by the system configuration for the support of pinched loop, intermediate turnback loop, reverse direction loop, or shuttle modes of operation.

Any reversal of a train shall also be possible by remote manual command from the central control.

5.1.13 Propulsion and Braking Interlocks

Propulsion and braking interlocks shall be provided by ATP on all APM systems.

Emergency braking shall be irrevocable, that is, once it is initiated, it shall remain activated until the train comes to a complete stop. After the train has stopped, the emergency braking shall be required to be reset for normal operation to resume. For situations where the method of reset is not specified by Chapter 5, the method shall be determined by an analysis conducted in accordance with Section 3.1.2.1,

Hazard Analyses. If conditions as determined by ATP are not correct for the train to move, the emergency braking shall remain applied regardless of any reset signals or actions, except that it shall be possible to switch to full manual operation, thus disabling the ATP functions of that train. If correct ATP conditions exist after irrevocability has been removed, the train shall be permitted to move, but if a subsequent malfunction occurs, the irrevocable emergency braking shall be applied as before.

The emergency braking controls shall be interlocked with the propulsion controls such that braking commands dominate.

5.1.14 Guideway Switch Interlocks

Guideway switch interlocks shall be provided by ATP for any APM system that operates trains under automatic control over a switch or switches installed along the guideway. For switching mechanisms on board the train, comparable interlocks that meet the intent of this section, as determined by analysis in accordance with the requirements of Section 3.1.2.1, Hazard Analyses, shall be provided.

ATP shall prevent a train from entering a switch that is not properly aligned and locked and shall prevent a switch from becoming unlocked and/or moved once a train is committed to traversing it.

Control circuits shall be arranged so that an aligned and locked switch cannot be signaled for a route until each portion of the switch is verified to be in the correct position. When switch conditions are not correct (whether the switch has been activated automatically or manually), the control signals normally transmitted to approaching trains shall ensure that any approaching train in automatic mode shall stop before reaching the entrance point of the switch.

Whenever a train is in the protected zone associated with a switch or a series of switches, route locking shall prevent the automatic or remote manual movement of any of the switches in the protected zone and shall prevent any conflicting train movements from occurring.

Presence detection locking shall be used to prevent a switch from being moved if there is a train occupying it, regardless of whether the switch is being operated under automatic or remote manual control.

Time locking (with approach release of that time locking optional) shall be used in the switching circuits so that, if the section of guideway approaching a switch has been cleared for movement over that switch, the switch cannot be moved until a definite time has elapsed after the speed limit for the approaching section has been placed in a zero speed condition and the switch is not occupied. The time allowance shall be at least 10 percent greater than the time required for the train to traverse the stopping distance, as calculated in accordance with Section 5.1.2. If the option of approach release of the time locking is used, then the time can be zero if there is no part of a train occupying the approach section. The

length of the approach section for the switch shall be greater than the worst-case stopping distance computed for that specific guideway section.

ATP shall prevent the automatic or remote manual unlocking of a switch after a train has committed to traversing it until the train has cleared the switch. Protection against inadvertent release of locking caused by momentary loss of power or train detection shall be provided.

5.1.15 Off-Line Sections Operation—Special Conditions

Off-line sections are defined as guideway sections featuring automatic operation at restricted speed, such as off-line stations or vehicle storage areas (lanes). For off-line sections operation, three different zones are considered:

1. Transition zone to and from the main line,
2. Circulation zone, and
3. Docking zone.

Transition zone: When entering or leaving the main line to or from the off-line section, the vehicle shall be detected by the ATP system of the off-line section, and speed shall be adjusted accordingly. Vehicle movement between main-line and off-line lanes shall be accomplished in accordance with the principles of Section 5.1.14.

Circulation zone: Contact between two moving vehicles may be acceptable at low speed, only under failure conditions, if the contact speed is low enough as determined by an analysis conducted in accordance with Section 3.1.2.1, Hazards Analyses, to

1. protect against damage to vehicles (reversible shock absorbers may be used) and
2. protect against passenger injuries (collision impact shall meet all criteria of Section 7.4.4.9.2). The permissible contact speed shall be enforced by ATP.

