VOLUME VII – SYSTEM EQUIPMENT

CHAPTER 6 – TRAIN CONTROL DESIGN CRITERIA

REVISION 1

Program Management Consultant

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6.01 SCOPE

This section defines and describes the degree of automation and performance, operation and configuration criteria for the train control system desired for the MDT Metro Rail extensions.
6.02 GENERAL

6.02.1 DEGREE OF AUTOMATION

Based upon previous evaluations the desired degree of automation for the train control subsystems shall be as follows:

A. Train Protection Subsystem shall be fully automatic; no manual intervention will normally be required.

B. The Train Operation Subsystem shall be semiautomatic. The train shall normally be operated semi automatically and a train operator shall manually intervene for opening and closing doors at stations and for starting the train.

C. The Train Supervision Subsystem shall be a semiautomatic combination of manual manipulation aided by automatic equipment.

D. The Yard Control Subsystem shall normally operate in a manual operating mode under the supervision of interlocking protection equipment located in the yard for control and protection. The performance, operating and configuration criteria for the subsystems listed above are fully explained in the following paragraphs. These data will form the basis of the Train Control specification. It provides a guideline document for checks and balances between performance, operating and configuration criteria. This effort will ultimately guide the final train control design specification work to be performed.

6.02.2 GENERAL CODES, STANDARDS AND REGULATIONS

The current adopted version of these codes, standards and regulations shall apply, and unless otherwise directed, all addenda, interim supplements, revisions and ordinances by the respective code body shall also apply.
Where conflicts exist between these requirements, the more stringent requirement shall take precedence, unless otherwise directed by MDT:

- National Electrical Code (NEC)
- National Electrical Safety Code (NESC)
- Florida Building Code (SFBC)
- American National Standards Institute (ANSI)
- National Electrical Manufacturers Association (NEMA)
- Institute of Electrical and Electronic Engineers (IEEE)
- Insulated Cable Engineers Association (ICEA)
- American Railway Engineering and Maintenance of Way Association (AREMA) Signal Manual of Recommended Practices
- Electrification Administration, Telephone Engineering and Construction Association
- Federal Railroad Administration (FRA)
- Joint Electron Device Engineering Council (JEDEC)
- Electronic Industries Alliance (EIA)
- Underwriters Laboratories, Inc (UL)
- American society for testing and Materials (ASTM)
- Other Federal State and Local regulations shall be adhered to when identified as applicable during the design.

6.02.3 AUTOMATIC TRAIN PROTECTION (ATP) SUBSYSTEM

The Automatic Train Protection Subsystem provides: complete protection against collisions and over speed conditions; control of interlocking; route security through interlocking; track surveillance; and protection of train door operation

A. ATP Subsystem Performance Criteria
The Train Protection Subsystem will be fully automatic; no Manual intervention will normally be required. Unless otherwise directed by MDT, the ATP Subsystem will provide:

1. Continuous detection of all revenue vehicles on mainline track, yard transfer zone, all yard tracks and non-critical yard tracks by indication circuits;

2. New mainline tracks will be equipped with either analog or digital audio frequency track circuits for train detection and cab codes. These jointless track circuits will be capable of detecting a broken rail. Analog track circuits will possess a minimum of 8 available carrier frequencies and a minimum of 12, available speed codes, one of which may be used as a zero code.

3. All interlocking crossovers will be equipped with single rail power frequency or audio frequency track circuits for train detection and audio frequency cab loops to convey speed commands to trains.

4. All interlocking track circuits shall be designed and equipped to detect broken down insulated rail joints.

5. Yard tracks will be equipped with audio frequency overlay track circuits for the purpose of train detection.

**Commentary:** There shall be coordination with the car rebuilder so the new onboard train control apparatus will recognize both the new and existing audio frequency track circuits and process the train control data they provide without errors, loss of code or carriers, or incorrect recognition of speed commands.
6. The maintenance of safe braking distances between running or stationary vehicles.
   - Headways not less than a 90 second theoretical design headway and a **120 second practical operating headway**. Actual design headways shall be determined based on the civil characteristics of the individual line segments.

