ATTACHMENT A

M-PRT 1-1 SYSTEM OPERATIONS DESCRIPTION MANUAL

To be provided
This document is organized into two major sections:

Part I: System Overview

Part II: System Description

This document provides more technical detail. The Table of Contents shows depth detail as required. The introduction and allows the reader to easily locate in this relationship and provides more technical detail. The Table of Contents shows the information contained in Part I and Part II.
OPERATIONS AND MAINTENANCE MANUAL DOCUMENT TREE

M-PRT-1-1 SYSTEM OPERATION DESCRIPTION MANUAL
M-PRT-1-3 SYSTEM SCHEDULED MAINTENANCE MANUAL
M-PRT-1-7 OPERATIONAL SAFETY MANUAL

CENTRAL CONTROL & COMMUNICATIONS SYSTEM (CCCS)
M-PRT-2-2 SYSTEM OPERATIONS MANUAL, VOL I AND VOL II
M-PRT-2-3 CCCS MAINTENANCE MANUAL
M-PRT-2-4 CCCS DIAGRAMS MANUAL

STATION CONTROL & COMMUNICATIONS SYSTEM (SCCS)
M-PRT-3-3 SCCS MAINTENANCE MANUAL
M-PRT-3-4 SCCS DIAGRAMS MANUAL

VEHICLE SYSTEM
M-PRT-4-2 VEHICLE OPERATIONS MANUAL
M-PRT-4-3.1 VEHICLE MAINTENANCE MANUAL, PART I
M-PRT-4-3.2 VEHICLE MAINTENANCE MANUAL, PART II
M-PRT-4-4 VEHICLE DIAGRAMS MANUAL
M-PRT-4-6 VEHICLE ILLUSTRATED PARTS CATALOG

FACILITIES, POWER & ANCILLARY SYSTEMS (FP&AS)
M-PRT-5-3.1 FP&AS MAINTENANCE MANUAL, PART I
GUIDEWAY, STATION FACILITIES EQUIPMENT,
POWER DISTRIBUTION, GUIDEWAY HEATING,
POWER RAIL HEATING
M-PRT-5-3.2 FP&AS MAINTENANCE MANUAL, PART II
FARE COLLECTION, DESTINATION SELECTION,
SURVEILLANCE, STATION COMMUNICATION
M-PRT-5-4 FP&AS DIAGRAMS MANUAL

