Washington Metropolitan Area Transit Authority

8000 SERIES RAILCARS

General Design Criteria for Industry Comment

January 24, 2017

Final

Preface

The Washington Metropolitan Area Transit Authority (WMATA) operates the second busiest transit system in the US, serving the District of Columbia and surrounding counties in Maryland and Virginia. The system is referred to as Metrorail or Metro. The system opened in March of 1976 and continues to expand. There are six lines (Red, Blue, Orange, Green, Yellow, & Silver). There are over 100 miles of standard gauge track, with more than 1000 vehicles operating on 750 Vdc third rail.

Vehicles are designated by series number, according to when they were procured. The 1000 series cars were the first ones procured. The 7000 series cars are the most recently procured. This document describes the 8000 series cars, which is the next procurement.

While the 8000 series cars will take a technological leap relative to earlier series, the 8000 series cars still represent an evolution from the 7000 series cars. This design criteria document is prepared to identify significant, potentially-new features of the 8000 series cars in order to solicit comments from the industry. This document does not contain the complete requirements, such as in a vehicle specification. At the time of procurement, complete technical specifications will be prepared based on WMATA needs and industry comments to this design criteria document.

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1.0 OVERVIEW OF THE EXISTING 7K CAR

This section describes the existing 7000 Series cars in order to provide a context for potential changes from the 7000 Series for incorporation into the 8000 Series.

Vehicle Configuration

The vehicles are configured in semi-permanently coupled married pairs which consist of an A-car and B-car that are attached to each other at their R-ends. The A-car has a full-width operator's cab at its F-end. The B-car has a hostler panel at the F-end. The hostler panel allows the operator to uncouple/couple cars and move the cars at low speeds in the yard or shop, while still allowing for additional seats during revenue operation.

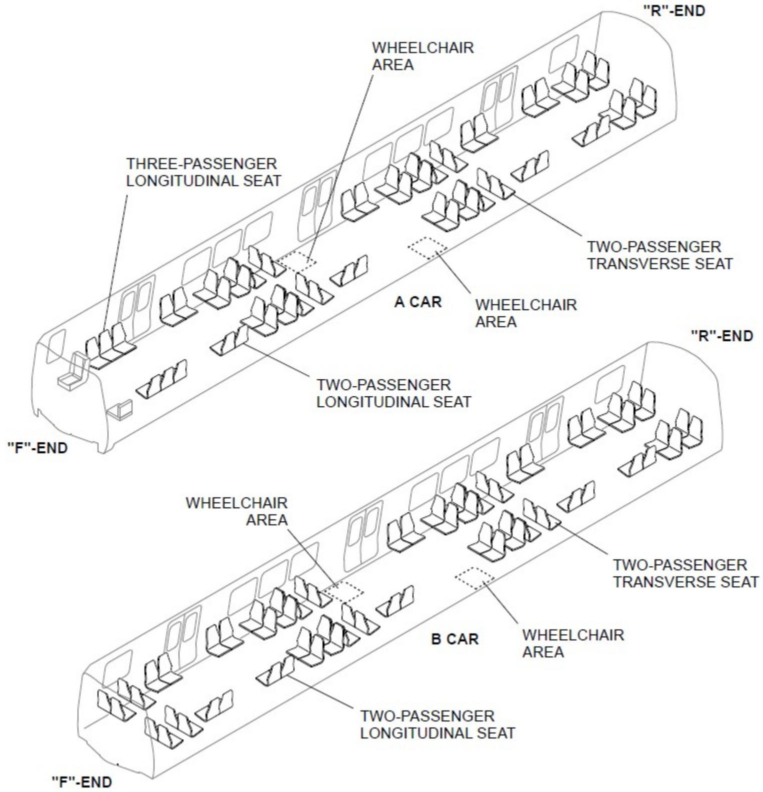
In revenue service, the 7000 series is desired to operate with a minimum of four cars (referred to as a Quad). Train consists can be four, six or eight cars. Married pair (2 car) operation is for yard and shop operation.