**Note:** If the actual design headway is greater than 90 seconds: MDT shall be advised of this condition and the Designer shall also advise MDT what alignment revisions are needed to achieve a design headway of 90 seconds.

   - Headways of 90 seconds shall be maintained at junctions between merging line segments, accommodating traffic from both lines, while minimizing operational bottlenecks.
   - The maintenance of safe operating speeds of vehicles based on grade and curve of the rail system, vehicle geometry, and design parameters;
   - Grant routing requests through Interlocking and eliminate conflicts and resolution of traffic handling problems arising from two vehicles requesting simultaneously routing through a particular interlocking;
   - Assurance that all wayside hardware is made safe for the vehicle prior to permitting travel on any route;
   - Assurance that vehicle door operation is permitted only when detected safe;
   - Continuous track surveillance;
   - Reverse running capability.
B. ATP Subsystem Operating Criteria

1. The ATP Subsystem will operate fully automated. Fail safe principles shall apply to all vital circuits
   - All vital circuits which directly affect safety shall be closed loop circuits.
   - Operation of these circuits will permit all failures to be self indicating.
   - Failures such as shorts, opens or grounds either singly, or in combination shall not cause an unsafe condition in vital circuits.
   - The failure of a vital circuit will cause conditions to become more restrictive rather than less restrictive within the ATP system.
   - Single component failures or multiple component failures shall not cause an unsafe condition

2. Each line in the system will be divided into zones. A train control equipment room will be located in each station to control its assigned zone. Each zone will be interlocked through vital logic with adjacent zones to form part of a closed loop system.

   Operation of ATP system equipment aboard the vehicle will be fail safe and closed loop. Provisions will be made on board to cut out the ATP equipment in the event of its failure and it becomes necessary to move the vehicle.
By way of nonvital hardware, trains operating on revenue mainline tracks in the ATP cut out mode will transmit an indication to Central Control.

C. ATP Subsystem Configuration Criteria: A vital circuit is any circuit which directly affects the safety of personnel and/or equipment.

1. Vital circuits using vital fail safe components and closed loop design principles will be provided for at least the following circuits:
   - Route Locking Circuits
   - Switch Locking Circuits
   - Approach Locking Circuits
   - Time Locking Circuits
   - Detector Locking Circuits
   - Digital Audio Frequency Track Circuits
   - Cab Signal Circuits
   - Vehicle Door Control Circuits
   - Vehicle Speed Detection Circuits
   - Vehicle Speed Selection Circuits
   - Vehicle Overspeed Circuits
   - Vehicle Braking Circuits
   - Station Platform Circuits
   - Switch Control and Indication Circuits
   - Line Circuits
   - Traffic Circuits
   - Slow Order Command Circuits
   - Loss of Traction power Circuits
   - Overrun protection at interlockings
2. Vital circuits shall be implemented with microprocessors that have been specifically designed to be vital and transit industry proven.

3. Vital processors shall be used in a configuration such as a hot standby where two processors are implemented, both sharing vital inputs but with only one processor providing the vital outputs. Should the first processor fail, the second processor would immediately provide the vital outputs and take over the functions of the first. If required, supplemental vital relays could be added to vital processors.

4. Vital processor design shall include a diagnostic function that will detect defects and indicate which lowest replaceable unit is in need of change-out.

5. All non-vital circuits shall be implemented with microprocessors that have been specifically designed to use closed loop design principles, be self detecting in failures and transit industry proven. These non-vital units shall be designed, constructed and installed as a subassembly of the vital processor assembly.

   a. Among the non-vital circuits and apparatus are On Track Signals for track personnel and Bus signals.

   o The On Track signals use lunar white aspects to alert the train operators that individuals are working in the track area. These signals will be used in areas of obstructed visibility such as curves, or where structures interfere with the train operator’s view of the track ahead.

   o Bus signals, will be installed near bus stops at the passenger stations. These signals, usually blue in color,
are triggered by a train approaching the passenger station. It informs the bus driver of passengers arriving at the station and to dwell longer at the bus stop.