SUPPORT EQUIPMENT
M-PRT-6-3.1 VCCS TEST SET MANUAL
M-PRT-6-3.2 VCCS CARD TEST PROCEDURE MANUAL
M-PRT-6-3.3 SCCS CARD TEST PROCEDURE MANUAL,
VOL I AND VOL II
M-PRT-6-3.4 GENERAL SUPPORT EQUIPMENT
MAINTENANCE MANUAL,
(INCLUDES VEHICLE WASH FACILITY)
<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
</tr>
<tr>
<td>2. System Overview</td>
</tr>
</tbody>
</table>
| 3. System
|   - Functional
|   - Design
| 4. Vehicle
|   - Architecture
|   - Design
| 5. Control and
| Communication
|   - Subsystem
|   - Design
| 6. Systems
|   - Analysis
|   - Design
| 7. Environmental
|   - Control
|   - Unit (ECU)
| 8. Vehicle
|   - Architecture
|   - Design
| 9. Station
|   - Revenue
|   - Control
| 10. Functional
|   - System
|   - Architecture
| 11. Maintenance
|   - Operations
|   - Software
| 12. Passenger
|   - Station
|   - Operations
| 13. Communication
|   - Control
|   - Architecture
| 14. Central
|   - Control
|   - System
| 15. Central
|   - Control
|   - Operations
| 16. Functional
|   - Description
| 17. Central
|   - Control
|   - Subsystem
| (CSS)  |
| 18. Auxiliary
|   - Power
| 19. Electrical
|   - Power
| 20. Power
|   - System
| 21. Guided
|   - Way System
| 22. Auxiliary
|   - Characteristics
| 23. System
|   - Overview
| 24. Special
|   - Features
| 25. System
|   - Operations
|   - Maintenance
| 26. Vehicle
|   - Main
|   - Guideway
| 27. Vehicle
|   - Maintenance
|   - Operations
| 28. Passenger
|   - Station
|   - Operations
| 29. Communication
|   - Operations
|   - Characteristics
| 30. Central
|   - Control
|   - Operations
| 31. Central
|   - Control
|   - Architectures
| 32. Functional
|   - Description
| 33. Central
|   - Control
|   - Subsystems
| (CSS)  |
| 34. Auxiliary
|   - Power
| 35. Electrical
|   - Power
| 36. Power
|   - System
| 37. Guided
|   - Way System
| 38. Auxiliary
|   - Characteristics
| 39. System
|   - Overview
| 40. Special
|   - Features
| 41. System
|   - Operations
|   - Maintenance
| 42. Vehicle
|   - Main
|   - Guideway
| 43. Vehicle
|   - Maintenance
|   - Operations
| 44. Passenger
|   - Station
|   - Operations
| 45. Communication
|   - Operations
|   - Characteristics
| 46. Central
|   - Control
|   - Operations
| 47. Central
|   - Control
|   - Architectures
| 48. Functional
|   - Description
| 49. Central
|   - Control
|   - Subsystems
| (CSS)  |
| 50. Auxiliary
|   - Power
| 51. Electrical
|   - Power
| 52. Power
|   - System
| 53. Guided
|   - Way System
| 54. Auxiliary
|   - Characteristics
| 55. System
|   - Overview
| 56. Special
|   - Features
| 57. System
|   - Operations
|   - Maintenance
| 58. Vehicle
|   - Main
|   - Guideway
| 59. Vehicle
|   - Maintenance
|   - Operations
| 60. Passenger
|   - Station
|   - Operations
| 61. Communication
|   - Operations
|   - Characteristics
| 62. Central
|   - Control
|   - Operations
| 63. Central
|   - Control
|   - Architectures
| 64. Functional
|   - Description
| 65. Central
|   - Control
|   - Subsystems
| (CSS)  |
| 66. Auxiliary
|   - Power
| 67. Electrical
|   - Power
| 68. Power
|   - System
| 69. Guided
|   - Way System
| 70. Auxiliary
|   - Characteristics
| 71. System
|   - Overview
| 72. Special
|   - Features
| 73. System
|   - Operations
|   - Maintenance
| 74. Vehicle
|   - Main
|   - Guideway
| 75. Vehicle
|   - Maintenance
|   - Operations
| 76. Passenger
|   - Station
|   - Operations
| 77. Communication
|   - Operations
|   - Characteristics
| 78. Central
|   - Control
|   - Operations
| 79. Central
|   - Control
|   - Architectures
| 80. Functional
|   - Description
| 81. Central
|   - Control
|   - Subsystems
| (CSS)  |
| 82. Auxiliary
|   - Power
| 83. Electrical
|   - Power
| 84. Power
|   - System
| 85. Guided
|   - Way System
| 86. Auxiliary
|   - Characteristics
| 87. System
|   - Overview
| 88. Special
|   - Features
| 89. System
|   - Operations
|   - Maintenance
| 90. Vehicle
|   - Main
|   - Guideway
| 91. Vehicle
|   - Maintenance
|   - Operations
| 92. Passenger
|   - Station
|   - Operations
| 93. Communication
|   - Operations
|   - Characteristics
| 94. Central
|   - Control
|   - Operations
| 95. Central
|   - Control
|   - Architectures
| 96. Functional
|   - Description
| 97. Central
|   - Control
|   - Subsystems
| (CSS)  |
| 98. Auxiliary
|   - Power
| 99. Electrical
|   - Power
| 100. Power
|    - System
| 101. Guided
|   - Way System
| 102. Auxiliary
|    - Characteristics
| 103. System
|    - Overview
| 104. Special
|    - Features
| 105. System
    - Operations
    - Maintenance
| 106. Vehicle
    - Main
    - Guideway
| 107. Vehicle
    - Maintenance
    - Operations
| 108. Passenger
    - Station
    - Operations
| 109. Communication
    - Operations
    - Characteristics
| 110. Central
    - Control
    - Operations
| 111. Central
    - Control
    - Architectures
| 112. Functional
    - Description
| 113. Central
    - Control
    - Subsystems
    (CSS)  |
| 114. Auxiliary
    - Power
| 115. Electrical
    - Power
| 116. Power
    - System
| 117. Guided
    - Way System
| 118. Auxiliary
    - Characteristics
| 119. System
    - Overview
| 120. Special
    - Features
| 121. System
    - Operations
    - Maintenance
| 122. Vehicle
    - Main
    - Guideway
| 123. Vehicle
    - Maintenance
    - Operations
| 124. Passenger
    - Station
    - Operations
| 125. Communication
    - Operations
    - Characteristics
| 126. Central
    - Control
    - Operations
| 127. Central
    - Control
    - Architectures
| 128. Functional
    - Description
| 129. Central
    - Control
    - Subsystems
    (CSS)  |
| 130. Auxiliary
    - Power
| 131. Electrical
    - Power
| 132. Power
    - System
| 133. Guided
    - Way System
| 134. Auxiliary
    - Characteristics
| 135. System
    - Overview
| 136. Special
    - Features
| 137. System
    - Operations
    - Maintenance
| 138. Vehicle
    - Main
    - Guideway
| 139. Vehicle
    - Maintenance
    - Operations
| 140. Passenger
    - Station
    - Operations
| 141. Communication
    - Operations
    - Characteristics
| 142. Central
    - Control
    - Operations
| 143. Central
    - Control
    - Architectures
| 144. Functional
    - Description
| 145. Central
    - Control
    - Subsystems
    (CSS)  |
PART I
SYSTEM OVERVIEW
SYSTEM ABSTRACT

The Morgantown People Mover is an Automated Guideway Transit system which provides personal rapid transit (PRT) service between the separated campuses of West Virginia University and the Central Business District. The system development and construction was funded by the Urban Mass Transportation Administration, and was completed in three phases (IA, IB, and II) over the period from 1971 to 1979. The system consists of a fleet of electrically powered, rubber-tired, passenger-carrying vehicles, operating on a dedicated guideway network at close headway (vehicle separation). The system provides a safe, comfortable, low polluting, reliable means of transportation. The system features year-round operation, as well as direct origin to destination service.