Basic 7k Vehicle Criteria

Carbody Construction	Stainless Steel
Length	75 Feet
Width at Floor Level	10 Feet
Height from Top of Rail	10 Feet 10 inches
Side Doors	3 per side – sliding bi-parting
Side Door Opening Width	4.21 Feet
Side Door Opening Height	6.35 Feet
Weight (AWO)	82,500 lbs. average
Crush Load	34,800 lbs.
Seat Capacity	A Car – 62
	B Car - 68
Maximum Speed	75 mph
Maximum Acceleration	2.8 mphps, nominal
Maximum Service Brake	3.0 mphps, nominal
Electric System	Third Rail - 700 Vdc (nominal)
Current Collection Method	Contact shoe
Minimum Radius Curve	225 Feet
Maximum Grade	5 Percent

Seating

Seating consists of a mixture of two person transverse seats and two/three person longitudinal seats. All seats have a 39 inch width and have the same contour. Transverse seats are cantilevered at the car side frames using three mounting points and the longitudinal seats are supported by a cantilevered connection to the door pocket panel and by stanchions on each end. All passenger seats are designed to meet APTA SS-C&S-016-99, Rev.1 Standard for Seating in Commuter Rail Cars.



Highlighted Subsystems/Components on 7000 series

- Automatic Train Control System includes the following three subsystems: The Automatic Train Protection (ATP) subsystem uses undercar antennas to receive the code rate modulated audio frequency speed command signals. The Automatic Train Operation (ATO) subsystem performs automatic speed regulation and programmed station stopping by using passive, wayside low frequency (92-180 KHz) marker equipment, in conjunction with the ATP data, to move the train between stations. Automatic Train Supervision (ATS) subsystem provides a two-way communication link between the train and wayside at selected locations using audio frequency FSK signals. Trains can be operated automatically with an Operator present or manually with ATP oversight.

- Friction Brake System: The friction brake system uses outboard-mounted disks.

- Propulsion System: The propulsion system uses per-truck, IGBT, VVVF Inverters with self-ventilated motors.

- HVAC System: Each rail vehicle is equipped with two, recessed, rooftop-mounted, and hermetically sealed HVAC units and a single control box located on the underfloor of the carbody.

- Linear Door Operator Assembly: Each doorway is operated by a linear synchronous motor (LSM). Both bi-parting door panels are operated in unison by a single door motor.

- Lighting: Interior lights are all LEDs.

- Communications: Audio announcements are automated and are VOIP. There are passenger video displays and electronic route maps, in addition to conventional electronic signage.

- Train Control Network: TCN (IEC 61375) is used to support the transmission of control data that require high levels of determinism, such as driving and braking commands, and monitoring of axle speeds or slide conditions. The TCN is composed of Wired Train Bus (WTB) trunks and of Multifunction Vehicle Buses (MVB) utilized to interconnect (at the car level) all subsystems.

- Ethernet Network: The Ethernet Network carries data other than control information, such as camera images and maintenance data from subsystems. The ETN is a 100BASE-TX Ethernet network. The Ethernet Network is comprised of an Ethernet Train Network, running the length of the train, and an Ethernet Unit Network, running within a married pair.

- Coupler: The coupler uses retractable electrical heads, with pin/sleeve connections.

- Vehicle Monitoring and Diagnostic System (VMDS): Each A car is equipped with a sophisticated VMDS that collects, stores, displays consist and equipment information.

- Train-to-Wayside Data Transfer (TWDT) System: The carborne TWDT is a wireless system to transfer data between vehicles and wayside servers via WMATA's wayside network access points. Data transfers include fault data, mileage data, video data, updated announcements, and updated commercial videos.

This concludes the overview of the existing car. With this context, the following sections provides WMATA's specific questions.