6. The ATP Subsystem will be an ungrounded system. Ground detectors will be provided for both AC and DC energy busses.
   a. The ATP Subsystem will be immune to electromagnetic interference as much as is possible by current industry standards. It will be equipped with circuit protection to mitigate the effects of power surges, lightning strikes, and transients.
   b. Mainline track circuits will conform to AREMA standards and recommendations, be of the continuous detection type, be capable of acting as double rail traction power returns, and provide for broken rail detection where possible.
   c. Wayside colored light signals shall be provided at interlocking boundaries to indicate route alignment and locking for manual train operation without cab signals.
      i. These signals shall be the three aspect, mast mounted, transit type with all aspects illuminated by light emitting diodes.
      ii. Mainline switch layouts will possess the following features: 110 VDC motor driven switch movements, operated remotely with point detection, vital indication, and the ability to be operated manually by hand. Mainline
switches shall be non-trailable and provide locking in both directions of operation.

iii. Yard switches will be motor operated by 110V either AC or DC, provide indications as to their position and be trailable. Yard switches must possess the same durability and MTBF characteristics as mainline switches and be similar to US&S YM2000 or approved equal.

iv. All non-vital circuits will, when applicable, use closed loop design principles, and be self detecting in failures. Non-Vital functions will be implemented using microprocessors that have been specifically designed for use as rapid transit devices.

All ATP wayside hardware will be of the rapid transit type:

v. Operation and indication of wayside hardware will be as fast as possible and, within the limits of technology, be fail safe and rugged in construction.

vi. Water, humidity, and general environmental factors shall not shorten the design life of the supplied hardware or cause service degradation.

D. ATP Subsystem Interface Standards and Performance Interface points to this system will be subsystems of the Train Control system, Trackwork, Traction Power, and Communications.
1. The train control equipment contractor will be charged with the task of maintaining vital integrity at all interface points and proving such through exhaustive testing approved by the Engineer.

2. Each interface point of the system will be designed such that a failure of the nonvital logic (interface) will not cause an unsafe condition or degrade the integrity of vital circuits in any way. Competent, trained personnel will install, test, inspect, and maintain the ATP Subsystem.

Periodic testing, inspection, maintenance and alignment will be required to ensure proper equipment performance. AREMA and FRA standards will be maintained.

6.02.4 AUTOMATIC TRAIN OPERATION SUBSYSTEM

The automatic Train Operation (ATO) Subsystem performs the functions of accelerating the train to running speed, regulating the train running speed, and stopping the train at proper locations at station platforms. Unless otherwise directed by MDT the ATO Subsystem shall provide the following:

- Must provide station stop program which is compatible with vehicles possessing new or old ATO systems.

**Commentary:** The train control contractor shall supply the ATO equipment on the vehicle if required.

A. ATO Subsystem Performance Criteria

Normal vehicle control functions will be semiautomatic. A train operator will be responsible for initiating and suppressing certain automatic functions. A train will normally operate in revenue service semi
automatically with a train operator taking manual actions for opening and closing doors at stations and for train starting. The ATO Subsystem will:

1. Accelerate the vehicle smoothly, within jerk limit rates to the civil speed or another reduced speed command as transmitted by the ATP system, anticipating the proximity of the targeted speed to minimize propulsion braking cyclic applications.

2. Regulate running speed, such that maximum allowable speed is maintained with a minimum of propulsion braking cyclic applications.

3. Automatically performs precise station stops with an accuracy of +/- 3 ft for 99.999% of stops and within jerk limit parameters when required. Propulsion braking cyclic applications shall be minimized.

4. Yard mode selection will only be allowed when the train is at rest with full service brakes applied.

B. ATO System Operation Criteria

The ATO System will contain three basic modes of Operation:

1. Automatic Mode

   The train operator will initiate train movement by depressing a start button. The train will accelerate automatically within jerk limits and regulate to the authorized speed limit. Station stops will normally be initiated by a wayside device, but may be overridden by manual manipulation. If the auto trigger is used, the train will use stored on board profiles with updates from wayside apparatus to perform station stops. Train performance level adjustments will be initiated by the operator upon direction from Central Control.
2. Manual Mode
   Manual mode selection will only be allowed when the train is stopped with full service brakes applied. The train operator will accelerate the train, regulate running speed, and perform station stops under the supervision of the ATP Subsystem. If an over speed condition is detected, the operator must respond promptly or the train will be brought to a stop via a penalty brake application. In this mode, operation of the train is fully manual within pre-established limits of the ATP Subsystem.