As the first urban deployment of Automated Guideway Transit technology, the objectives of the system are to:

- Demonstrate the technological, operational and economic feasibility of a fully automatic urban transportation system.
- Determine, through system evaluation and operational experience, the potential applicability of personal rapid transit to national needs.
- Qualify the system as a candidate for use in other locations.
- Provide a functional and economic transportation system for the University of West Virginia.

The Phase I system was developed under the auspices of the Urban Mass Transportation Administration (UMTA) by the Boeing Aerospace Company, the System Manager. The Phase II UMTA capital grant expansion was under the direction of the West Virginia Board of Regents (WVBOR).

The Phase I development team included the following major contractors and subcontractors:

The Boeing Aerospace Co. - System Management & Integration & Vehicles.
F.R. Harris - A & E Design
The Bendix Company - Station Electronics
The Trumbull Corp. - General Contractor
The Melborne Corp. - General Contractor
The Irey Corp. - General Contractor
Barnes & Brass Corp. - General Contractor

Phase II expansion was accomplished by the following team:

West Virginia Board of Regents - System Management
The Boeing Aerospace Co. - Station Electronics, Vehicles, Guideway & Station Equipment Installation, and System Checkout.
F.R. Harris - A & E Design
The Trumbull Corp. - General Contractor
Daniel, Mann, Johnson & Mendenhall (DMJM) - Consultants to WVBOR.
SYSTEM OPERATIONAL DESCRIPTION

The Morgantown PRT system is operated in either schedule or demand mode. During those periods when passenger demand is highly predictable, the system is operated in schedule mode. Vehicles are dispatched between origin/destination pairs on a preset schedule. When passenger demand is less predictable, the system is operated in demand mode. Vehicles are then dispatched only in response to a passenger request. Passenger actions upon entering the system are always the same regardless of the mode in which the system is operating.

Operation of the PRT system, as summarized from a passenger's viewpoint, is as follows: arrive on concourse level of origin station; where static and dynamic displays provide direction to the platform servicing his destination; proceed to the platform level; insert a coded card or exact change in a fare gate and press a button selecting destination. A gate display illuminates informing passenger to "proceed" to the vehicle loading area. A Vehicle Destination Display above the loading gate provides vehicle boarding instructions. If assistance is needed for any reason, a dedicated telephone link to the central operator is available near each entry gate area. The passenger is kept informed of changes in the system operating status via station public address system.

The passenger boards a vehicle when it arrives at the loading gate, and the display indicates the vehicle is assigned to his destination. The door closes and the vehicle automatically proceeds to his destination. At the destination station the vehicle stops at an unloading gate, the door opens and the passenger leaves the station through an exit gate.

Elevator service is provided from station concourse levels to each platform to permit use of the system by the handi-capped and elderly.

The operation of the system elements required for the passenger service described above, is provided in the following discussions.
PRT SYSTEM ELEMENTS

The Morgantown PRT System consists of three major system elements.

Structures and Power Distribution System

Includes the guideway structure, passenger stations, co-located maintenance and central control facilities, guideway heating, the electrical power distribution system, and a small auxiliary maintenance and wash facility.

Control and Communications System

Includes the Central Control and Communications System (CCCS), Station Control and Communications System (SCCS), and Guideway Control and Communications System (GCCS).

Vehicle System

Includes all the vehicles in the system.
If 15 minutes is achieved, the figure for passenger safety rules and guideway lighting are provided for passenger safety. Above the sign of the guideway, the left and right signs each include the guideway operating name. The roundel style of the guideway is colored, the remainder of the RTD station and the maneuvering facility. The roundel style of the guideway is colored, the remainder of

GUIDEWAY
PASSENGER STATIONS

The station facilities provide access to the system, directing passengers to and from the vehicle loading areas. The facilities also house control and communications equipment required for controlling vehicle operations within the station area.

Two types of passenger stations are utilized, end-of-line and off-line. As the name indicates, end-of-line stations are located at the extremities of the system (Walnut and Medical Center). The off-line stations (Beechurst, Engineering & Towers), allow vehicles to either bypass or stop, providing passenger non-stop service. All stations have two levels, the entry or concourse level and the loading platform level. This eliminates interference of vehicle and passenger movement. Each platform channel has one loading position and two or three unloading positions, (depending upon length).

Passengers entering the station on the concourse or street level are directed to the proper platform by the Platform Assignment Display. A stairway or ramp to the loading platform level introduces the passenger to the Morgantown MPM II system. The stations are designed to provide full passenger service without a station attendant.