2.0 CARBODY DESIGN PARAMETERS

2.1 OPEN GANGWAY IN A MARRIED PAIR

Increasing passenger loading and improving passenger flow is an objective for WMATA's 8000 Series trains. This may be achieved by keeping an open passage between the two cars of a married pair. Each car would still be 75 feet long and be supported by two trucks. A semi-permanent connection using a draw bar would be made between two cars, as with any other married pair. Where the two cars meet, there should be an open passageway by which passengers can move between the cars without opening any doors or exposing themselves to the elements. A floor mechanism and a diaphragm that connects the interiors of the cars could be used to create an open gangway within the married pair. These should be flexible/moveable to allow the cars to shift and turn apart from each other, yet durable enough to withstand a rail environment and passenger wear and tear.

Q2.1-1: What challenges would a carbuilder experience in accomplishing this configuration?

Q2.1-2: Is the carbuilder aware of other heavy-rail vehicles with this configuration and whether it has proved successful?

Q2.1-3: How will this configuration affect the design of the end frame in meeting crashworthiness requirements, and how will it affect the crash energy management design?

Q2.1-4: Will an extra-wide opening in the car body end frame affect the torsional stiffness of the car body?

Q2.1-5: When a married pair must be split apart, how much extra time will be necessary to disassemble the diaphragm assembly? Are there other significant maintenance tasks associated with the open gangway?

Q2.1-6: Currently the maximum car interior noise levels (82.5 dBA) occur in areas immediately above the trucks. Are the Interior noise levels expected to be higher than 82.5 dBA around the gangway? If so, by what approximate magnitude?

Q2.1-7: How will this configuration affect the safety of passengers during emergency evacuations? Will it provide for faster or slower passenger egress? Will it improve or inhibit emergency responder access to the railcars during emergency response events.

Q2.1-8: Does such a configuration present any additional security concerns that should be considered?

2.2 OPEN GANGWAY IN A QUAD CONFIGURATION

This configuration would build on the concept of the open gangway within a married-pair. In this configuration, two married pairs would have an open gangway between them (i.e., at the F end of the B Cars). This further allows for easier passenger movement and level loading. As with the married-pair, there should be a diaphragm between the two pairs to allow for easy and safe passenger access between cars.

WMATA notes that its shops are designed to service and maintain married pairs. While considering the open gangway for a quad, WMATA is not currently considering a modification of its shops to include, for example, four-car lifts.

Q2.2-1: Does the carbuilder envision a maintenance-friendly way to separate a quad into two married-pairs?

Q2.2-2: How would the open end of a married pair be closed or protected during a yard move or yard storage?

Q2.2-3: Are ther other significant maintenance tasks associated with the open gangway?

Q2.2-4: What are any additional concerns regarding crashworthiness, crash energy management, and car body torsional stiffness?

2.3 CRASH ENERGY MANAGEMENT DEMONSTRATION

WMATA is considering requiring a full-scale dynamic test of the complete Crash Energy Management (CEM) system to validate the CEM model. A full-scale test article would be required, limited in extent to the portions of the structure that are specifically designed to provide the CEM.

WMATA would expect an approach to this test that includes the following, as a minimum.

a) Quasi-static or dynamic testing of energy-absorbing crush elements prior to the dynamic test of the complete CEM system,

b) Selection of an appropriate CEM test article,

c) Selection of the method of applying the dynamic impact,

d) Data and instrumentation, including videos, and

e) A plan for comparing test and analytical results to validate the CEM model.

Q2.3-1: Do you have any concerns about this method of validating the CEM model?

Q2.3-2: Do you prefer other methods of validating your CEM model? How successful have these been, and what is the measure of success?

2.4 WIDER DOORS / LARGER WINDOWS

WMATA would like to increase the size of passenger windows and doors to improve passenger experience and security, and to improve passenger flow. WMATA recognizes that body stiffness and other car body structural parameters may be affected by these changes.