Docking zone: Contact between a moving vehicle and a vehicle stopped at a docking position (with doors open and brakes applied as per Section 5.1.8) may be acceptable at low speed, only under failure conditions, if the contact speed is low enough, as determined by an analysis conducted in accordance with Section 3.1.2.1, Hazards Analyses, to

1. protect against damage to vehicles (reversible shock absorbers may be used);
2. protect against passenger injuries (collision impact shall meet all criteria of Section 7.4.4.9.2); and
3. prevent any movement of the stopped vehicle. Passenger on platform and passenger embarking and disembarking safety shall be in accordance with Section 10.2, Platform Edge Protection. Door control protection and departure interlocks shall be in accordance with Sections 5.1.10 and 5.1.11, respectively.

5.2 AUTOMATIC TRAIN OPERATION (ATO) FUNCTIONS

The ATO shall function to automatically operate trains around the system in accordance with prescribed operating criteria but within the safety constraints imposed by ATP.

5.2.1 Motion Control

The starting, stopping, and regulation of the train speed as it travels along the guideway shall be controlled by ATO so that the acceleration, deceleration, and jerk rates are within acceptable passenger comfort limits and the speed is maintained below the overspeed limits imposed by ATP.

5.2.2 Programmed Station Stop

Programmed station stops shall be made within acceptable passenger comfort limits. When boarding and discharging passengers, the train shall provide at all doors at least an 82-cm (32.5-in.) clear opening within the designated boarding zone. This opening shall allow egress only onto the platform.

If the train and station doors are misaligned by more than the distance permitted in the preceding paragraph, the doors shall not open automatically. An alarm shall be sent to central control.

5.2.3 Door and Dwell Time Control

Train doors shall be automatically controlled by ATO during passenger boarding and discharging. If automatic station doors are provided, they shall be controlled as a set with matching train doors. Train and matching station doors, if provided, shall open and close together.

It shall be possible to manually disable the operation of any door set (on the train or at the station) without affecting the automatic operation of other unaffected sets. When automatic station doors are provided and a door set (of the train or station) is disabled, then the matching set shall also be disabled with respect to automatic operations but without the need for manual intervention.

If any doors fail to open or fail to close within 10 seconds of being commanded to do so, an alarm shall be sent to central control.

The amount of time the train remains in the station with doors open shall be established by the designer and automatically controlled by ATS as a function of fully automated operation. Once door open time has expired and any “hold door open” commands initiated by ATS or the central control operator have been removed, all doors shall be commanded to close.

When a train under manual control is properly berthed in a station and the train operator commands the train doors to open or close, the corresponding station doors, if provided, shall also open or close.

5.3 AUTOMATIC TRAIN SUPERVISION (ATS) FUNCTIONS

Automatic train supervision (ATS) shall monitor and manage the overall operation of the system. ATS shall provide the interface between the system and the central control operator. Through audio and visual displays, information shall be presented describing the status of the system on a real-time basis. This information shall allow the central control operator to assess conditions throughout the system and to take appropriate actions. The central control operator shall be able to issue commands to initiate and terminate system operations, override selected automatic commands and operations, and perform other system management functions.

For APM systems where there is no operator physically located in a central control office, alarms and malfunction information must be transmitted to a responsible individual authorized to respond to the situation in a timely manner.

5.3.1 Constraints on ATS

Should ATS become completely inoperative for any reason, ATP and ATO shall remain operable unless a system shutdown is commanded by the central control operator. Emergency controls on the central control console shall, independent of the ATS equipment, provide at least the following system emergency shutdown functions:

1. All trains stop, and
2. All propulsion power shuts off.

5.3.2 Status and Performance Monitoring

System status and performance information shall be presented to the central control operator by way of functionally separate displays: the system operations display and the power schematic display.