MORGANTOWN MPM PASSENGER STATIONS
ENGINEERING MAINTENANCE FACILITY

Maintenance facility

The maintenance facility provides for operation, maintenance, and repair of all vehicles and equipment utilized in the system. The facility consists of a main maintenance shop, a control tower, and the associated auxiliary buildings. The buildings house maintenance shops, control centers, and auxiliary buildings. The facility is located at the engineering station.
ELECTRICAL POWER DISTRIBUTION SYSTEM

The electrical power distribution system provides the prime power necessary to operate the Morgantown PRT system. The power system consists of a main power substation, propulsion power substations, housekeeping power substations, uninterruptable power supplies and standby power generators. Electrical power is used for vehicle propulsion because of its low polluting qualities and its adaptability to the automatic control system.

The system receives 23kV, three-phase, 60 Hertz power from the Monongahela Power Company via overhead transmission lines to the main power substation. The main power substation distributes the 23kV power underground to each of the three propulsion substations located along the guideway and to housekeeping substations located at each station facility. The propulsion substations transform the 23kV input power to 575 VAC, three-phase, delta power for distribution to the guideway power rails. The propulsion substations are connected in parallel to the guideway at selected intervals. This assures proper voltage regulation is maintained along the guideway at peak operating loads. The housekeeping power substations supply 480/277 VAC, three-phase power to the passenger stations and to the maintenance facility for heating, lighting, air conditioning, displays and the uninterruptable power supplies.

Uninterruptable power supplies are used for control and communications system power during main power dropouts. Standby power generation is provided for critical surveillance equipment, guideway and facilities lighting if normal power is lost.
Redundant computers with automatic switch-over capability.

Communication loops exist in the guideway.

System 1) C2CS-Central Control and Communications Sub-

System 2) C2CS-Station Control and Communications Sub-

System 3) C2CS-Gateway Control and Communications Sub-

Functional areas:

1. Intercom equipment: The C2CS is divided into the following areas. Each area includes bidirectional and onboard vehicle control and communication links between the central controller and each station. The C2CS also has dual station control computers and the communication links.

2. Sensor assistance: Video dynamic graphics and other communication for passenger information via the data handling unit provide passengers with essential information. The passenger advisory displays, which are distributed throughout the station area and between the stations, provide essential information.

3. The C2CS controls the movement of the vehicles on the guideway.
CENTRAL CONTROL AND COMMUNICATIONS CHARACTERISTICS

The central control equipment includes the central computers, peripherals, control console/displays, and communications equipment. The system operators, located at central control, monitor and exercise direct control over the system during conditions of initialization, failure, or shutdown. At all other times, the central computer provides control and supervision of vehicles in the station, on the guideway and at the maintenance facility. The system operators merely monitor the operation. All commands are routed from the central control console through the central control computer to the remote computers located at each facility. The operators can call on certain software routines by typing the required message on a control console keyboard.

Software routines allow the operator to restart the system, run vehicles at reduced performance levels, assign vehicles to various locations, and perform other system control and override actions. Performance level modification involves running the vehicles at speeds lower than normal for use during abnormal or emergency conditions.

In the scheduled mode of operation, the central computer manages vehicles by assigning destinations and dispatch times to each vehicle in the system. The passenger enters the station and boards a vehicle assigned to his destination. In the demand mode, the central computer allocates vehicles only if the number of vehicles within the station is inadequate for handling passenger demands. Dispatch times are assigned by the central computer in both the schedule and demand modes to ensure that no conflicts exist at guideway merge points between vehicles enroute to their destinations.

The central console equipment permits the operators to monitor and control the transit system. The consoles include display and control equipment, as well as communications equipment. The central control room also includes a mimic display which permits the operators to monitor the progress of each vehicle operating in the system, and closed circuit TV monitors for system security and passenger safety.
characteristic
station control and communications

Each station has a Collision Avoidance System (CAS) which
positions the last block and maintains a "clear" street.

When a vehicle enters a block of the CAS system, it
proceeds when verification of proper switching
action has been received.

vehicle to proceed when verification of proper switching

the CAS control electronics. At each switch point on the guideway, one set of

vehicle is turned on slowing a vehicle to proceed when vehicle

artefacts move into one set or more off this set.

if this artefact moves into one set or more off this set.

If a remote artefact moves into the block, immediately it

progresses through the guideway, the CAS control electronics

determine correct occupancy of the block. As a vehicle

and redundant control electronics (and software) which

loops which transmit a safe lane to the vehicle to the block;

decide the command in the guideway instantly performs the

vehicle enters into a control block. Inductive communication

vehicle sensors which detect

Command and Control System should tell the

Command and Control System should tell the

The station computer controls vehicle switching.

system computer, which reads

vehicle is equipped with electrical switching devices

vehicle switches the guideway into the guideway.

The station computer controls vehicle switching.

Communication of control signals to

The station computer controls vehicle movement.
GUIDEWAY CONTROL AND COMMUNICATION CHARACTERISTICS

The Guideway Control and Communications Subsystem (GCCS) consists of the equipment installed on the guideway. This equipment includes digital data cables, tone signal cables, passive presence detectors, and the cable and hardware required to connect the GCCS equipment to the SCCS equipment. All active electronics which drive the cabling are located in station and maintenance facility SCCS equipment rooms. Station generated commands are inductively coupled to the vehicle from the loops buried in the guideway surface. The function of these guideway mounted control loops is as follows:

**Station Stop Loops.** The station stop tone transmitter generates a signal to decelerate and stop the vehicle +6 inches from the center of the station platform unloading/loading gates. The vehicle enters the stop loop at 4 feet per second and is decelerated to a precise stop as brakes are applied.