3. Yard Mode
   The train operator will control the train with limited on board ATP protection. The on board ATP Subsystem will limit the top speed of a train to 15 mph. If the top speed is exceeded, a penalty brake application will result unless prompt response is made by the train operator. Other protection is provided in Yard Mode operation, via operational procedures and rules.

4. Other Criteria
   Door control and station dwell adjustments will be by manual control. The ATO Subsystem will provide for automatic routing for reversing of trains in terminal turn back zones using vital interlocking techniques.

C. ATO Subsystem Configuration Criteria
   The ATO Subsystem will be an ungrounded system designed to incorporate at least the following:
1. Maintenance indicators will be provided to monitor all major ATO system functions for ease of maintenance;

2. The system will be standardized in that like functions will be performed by like pieces of hardware or electronics;

3. Station stopping profiles and performance level settings will be on board for execution as needed;

4. All speed regulation hardware will be designed to project itself that is look ahead in time, thus minimizing the number of propulsion/coast/braking applications called for to effect precise speed regulation.

D. ATO Subsystem Interface Standards and Performance

The ATO Subsystem interfaces to the following:

1. The train operator;
2. The vehicle with sensors
3. The propulsion and braking systems.
4. The train operator interface will be analog except for alarms of other than speed conditions or speed information. Other alarms will be via colored, grouped indicators; grouping will be by type or degree of information required. The train control package on board the vehicle will be electrically isolated from other vehicle systems at interface points. All sensing equipment will interface via equipment which will not allow a ground condition, even with a failure. (Electrical isolation will be maintained to all systems or subsystems). Pushbutton controls will be of the self indicating type, when established, to confirm an action by the operator. Wiring shall
not be allowed at any Interface point. Supplied equipment for
carborne train operation will be thoroughly tested at the
manufacturing level, installation level, and at system operational
levels for safety and reliability.

6.02.5 AUTOMATIC TRAIN SUPERVISION SUBSYSTEM

The Automatic Train Supervision (ATS) Subsystem will monitor and supervise
the operation of the transit system. Unless otherwise directed by MDT the
ATS Subsystem will provide the following:

A. ATS Subsystem Performance Criteria Normal train supervision functions
   will be semiautomatic, a combination of manual manipulation aided by
   automatic equipment. Dynamic situation response is provided by the
   Transit Authority's operations personnel in the Central Control facility.

The Train Supervision Subsystem will:
1. Provide automatic dispatching at turn back and terminal stations.
2. Provide automatic routing of trains at turn backs and other
designated areas, based on pre-established destinations.
3. Provide train to wayside receivers (TWC) at each station.
4. Provide automatic monitoring and display of train location at Central
   Control.
5. Provide alarming and recording of system operating data and
   communication necessary for detailed operations analysis.
6. Provide local control panels mounted in TC&C rooms at stations.
7. Provide local control panels mounted in Supervisors booths on
   station platforms.

B. ATS Subsystem Operational Criteria
The ATS Subsystem will normally operate to monitor system response to manual schedule implementation. Trains being added to mainline service will be brought to the transfer zone in the manual mode. The train will then be placed in the Automatic Mode and dispatched by the ATS Subsystem after the operator initiates train starting. Turnback routing at terminals with crossovers will be established automatically upon the detection of the approaching train per the mode selected by the train dispatcher at Central Control.

1. The three possible turnback modes are:
   - All trains turnback in track one,
   - All trains turnback in track two,
   - Successive trains turn back alternatively in track one and track two.