The WMATA car, like all modern passenger rail cars, efficiently uses all elements of the car body as structure – sides (side frames), ends (end frames), roof as well as the underframe. This type of design is often called “semi-monocoque” which means that it is like the best example of monocoque structure, an airplane fuselage, except that rail cars have an extra heavy underframe to resist buff and draft loads, collision loads, and to provide convenient mounting for equipment – hence “semi-monocoque”.

Of the various elements of the car body, the vertical load is carried by the side frames. The vertical load consists of the weight of the empty, ready-to-run car body (AW0 minus truck weight) plus passenger load. The shape of the car body viewed in side elevation (camber) is defined by the side frame, as is the stiffness of the structure in carrying the vertical load.

A practical design must have windows and doors. Any hole in the side frame potentially reduces the stiffness of the design. More and larger windows and doors must be compensated for by shear reinforcement throughout the side frames in order to maintain camber, and meet specified limits on deflection under passenger load.

Q2.4-1: Discuss (at a high level) the effect that larger passenger side windows and doors have on the structural design, including at least the following issues;

- Camber at all loads
- Limiting vertical deflection under specified end loads
- Avoiding uncomfortable dynamic modes
- Ride quality
- Avoiding problems with side door operation under all passenger loads
- Avoiding fatigue at door and window corners, and other associated details in the side frames
- Impact on diagonal jacking

Q2.4-2: Would you expect the need to add shear reinforcement, and if so, how will this affect car body weight?

Q2.4-3: Would larger windows have a substantial effect on cooling loads or car weight?

3.0 MOCK-UPS

For the 8k procurement, WMATA is considering requiring at least two major mock-ups. The first would be a soft mock-up of the Train Operator’s Cab. The second would be a full scale hard mock-up.

3.1 HARD MOCKUP USES ACTUAL CARBODY

The full scale mock-up will have multiple purposes. Initially, the purpose of the mock-up is to aid the design process for individual equipment packages and their installation on the car. Later in the design phase, the mock-up could be used as a test platform for electrical integration. At the end of the design phase, the full scale mock-up would be shipped to WMATA for use in orientation and training of operators and maintenance personnel.

WMATA envisions that the carbuilder will construct a full scale mock-up of the entire A Car using the same design and materials as used for the production cars. In essence, the foundation of this mockup will be a prototype carbody. The mock-up would be fitted with equipment from the carbuilder and from its suppliers. Equipment would be installed in phases. For example:

- Install plywood equipment boxes

- Install empty prototype equipment boxes
- Install prototype functional equipment boxes
- Update equipment to the production configuration

Although, the list above focuses on supplier equipment, carbuilder items (e.g., wire trays, conduit, and interior duct work) would be similarly phased. WMATA would conduct pre-FAIs and design verification reviews throughout the design phase.

Q3.1-1: WMATA understands that there is a cost associated with a full-scale hard mock-up. Does the carbuilder find this approach to be useful or are there less expensive approaches that provide equivalent mock-up utility?

Q3.1-2: If an open gangway design is specified, what are your recommendations regarding a mock-up of the gangway?

Q3.1-3: For integration tests, there are interconnected controls on both the A and B cars. This includes Hostler Controller on the B Car. How would such tests be accomplished if done in conjunction with the mock-up?

4.0 PERFORMANCE

4.1 BRAKE EFFORT DISTRIBUTION ON A TRAIN BASIS, MARRIED-PAIR BASIS

WMATA would like to improve the ability of trains to respond to equipment failures without creating operational impediments. In present WMATA designs, dynamic brake and friction brake are blended on a truck. If there is a dynamic brake failure on a truck, then the friction brake automatically applies on that same truck. With the advent of network communication, some modern designs distribute the supplemental braking force among the trucks in the train. For example, if there is a loss of dynamic brake on one truck, the other trucks could replace the lost braking effort by slightly increasing the dynamic brake on all of the remaining trucks. This could include a small amount of friction brake on the truck with failed dynamic brakes. WMATA is considering requiring a distributed braking system on the 8k cars.