**Switch Tone Loops.** The switch tone transmitter generates a signal to command the vehicle to "steer left" or "steer right." The vehicle is sent a switch command at every guideway juncture (merge and demerge). The vehicle must verify that switching has been accomplished or it is brought to a stop.

**Calibration Loops.** The calibration tone generator transmits a signal to the vehicle to provide measured distance reference. This nonvital signal is used by the VCCS as a reference for calibrating the vehicle’s odometer. The vehicle measures distance traveled and calibrates the odometer, removing any error accumulated since the last loop.

**Frequency Shift Keying (FSK) and Speed Tone Loops.** The FSK transceiver unit transmits performance level, brake commands, door commands and identification requests to the vehicles operating in the system. These commands are transmitted over one set of loops. A second set of loops is used for receiving vehicle identification, door responses and fault status.
VEHICLE CHARACTERISTICS

The Morgantown vehicle has ten major subsystems: passenger module, environmental control unit, chassis, hydraulics, pneumatics, electrical power, propulsion, steering, braking, and vehicle control and communication systems.

Commands are transmitted to the vehicle from communication loops buried in the surface of the guideway and are received by the onboard vehicle control and communications system (VCCS). The commands operate the vehicle motor, brakes, steering and doors. Three-phase, 575VAC electrical power is received from the power rail, rectified, and controlled for the operation of the 70 horsepower, DC motor. The electrical power also operates the lights, air conditioner, hydraulic and pneumatic pumps, control system, and also charges the batteries. The pneumatic system provides an automatic vehicle leveling control. The vehicle is powered from guideway wayside power rails, through a passive run-on, run-off power collector mounted on the front wheel spindle which contacts the guideway power rail. The redundant four-wheel disc brakes are hydraulically operated in response to input commands and are actuated automatically under emergency conditions. Independent parking brakes operate when the hydraulic pressure is below a safe level. Guide wheels control the steering of the vehicle via the hydraulic, four-wheel, power-steering subsystem. Normal door operation is electrical in response to input commands from the Control and Communication System (C&CS).

PHYSICAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>15 Ft 6 In.</td>
</tr>
<tr>
<td>Height</td>
<td>8 Ft 9 In.</td>
</tr>
<tr>
<td>Width</td>
<td>6 Ft 8 In.</td>
</tr>
<tr>
<td>Weight</td>
<td>8,750 lbs Empty</td>
</tr>
<tr>
<td>Wheel Base</td>
<td>127 In.</td>
</tr>
<tr>
<td>Tread Width</td>
<td>62 In.</td>
</tr>
<tr>
<td>Accommodations</td>
<td>21 Passengers</td>
</tr>
</tbody>
</table>

PERFORMANCE CHARACTERISTICS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Automatic-Remote</td>
</tr>
<tr>
<td>Propulsion</td>
<td>70 HP Electric Motor</td>
</tr>
<tr>
<td>Velocity</td>
<td>44 fps (30 mph) Max</td>
</tr>
<tr>
<td>Suspension</td>
<td>Air Bag-Automatic Leveling</td>
</tr>
<tr>
<td>Tires</td>
<td>Dual Chamber (1.5 In. Deflation)</td>
</tr>
<tr>
<td>Steering</td>
<td>Side Sensing (1.2 Sec Transfer)</td>
</tr>
<tr>
<td>Brakes</td>
<td>Redundant Dual-Piston Caliper</td>
</tr>
<tr>
<td>Conveniences</td>
<td>Environmentally Controlled, Quiet,</td>
</tr>
<tr>
<td></td>
<td>Comfortable, Safe</td>
</tr>
<tr>
<td>Turning</td>
<td>30 Foot Radius</td>
</tr>
</tbody>
</table>
VEHICLE CONTROL AND COMMUNICATIONS CHARACTERISTICS

The Vehicle Control and Communications Subsystem (VCCS) is that portion of the automatic control system which is carried onboard the vehicle. The VCCS controls vehicle movements and operations from commands generated by the Station Control and Communications Subsystem (SCCS); it also identifies and transmits vehicle status to the SCCS. The data interface between the VCCS and the SCCS is an inductive communications link via the Guideway Control and Communications Subsystem (GCCS) over which vital signals are transmitted by tones and nonvital signals are transmitted by digital messages. The VCCS consists of 1) antennas, 2) communications unit, 3) data handling unit, 4) control unit, and 5) support unit, which perform the following functions:

Antenna—Two antenna assemblies provide the VCCS two-way communication with the C&CS through buried loops in the guideway. There is one dual antenna assembly for receiving and one antenna for transmitting low frequency electromagnetic signals. The antennas are mechanically fixed to the vehicle and electrically linked to the VCCS.