2. Routing of trains at diverging junctions and turnbacks at midline terminals with pocket tracks will be initiated automatically by local dispatching type equipment utilizing data from the TWC system. Routing of trains at emergency crossovers and pocket tracks will normally be initiated manually from Central Control. The dispatch of vehicles will be automatic by local equipment with override capability by Central Control. Train tracking or monitoring will be an automated function. Train tracking shall use automated hardware. The train tracking information, through DTS hardware, will be made available to a status board for computation of management information system data. Alarm information will also be made available, through DTS hardware, to the data logger for display to a terminal and a hardcopy line printer.

C. ATS Subsystem Configuration Criteria
The ATS Subsystem shall use the most reliable digital equipment available that fulfill the requirements of previously stated goals and objectives for this subsystem. Equipment proposed for the ATS Subsystem will be selected on the basis of proven service history, reliability, and availability for the hardware and software selected. Deviations on qualification will impose the burden of necessary acceptance and demonstration tests on the supplier, to the satisfaction of the Engineer, prior to equipment approval. Maintenance indicators will be provided to monitor the equipment at a sufficient number of points to visually ascertain whether or not the equipment is in a properly functioning condition or is in need of maintenance. Failures shall be self indicating and provide an alarm condition.

D. ATS Subsystem Interface Standards and Performance
The ATS Subsystem will interface with equipment and personnel in Central Control, and to station Train Control and Communications rooms and equipment rooms throughout the system. Normal telemetry standards will be allowed for interfaces to all equipment. Personnel interface shall make efficient use of visual, audio, and other sensory devices to eliminate confusion and boredom. Hardware, which will implement the actions of Central Control personnel, will be rugged and tamperproof with regard to a normal environment. Hardware with a proven operational history and reliability are required to be established as part of the equipment vendor's qualifications for this subsystem.

E. ATS Local Control at Stations
1. If normal communication is present between Central Control and the TC&C room, the ATS Subsystem shall allow Central Control to transfer train control to a local control panel mounted in the TC&C
room. If normal communication is not present between central control and the TC&C room, the local control panel shall have the ability to obtain train control by use of a key switch.

2. The ATS Subsystem shall also allow Central Control to transfer train control to a local control panel mounted in the supervisor’s booth on the station platform.

6.02.6 YARD CONTROL SUBSYSTEM

The Yard Control Subsystem will normally operate in a manual operating mode under the supervision of the Automatic Train Protection equipment located in the yard.

A. Yard Control Performance Criteria

The Yard Control Subsystem will control and protect the movement of vehicles within the yard limits to protect equipment and personnel, and will:

1. Provide mainline type track circuits and cab signal Automatic Train Protection on the transfer tracks, test tracks and tracks leading from the transfer tracks to the mainline. Wayside color light signals, vital track circuits and interlocking circuits will be provided at all interlocking and other critical areas within the yard to provide train protection, route locking and to indicate route alignment and locking. Vehicles will be operated in the Yard Mode (manually without ATP) within the yard.

2. Provide one supervisor with the ability to safely regulate and coordinate simultaneous yard movements.

3. Safely coordinate route alignment and movement of vehicles from the yard areas to the yard transfer zone.

4. Safely coordinate route alignment and movement of vehicles into and out of repair facilities located within the yard limits.
5. Provide information on the position and identity of all vehicles and the movement of all vehicles to the yard supervisor.

6. Include provisions to insure daily vital function vehicle qualification prior to dispatching for further tests on the test track or to revenue service on the mainline.

B. Yard Control Subsystem Operational Criteria

The train will be operated in the Yard Mode within the yard limits. Vehicle speed will be limited to fifteen mph within yard limits. Wayside signals will be used to authorize vehicle movement. The Yard dispatcher will be responsible for initiating the routes over which safe movement is to be allowed within the limits of the Yard Control Subsystem. Parameters, performance, operation and configuration criteria detailed in Section 2 of this document shall apply to the yard operating system with the single exception of cab signal provisions shall not apply within the yard limits. The transfer zone in all respects is considered mainline for design of the entire ATP System.