Q4.1-1: Do you see any advantage to distributing brake effort on a married-pair basis as opposed to a train basis?

Q4.1-2: What impact would you expect for the propulsion system design if it had to provide supplemental braking effort for the loss of one truck in a four-car train, and remain in continuous service with no speed reductions?

Q4.1-3: What impact would you expect for the friction braking system design if it had to provide supplemental braking effort for the loss of one truck in a four-car train, and remain in continuous service with no speed reductions?

Q4.1-4: What is the expected impact on the propulsion system and brake system reliability and safety?

4.2 INCREASE DUTY CYCLE REQUIREMENTS FOR FRICTION BRAKE

WMATA would like to improve the ability of the friction brake system to respond to equipment failures without creating operational impediments. In the event of a dynamic brake failure, friction brakes are automatically applied on the truck with the dynamic brake failure. The current thermal requirements on the friction brake system are based on an AW1 load. While AW1 may represent a reasonable long-term average, individual segments of the route may have a higher loading. WMATA would like to explore increasing the duty cycle load from AW1 to AW2 or AW3, such that a dynamic brake failure does not result in any degradation of performance during continuous service. WMATA notes that there are substantive space issues with incorporating friction brakes with higher thermal capability.

Q4.2-1: Other than distributed braking mentioned previously, are you aware of other creative methods of increasing overall braking thermal capability? If so, what?

4.3 TOWING POWER BOOST

A typical rescue scenario would be eight cars towing eight cars. The maximum grade at WMATA is 5 percent. It is WMATA's desire that the 8k cars be designed such that a 16-car train (eight good cars and eight dead cars) be able to start on any grade in the system, including consideration of system tolerances. In addition, this feature would increase initial acceleration, thereby providing more cooling air to convection-cooled equipment sooner. Therefore, WMATA may wish to specify a low speed boost in tractive effort to enhance towing operations, including control of rollback while towing.

Q4.3-1: Are you currently aware of any concerns with such a feature?

5.0 DOORS

5.1 PASSENGER-OPERATED DOOR PUSHBUTTONS

WMATA is exploring how to improve passenger comfort and save energy during extremes of environmental conditions. In WMATA's current fleets, doors can be opened and closed automatically, opened automatically and closed manually, or opened and closed manually. In all door operating modes the doors can be controlled by the Train Operator. At terminal ends of each line when a train is parked for extended periods of time, this results in two situations. The first situation is that doors are closed and passengers wait on the platform. The second situation is that doors are open, allowing passenger flow, but car interior temperature normalizes to the exterior temperature. Both cases result in passengers being hot in the summer and cold in the winter, while waiting for train departure. The latter situation also results in energy loss and a time delay before the car interior temperature is re-established at a comfortable level.

WMATA is considering the following operation. A Passenger-Door-Open pushbutton switch would be provided on both the interior and exterior of the car at each side door location. When the train consist is stopped for an extended period of time, such as at an end-of-line terminal, the Operator is to have an option of enabling the doors for passenger operation. In this mode, the cars will be maintained at the station with all doors closed and with the Passenger-Door-Open switch illuminated. Upon switch activation by a passenger on either the interior or exterior of the car, the applicable doorway will temporally open and then reclose after a predetermined time delay allowing passenger ingress or egress from the corresponding doorway only. This operation is intended to mimic similar operation in trains world-wide.

Q5.1-1: Does the carbuilder have any concerns with this operation?

Q5.1-2: Does the carbuilder have any experience where such switches are not on every door (e.g., center doors only)?

Q5.1-3: What is the expected impact on the door system reliability?

6.0 HVAC

6.1 HVAC SUPPLIER DESIGNS DUCTWORK

In any system, it is desirable that one entity be responsible for all parts of that system. This is generally not the case with HVAC systems, where the ductwork is designed and provided by the carbuilder. WMATA is considering requiring the HVAC supplier to design the ductwork in order to put complete system responsibility on one entity. Of course, this still requires close coordination between the carbuilder and the HVAC supplier.