Communications Unit—The communications unit receives low frequency signals from the receiving antenna. These signals are conditioned and transferred to the data handling unit. The communications unit also receives signals from the data handling unit; conditions and transmits them through the transmitting antenna to the guideway.

Data Handling Unit—The data handling unit (DHU) receives conditioned logic signals from the communications unit. The DHU decodes the signals and produces logical instruction and response sequences unique to the input. This unit will initiate logic commands and messages when vehicle conditions change.

Control Unit—The control unit reacts to signals from the vehicle and the DHU to control the following vehicle functions:

1) Brakes
2) Steering
3) Doors
4) Propulsion

Support Unit—The support unit provides synchronization of logic signals between units, power conditioners, test circuit isolation and interface signal receivers and transmitters.
SYSTEM OPERATIONAL LOGIC

The system is designed to efficiently and safely move people between the five passenger stations. The chart shows the series of passenger-oriented events which occur during a typical trip. Each passenger destination request is logged into the software by the Destination Selection Unit (DSU) which is part of the Fare Gate. The Fare Gate accepts coins or magnetic fare cards. These cards are periodically issued to students. A vehicle is supplied by the system through either the demand mode or scheduled mode logic, and the passenger rides to the selected destination. While a passenger is in the system, there is continuous monitoring by either the system software or operator TV surveillance.

*These functions are under system/software control.

**These functions are under operator controllity surveillance.
IN-STATION VEHICLE MANAGEMENT AND DISPATCH

The station computer system controls in-station vehicle movements with overall direction from the control center. Routing of an incoming vehicle to an unloading berth is based on: 1) channel assignment and station inventory policy, 2) the availability of an open berth.

The routing logic decisions are implemented at the station branch points by steering commands which direct the vehicle into the proper channel. Normally, the vehicle is moving at 8 ft/sec during channel switching. Time delays for control system operation, steering response to commands, and switching verification must be accommodated in the distance available.

After the switching region is cleared, the vehicle is decelerated to the 4 ft/sec velocity from which a vehicle can execute a precise stop (+6 inch accuracy). Stopping deceleration is controlled by an on-board speed profile. The vehicle initiates the precise stop in response to an energized guideway stopping loop. The station computer commands energizing of the stopping loop at the channel location at which the vehicle is scheduled to unload.

In unloading positions, the door is commanded open for a preselected time to allow passengers to depart. The door is then automatically closed and the vehicle is commanded to "move up" to the forward position in the channel (loading position) and open its door (in the scheduled mode) or wait for a destination request (in the demand mode). The first empty car in a station channel may be sent to another station to meet demands if not required at this station. During the scheduled mode, vehicles are commanded to have station dwell times sufficient to unload, move up, and load to meet their scheduled departure. After the passengers have boarded and the allotted vehicle door open time has expired, the door is automatically closed and the vehicle is ready for dispatch. If, however, the sensors detect any object in the door opening, the door will automatically cycle open and delay dispatch until this condition is corrected. The station informs central of the vehicle destination, and requests a dispatch time from central. The dispatch time is determined so that a vehicle following the nominal dispatch profile for that station and starting position will merge on the guideway with its assigned moving slot position. The station is synchronized with central so that the system operates relative to a common time standard. The stop tone is removed from the stopping communication loop at dispatch time.

The vehicle accelerates to 8 ft/sec velocity. Switching commands direct the vehicle from the platform channel to the acceleration ramp. On the acceleration ramp the vehicle accelerates at 2 ft/sec² until main guideway speed is reached (22 or 33 feet per second).

Station control monitors dispatched vehicles on the acceleration ramp via presence detector data to assure that guideway speed is reached and that the assigned slot position is utilized. If the speed and position (time of presence detector actuation) are within tolerance, the vehicle is permitted to proceed to the main guideway. The vehicle steers right on the acceleration ramp past the merge point on the main guideway and is then commanded to steer left. The collision avoidance systems on the acceleration ramp and on the appropriate section of the main guideway are interlocked so that out-of-tolerance vehicles will initiate emergency braking.

22
VEHICLES ON MAIN GUIDEWAY

Vehicle progress on the guideway is monitored by the station control computer by observing the time of actuation of presence detectors. Vehicle status is also monitored by station control. A vehicle status report includes: 1) vehicle ID, 2) current location, 3) current destination and switch condition, 4) speed performance level, 5) current civil speed command, 6) door status, 7) braking condition, and 8) any current anomaly. Status data are periodically transmitted to central for overall system monitoring and for control of handover from station to station.

Responsibility for detailed vehicle management is transferred from one station to the next at a particular guideway presence detector. Central control informs the receiving station of the enroute vehicle's identification, destination, status, and assigned guideway slot. When the vehicle arrives at the guideway section boundary presence detector, the receiving station performs the position and fault report monitoring tasks.

Civil speed is 22, 33, or 44 feet per second on different sections of the main guideway. A speed change is commanded by a frequency change in the speed tone at two adjacent speed tone communication loops. This frequency change is detected by the VCCS and a standard 2 ft/sec² speed transition is accomplished. A smooth, controlled transition is effected to the new speed.