C. Yard Control Subsystem Configuration Criteria

Vital circuits using vital fail safe components and closed loop design principles shall be provided for at least the following circuits:

1. Time Locking Circuits
2. Detector Locking Circuits
3. Track Circuits

Vital circuits using closed loop design principles and non-vital components shall be provided for the following circuits:

1. Route Locking Circuits
2. Switch Locking Circuits
3. Directional Stick Circuits
4. Switch Control and Indication Circuits
5. Storage Track Detector Circuits

Yard track circuits shall conform to AREMA standards and recommendations, be of the continuous detection type, be capable of acting as single rail traction power returns, and provide for broken rail detection and protection.

The Yard Control Subsystem shall be an ungrounded system. Ground detectors shall be provided for both AC and DC energy busses. All non-vital circuits shall use closed loop design principles where applicable.

The yard control panel logic will use vital design principles and, in and of itself, be incapable of creating an unsafe condition.

D. Yard Control Subsystem Interface Standards and Performance

Each interface point shall be designed so that a failure of the non-vital or interface logic will not cause an unsafe condition or degrade, in any way, the integrity of the safety circuits. The yard control panel will mimic the yard; the track configuration will be depicted on a board as it actually exists in the yard. The Yard dispatcher will have a full view of the yard to aid in traffic management. Interface requirements delineated in paragraph D above shall also apply to the Yard System. Periodic testing, inspection, and maintenance will be required to insure proper yard operation system functioning.
6.03 SAFE BRAKING CRITERIA

The Safe braking criteria for this system shall be based on the safe braking model. This model contains several components which affect safe braking and are obtained from the characteristics of MDT rolling stock.

The components of the safe braking model are listed below with a short description:

- **Cab response** - Overspeed velocity with zero acceleration
- **Overspeed reaction** - Full acceleration
- **Power cut assurance** - Full acceleration
- **Power cut** - Linear decay of acceleration to coast
- **Coast** - Train resistance as specified
- **Brake build up** - Linear de-acceleration build-up with time to a maximum de-acceleration of 1.5 MPH/second
- **Full deacceleration** - is 1.5 MPH/second for ATP Safe Braking
- **Overhang** - 20 ft
- **Acceleration** - Maximum tractive effort

The example of the safe braking model is graphically depicted in section 6.04.

**Commentary:** For additional information about the components of the safe braking model used in Stage I, see MDT.

There shall coordination with the new car builder so the performance of the new rolling stock does not exceed that of the existing criteria. Care shall be taken to prevent increased stopping distances in any type of consist, due to dissimilar characteristics in the safe braking model as it relates to the rebuilt MDT fleet.
In the calculation of safe stopping distances, the following shall be considered:

- All constituent parts of the safe braking model
- Civil characteristics of the alignment, including but not limited to:
  - Curves
  - Grades
  - Civil design speeds
  - Civil speed restrictions
  - Superelevation
  - Wind resistance of the consist (Davis Drag)
  - Curve resistance
6.04 SAFE BRAKING MODEL

Commentary: The data for the Stage 1 Braking Model is provided in Acceleration Table 1)
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6.05 TRAIN CONTROL SYSTEM DESIGN

The design of the train control system will be such that the highest degree of maintainability will be achieved. Modular design and construction will be utilized to the greatest extent possible. When modular design is achieved the greatest commonality of modules possible will be incorporated. Within cost constraints, applied self diagnosis and fault alarming of individual modules will be accomplished to accelerate system repair. Train Control signaling and control circuits will be routed in separate sections of cableways and conduits and will not be intermixed with either communication or power cables/circuits.
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6.06 ACCELERATION TABLE 1

The table below shall be used in calculating safe braking distance. Linear interpolation shall be used between values shown in the table. Note: This table does not include train resistance.

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* Abnormal condition used as upper limit.
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6.07 SPEED COMMAND TABLE

**Commentary:** Stage 1 speed commands.

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6.08 BLOCK DESIGN

The parameters listed below are to be used when implementing the block design.

Berthing commands shall facilitate the opening of the doors on the left or right side of the train and will be controlled by the AF Track Circuits.

Station stops shall be 35 seconds at Government Center and 30 seconds at Civic Center.

Station stops at all other stations shall be 15 seconds.

Terminal dwell times shall be a minimum of 4 minutes.