Q6.1-1: Does the carbuilder consider this to be a viable process?

Q6.1-2: Does the carbuilder have alternate ideas to enhance system integration vis-à-vis HVAC.

6.2 HEATED FLOORS

In WMATA's current fleets, heating is provided by electric strip heaters mounted around the perimeter of the car at floor level and overhead electric heaters that are a part of the HVAC system. WMATA has observed the rise in development, test, and use of heated floors for passenger comfort and weight savings. To evaluate whether to require heated floors or a combination of strip heaters and heated floors, WMATA has several questions.

Q6.2-1: Considering a reduction in conventional floor heaters and a possible increase in overhead heat, would you expect an overall weight reduction from the use of heated floors?

Q6.2-2: With heated floors, would you have any concerns over the long-term impact on floor adhesives?

Q6.2-3: In conjunction with heated floors, would you recommend bringing the heated elements up the side wall?

Q6.2-4: What is the expected impact on the floor heater and overhead heater system reliability?

Q6.2-5: Does the current state-of-the-art allow for easy repair of heated floors?

7.0 NETWORKS

7.1 USE ALL ETHERNET

The WMATA 7k cars use a combination of TCN and Ethernet networks. This combination could be used for the 8k car design. However, WMATA notes that the technology has advanced to the point that all-Ethernet designs are now being used. WMATA is considering specifying all Ethernet.

Q7.1-1: Does the carbuilder favor either of the two solutions above? If so, why?

Q7.1-2: How would you address determinism with an Ethernet solution?

Q7.1-3: WMATA notes that Ethernet switch manufacturers tend to promote individual features that preclude intermixing alternate suppliers. What is your experience with addressing this issue?

Q7.1-4: Is it time to require IPV6?

8.0 TRAINLINES

8.1 USE 4-WIRE EMERGENCY BRAKE AND ELIMINATE THE BRAKE PIPE

Vehicle weight reduction is always a goal for rail car procurements. For emergency brake, WMATA currently uses a typical heavy-rail implementation with a pneumatic brake pipe and a two-wire electrical overlay. This arrangement is heavy inasmuch as it includes piping and pneumatic valves on the carbody and in the coupler.

WMATA is investigating whether to use a four-wire emergency brake control instead of the brake pipe. In this arrangement, two wires run the length of the train, interlocking every device or control that commands emergency brake. From the end of the train, two wires run the length of the train, energizing emergency magnet valves. This arrangement is common in light-rail vehicles and is allowed by IEEE Std 1475™. This arrangement will decrease the response time to some emergency brake applications. In addition, WMATA believes that this arrangement may be more reliable and maintainable. WMATA would maintain an air pipe connection through the couplers to allow air to be shared among cars in the event of a compressor failure.

Q8.1-1: Does the carbuilder have any concerns regarding the use of a four-wire emergency brake control?

Q8.1-2: Does the carbuilder have any comments regarding weight of the two approaches?

Q8.1-3: Does the carbuilder have any comments regarding the reliability of the two approaches?

Q8.1-4: Does the carbuilder have any comments regarding the maintainability of the two approaches?

9.0 PASSENGER AMENITIES

9.1 PASSENGER WIFI

Even with expanding use of personal cellular modems, national and international ridership seems to continue to desire WiFi access on trains. Some of WMATA's ridership travel short distances and may make relatively little use of WiFi. Other passengers travel comparatively longer distances and may find WiFi to be helpful. As a result, WMATA is considering equipping the 8k trains with WiFi. WMATA assumes that this would be provided via cellular modems on the cars.

Q9.1-1: What bandwidth would be expected to be provided to accommodate passenger use (i.e., how many modems per car)?

Q9.1-2: If cellular modems are used, do you foresee any issues with using those same modems for other purposes? One example is to allow real-time video surveillance during a crisis situation.