As the vehicle approaches each enroute station, the software determines if the vehicle should be switched into the station. The availability of an open unloading berth in the station is checked. If no space is available at an on-line station, the vehicle is stopped on the ramp until a space opens. If no space is available at an off-line station, the station is bypassed. The central operator is notified to take appropriate action to return passengers to their selected destination. Under normal operating conditions, an unloading berth will be available and a switching command is sent to exit the vehicle from the main guideway to the destination station. Verification that positive switching action has been completed is provided to the station by the vehicle. Failure to receive switching verification initiates braking.
The Business Manager's Office provides the accounting and maintenance functions, as well as the collection, and spare parts storage function. The Business Manager's Office performs scheduled maintenance on all systems elements and provides the troubleshooting and recovery from abnormal events. The Operations crew performs daily operations through a system manual, system performance, and manage the systems of two operators and one shift supervisor who consistently monitor the Operations of system operation, readiness, safety, and quality. The System Supervisors are responsible for overall coordination of this team. The organizational concept for this team is shown below.
SPECIAL FEATURES

Passenger and Personnel Safety. During the design and development of the Morgantown PRT System a great deal of effort was directed towards making the system as safe as possible. Potential hazards to passengers and system personnel were identified and eliminated through appropriate design and procedural concepts. It is very important that those components and procedural actions, which affect system safety, be properly maintained and observed. The O&M Manuals clearly identify the safety related items, and it is the responsibility of System Management to ensure their proper use. To the greatest extent possible, the system has been designed so that human errors tend to result in safe conditions. The success of this approach is evidenced by the more than 7 million passenger mile injury-free record of Phase IB operation. Some of the system’s major safety features are listed on the chart below.

Handicapped Persons Access. The system has been designed to allow easy access for handicapped persons. Elevators at each station move handicapped persons to the station platforms; vehicles can be used by those confined to wheelchairs; and persons with sensory handicaps receive directions from visual and auditory aids located at convenient places within the system.
GUIDEWAY CHARACTERISTICS

The Structures and Power Distribution System (S&PDS) provides a guideway network to guide and support operation of the Vehicle System, and the Control and Communications System (C&CS). The S&PDS provides stations for handling the passenger traffic demands; a maintenance facility consisting of a maintenance building with office and working space for maintaining S&PDS, Vehicle System, and C&CS equipment; and a central control facility for the control and operation of the transit system. A small maintenance facility is located at Engineering station. The power distribution system receives, converts, and distributes power to all facilities and the guideway network.

Approximately 8.7 lane miles of guideway network links the passenger stations and the maintenance facility. The guideway is limited to a maximum slope of ±10 percent and its curves have a minimum radius of 30 feet. The concrete guideway running surface contains a heating system for all-weather operation. A heated water/propylene-glycol solution is circulated through pipes embedded in the running surface. The C&CS communications lines are also embedded into the running surface. The right-hand loops (facing the direction of vehicle travel) provide commands to the vehicles and the left-hand loops provide status or downlink messages back to the C&CS.

The running pads are concrete with angle iron caps at section ends. The communication loops are No. 4 awg wire placed in slots cut into the concrete and then epoxied in place. The vehicle tires run outside the communications loops.
operator must then take appropriate action.

Level is low, or a fire exists in the boiler plant. The system
boiler does not start when required because the watertower
an audible alarm will be sounded at Central Control if a
be indicated to Central Control unless a malfunction exists.
boiler plant operation is automatic and normal operation will
from his console at Central Control once room on, the
operator and he must read boiler plant No. 3 or O.F.P.

The Guideway Heating System is under control of the system

In the expansion tanks,

automatic boiler feed system maintains an acceptable fluid
required pumps are necessary. Expansion tanks pressurized
standby mode that can be supplied for either of the
system. Normally one pump motor combination is in a
hot 12. The expansion tanks can be added to those that are in the
through two lines. Each boiler is provided with two
can load conditions and automatically modulates the boilers
boilers. The number of boilers required to meet the
which is approximately 180°F and over 100 psig
of each plant is different in the number and capacity of
the boilers, pumps, and expansion tanks is controlled by the

 Each steam plant is different in the number and capacity of

its area of control and is not maintained to adjacent zones.

of each plant is different in the number and capacity of

Guideway Heating System
POWER SYSTEM DETAILS

The propulsion substations receive power from the 23kV distribution cables and deliver 575VAC, three-phase power to the power rails. Substation spacing prevents the overall guideway voltage variations from exceeding ±7 percent (exclusive of the power company regulation, which is +0 and -5 percent).

Five 1000kVA, three-phase transformers provide the power for the rails. The switch gear is equipped with electrically operated circuit breakers which are controlled from the System Operator Control Console located in the Central Control Room.

The housekeeping substations located at the passenger stations receive power from the 23kV distribution cables and deliver 480/277 volt three-phase power for lighting, heating, cooling, and operation of noncritical displays and the uninterruptable power supplies (UPS). The housekeeping substations also provide for operation of pumps and boiler controls for the guideway heating system.