5.3.2.1 System Operations Display

The system operations display shall provide a visual representation of real-time operating conditions throughout the system. The display design shall

1. Be of sufficient size and/or quantity and display resolution to be viewed with ease from the normal seating area at the central control operator consoles;
2. Show approximate geographical representations of the guideway and the locations of relevant physical features, such as passenger stations, switches, and/or maintenance and storage facilities;
3. Dynamically depict any of the following system operating conditions that are pertinent to the system configuration:

a. The location and identification of all trains in all parts of the system designed for automatic operation,

b. The direction of travel of all active trains,

c. The number of cars comprising each train (if train consist is variable),

d. The train identification number used to interact with the train (if train identification is not obvious from the system configuration),

e. The status of any switches in the system,

f. The operating mode and status of selected system equipment, and

g. The status of each station, including the current active dwell for each station; and

4. Incorporate such other visual aids as may be necessary to permit the central control operator(s) to manage the system efficiently.

5.3.2.2 Power Schematic Display

The power schematic display (PSD) shall provide a visual indication of the power distribution system status throughout the system. The PSD shall be of sufficient size and/or quantity and display resolution to be viewed with ease from the normal seating area at the central control operator console(s).

The PSD shall clearly display the following conditions as a minimum:

1. The presence or absence of electrical power in each propulsion power circuit that may be individually energized or deenergized;
2. The presence or absence of any power distributed along the guideway by guideway segment for each power segment that may be individually energized or deenergized;
3. The status of all circuit breakers and/or switches in the power supply system (any tripped condition shall be alarmed);
4. The presence or absence of backup power; and
5. The presence of any alarm condition.

Indication of power status shall be by both voltage monitoring and device position indication. PSD indication and control functions shall not be affected by any single-point failure.

5.3.3 Performance Control and Override

Management and operation of the system shall be accomplished by the control and override functions. There shall be both automatically controlled and manually initiated control and override functions, as described in this section.

5.3.3.1 Automatic Control Functions

To the extent warranted, the ATS system shall perform the control and coordination functions necessary to achieve fully supervised automatic operation of the system.

5.3.3.1.1 Mode Management

The ATS shall manage all specified modes of operation. Available modes shall depend on system technology, guideway configuration, operating plan, and failure mode recovery plan.

5.3.3.1.2 Train Tracking

The ATS shall systematically track each train around the system to the extent warranted by the system configuration and in a manner that is consistent with the requirements for management of the specified modes of operation.

5.3.3.1.3 Headway Management

Consistent with the selected mode of operation and the specified degree of interactive train regulation, the ATS shall act to maintain the required time (as measured at a fixed point on the guideway) and/or distance spacing between trains in automatic operation on the system.

5.3.3.1.4 Train Routing

The ATS shall automatically accomplish all routing functions required by the selected mode of operation. This set of functions shall include initiating route, switch position, and travel direction reversal requests, as required.

5.3.3.2 Manual Control and Override Functions

The capabilities and functions described in this section shall be incorporated in the central control console. Controls and displays associated with ATC shall be integrated with the controls and displays of the communications (see Chapter 6, Audio and Visual Communications) and electrical (see Section 5.3.2.2, Power Schematic Display) subsystems to facilitate the efficient and effective supervision of all subsystems by one operator at the console.

Manual controls shall be provided that enable the central control operator to perform the following functions:

1. *Train dispatching*—The central control operator shall be able to dispatch trains into service from any designated off-line launch point.
2. *Train routing*—Depending on the system configuration, the ATS shall be designed so that each train can be assigned to a specific operating mode, lane, or route, via an instruction from the central control operator.