Q9.1-3: What type of wayside infrastructure for tunnels, stations and open air is required to permit uninterrupted WiFi access?

10.1 INTEROPERABILITY

10.1 EXPLORE INTEROPERABILITY WITH THE 7K CARS

In order to realize the new features herein, WMATA intends that the 8k cars will not be electrically interoperable with the existing 7k cars. For reasons of due diligence, WMATA would like industry comments regarding interoperability. The 7k cars use discrete trainlines, TCN networks, Ethernet networks, other controls, and pneumatics as part of the interface between married pairs. It is at least conceptually feasible to have 8k cars that interconnect with 7k cars such that there are no restrictions on which married pairs (7k or 8k) are intermixed when forming a train.

Q10.1-1: Discuss the challenges and practical feasibility of creating interoperable cars.

Q10.1-2: Are there any concerns with intermixing pairs with respect to crash energy management?

10.2 FORWARD COMPATIBILITY

Independent of whether the 8k cars are compatible with 7k cars, WMATA desires to maintain forward compatibility with future series. To accomplish this, the carbuilder would be required to do the following:

- Design the cars in a way that provides for future series of cars to be compatible.
- Document the interface design in a manner that allows another carbuilder to provide an acceptable interface to the 8k cars.
- Acknowledge commercial terms that allow for the free exchange of the interface information with a future carbuilder.

There are many types of electrical interfaces, and this makes forward compatibility a non-trivial task. Interfaces include: Propulsion Control, Door Control, Auxiliary Control, ATC System, Diagnostics, Video Surveillance, Low voltage power, and couplers.

Q10.2-1: What challenges does the carbuilder foresee in designing for forward interoperability?

Q10.2-2: Would the carbuilder be willing to work with other carbuilders to standardize (e.g., IEEE Recommended Practice) a design for forward network and/or diagnostic compatibility?

11.0 RELIABILITY

Improving reliability is an objective for WMATA’s 8000 Series trains. WMATA would like to solicit ideas for such improvement and incorporate selected ideas in the 8000 Series Specification.

The system reliability requirement currently specified for 7000 Series Cars is Mean Distance Between Failure (MDBF) of 20,080 miles with a failure defined as any malfunction that requires an unscheduled equipment maintenance action. The fleet reliability currently specified is Mean Distance Between Delay

(MDBD) of 200,000 miles with a delay defined as an incident that causes a revenue train to be offloaded, a 4 minute or greater delay to service, or a lost trip.

11.1 SUGGESTIONS FOR RELIABILITY IMPROVEMENTS

Q11.1-1: What challenges does the carbuilder foresee in meeting or improving WMATA's reliability requirements? Based upon the carbuilder's experience, can the carbuilder recommend certain designs or configurations that have proven to exceed reliability forecasts?

Q11.1-2: There is a preponderance of similar equipment on WMATA's cars that are not shared among equipment suppliers (e.g., speed sensors and voltage monitors). There are also systems that are redundant, at least to some extent. In any railcar design there is a tension between adding redundancy and backup modes to improve MDBD and not adding those elements to improve MDBF. Do you have any specific recommendations regarding redundancy, backup modes, or sensor sharing to optimize both MDBD and MDBF?

Q11.1.3: The WMATA system contains many non-bridgeable third rail gaps. Systems that rely upon the third rail for power experience a momentary shut-down every time the car goes through the gap. Some vehicles use a low level of regenerative brake to support auxiliary loads through gaps. Conceptually, this should improve the reliability of equipment by not having frequent start-ups. At the same time, there is a greater duty on the propulsion system. In your experience, is such a system beneficial or not?

Q11.1-4: Have you implemented any early warning or predictive systems that alert the maintenance shop of deteriorating equipment performance before an actual equipment failure occurs?

Q11.1-5: Besides dynamic and friction braking discussed above, are you aware of any other carborne systems where functionality can be distributed on a married pair or train basis to improve system availability?

End.