3. *Initiation of service*—The central control operator shall be able to initiate system service.
4. *Termination of service*—The central control operator shall be able to terminate system service.
5. *Modify train operations*—The central control operator shall be able to issue commands that modify normal train operation.
6. *Remove trains*—For systems that provide off-line storage, the central control operator shall be able to direct a train to proceed out of service.
7. *Initiate failure mode operations*—The central control operator shall be able to convert the system from its normal operating mode to any available alternative operating mode for failure management purposes.
8. *Hold trains*—The central control operator shall be able to command trains to hold in the stations.
9. *Command switches*—When switches are provided, the central control operator shall be able to individually command switches to move.
10. *Stop all trains*—The central control operator with one command shall be able to stop all trains on the guideway.
11. *Command power off or on*—The central control operator shall be able to command propulsion power off or on to the entire system or to individual power circuits, depending on the segmentation provided.
12. *Acknowledge and process alarms*—The central control operator shall be able to receive from several subsystems, acknowledge, store, and recall alarm message displays and acknowledge accompanying audible alarms.

Except for a single-event command, once a command is imposed by the central control operator and accepted by ATS, the action shall remain operative until it is subsequently removed by the operator.

5.3.3.3 Alarms and Malfunction Reporting

Major system components shall be automatically monitored and alarms shall be annunciated for malfunctions and failures thereof. Also, system-related facilities shall be monitored and alarms annunciated for fire and life safety problems and/or security intrusions. The central control console shall incorporate both an incident (message) display and audible alarms for the benefit of the central control operator. Within 2 seconds of detection, the occurrence of an incident or condition shall be reported on a display, indicating the time of the incident, the nature and classification of the incident or condition, the identification of the vehicle and train, and/or the specific guideway or station location involved. Each alarm shall be indexed and time-tagged as to when the fault was detected. Alarms shall be stored and have the capability to be recalled and/or redisplayed by an index number or by hardware type with which it is associated (e.g., train, substation, passenger station, or switch). Acknowledgment of the alarm by the central control operator shall cause the audible alarm to cease; however, the associated alarm indication

shall persist until the condition is cleared. All alarm reports and clearing shall be recorded in memory and printed on a line printer.

Data communications between central control and trains shall be maintained and confirmed. Failure of any train to respond shall be alarmed and annunciated at central control.

5.3.3.3.1 System Alarms

System operation malfunctions, alarms, and reporting shall be primarily for security, safety, and unscheduled stoppage problems.

As a minimum, system operations malfunctions shall be reported in one of two priority classifications, described as follows. The level of classification and reporting of faults shall be sufficiently detailed to allow operating and maintenance personnel to make rational decisions in reacting to the reports, consistent with the functions required of them in the operation and maintenance plans, procedures, and manuals.

Priority I malfunctions pose an immediate threat to passenger safety and/or the threat of damage to system equipment.

Priority II malfunctions do not pose an immediate threat but could cause a potential threat to passengers or equipment if not corrected quickly.

5.3.3.3.2 Facility Fire and Intrusion Alarms

Facility fire and/or smoke and intrusion alarms, if provided, shall be annunciated separately and redundantly (audibly and visually) on the central control console. The location of the alarm point shall be indicated.

5.3.3.4 Data Recording and Reporting

The ATS subsystem shall include the recording of selected data transactions between central control and other portions of the system. Such data shall be recorded in a format that includes the date and exact time of each data transmission. Data shall be recorded and stored on appropriate media in a format suitable for both a permanent file and random access retrieval and for use with system data processing software to produce reports, if provided.

If specified, an appropriate subset of this recorded data shall be able to be printed in real time on a printer at central control. This printout shall constitute the daily operations log.

5.4 MANUAL OPERATION LIMITATIONS

This standard is intended for fully automatic operation and does not apply to extended passenger service in manual mode. Manual mode operation may be used for testing, recovery, maintenance and system failures and failure management, or other abnormal conditions. The hazard resolution process of Section 3.1.2 shall address the hazards introduced by manual operation.

For limited manual operation, the design shall enable the operator(s) to observe guideway conditions; communicate with central control and passengers; observe vehicle status indications; and control vehicle propulsion, braking, and doors. When not in use, the controls and status indicators shall be protected from access by passengers.