An uninterruptable power supply (UPS) is capable of supplying power to critical loads for 15 minutes in case of loss of primary power. The critical loads include the computers, the processors, and the critical communication circuits. The UPS is composed of batteries, switching gear, and the equipment necessary to detect primary power interruptions.

Standby power generators at each passenger station and the maintenance facility are able to start automatically, with a manual start override, and will assume some of the loads of the housekeeping power within one minute of power loss. The station platform and guideway emergency lighting, the Radio Frequency (RF) Voice Communication system, the PA system, the TV system, and the passenger assistance telephone are powered by the standby power generator.
The propulsion power distributor distributes the power to the vehicles. The power is distributed through the propulsion power distribution system. The system includes the propulsion power distribution system, the power distribution system, and the control system. The power distribution system provides the necessary power to the propulsion system. The propulsion system is responsible for moving the vehicles. The system is designed to ensure that the power is distributed efficiently and effectively to the vehicles.
The CPCS controls the position of each vehicle by a synchronized point follower system. The point follower system is controlled by the CPCS, which automatically manages and controls the move-out of vehicles according to the predefined schedule of passenger-activated event. The CPCS is responsible for passenger management, station signals, and their control, providing information to passengers using the system's all-communication protocol. The CPCS also manages the maintenance of the system and monitors the wear and tear of the vehicles. The primary purpose of the CPCS is to automatically control the position and movement of the vehicles.
C&CS FUNCTIONAL DESCRIPTION

The Central Control and Communications Subsystem (CCCS) is responsible for overall control and monitoring of the transit system operations. The CCCS equipment is located at the maintenance facility and is comprised of dual central computers, peripheral communications equipment, monitors, displays, and central software segment.

The Station/Guideway Control and Communications Subsystem (CCS) controls and monitors system operations at the five passenger stations and the maintenance facility. The CCS equipment is located at each passenger station, at the maintenance facility, and throughout the guideway network. Equipment associated with the CCS includes dual station computers, control and monitor equipment, fare collection/destination selection equipment, vehicle boarding displays, guideway-mounted control and communications equipment, and station software. The functions of the stations and the maintenance facility are identical except for the lack of fare collection/destination selection equipment and vehicle boarding displays at maintenance.

The C&CS software subsystem uses real-time operational programs to manage and control a fleet of vehicles between the five passenger stations and the maintenance facility. The software subsystem is modular and is readily adaptable to an expansion of the system.

The M-PRT software resides and operates in a distributed computation system composed of central, passenger station, and maintenance station programs. The computation system controls all major operations required for the movement of vehicles and the correlation of vehicle movement to passenger-requested destinations.

The PRT is automatically managed by real-time operational computer programs of the central computer. The central software coordinates and directs all activities of maintenance and passenger station computers in the system, and responds to passenger demands. The central software maintains current information on the status of every vehicle in the PRT system, determines vehicle dispatch requirements for each station, manages empty vehicles and, under the control of the operator, directs vehicles to maintenance if repair is required.

Passenger station real-time operational computer programs manage and control all passenger information displays, processing of passenger destination requests, vehicle berthing, passenger loading and unloading, and vehicle dispatching. The station software monitors and controls each vehicle in the station channels, on the ramps, and on the main guideway. The station software coordinates with central, providing operational data and accepting data and commands originated at central.
C&CS SOFTWARE

The Operational Software is the subsystem within the C&CS which controls the system configuration, manages the movement of vehicles and passengers between stations, and controls the movement of vehicles on the guideway and in the stations. The operational software consists of three segments which reside in separate computers at separate locations. The Passenger Station Segment resides at each of the five passenger stations; the code for this segment is identical for each station, and unique parameters are contained in each data base to accommodate the differences in station configurations. The Central and Maintenance Station segments reside at Central and Maintenance. Each segment is divided into two programs: executive and applications. Applications programs perform functions which control system operation from the passenger and operator point of view. The Executive program controls the processing performed by the applications programs, provides the software interface with the computing system and external environment, and controls the configuration of the operational resources. The following paragraphs discuss the functions performed by the total software subsystem.

System Startup and Control. The software provides for loading of the computer network, for setting vehicle locations, and for initialization of variables to enable startup of the system. The software also controls the configuration of system elements, displays system status to the operator, processes operator command and data inputs, and records system operational data.

Vehicle Management and Control. There are two modes of system operation: schedule mode and demand mode. Schedule mode operation provides passenger service on the basis of a predetermined schedule of vehicle destination assignment rates. Demand mode operation provides passenger service in direct response to passenger destination requests received by the software when the passenger enters the station platform area. In both modes, destination requests are assigned to an available vehicle with the correct dispatch direction, and passenger loading is initiated. In demand mode, vehicle inventories for each station are based on the number of passengers waiting for service at any time.

Vehicle separation on the guideway is maintained by monitoring the position and status of each vehicle and by controlling the time at which vehicles are released from an origin-station load berth such that vehicles will merge with existing guideway traffic and travel down the guideway at intervals of 15 seconds (or multiples thereof). Vehicles approaching their destination station are routed to the station demerge ramp, and to a selected channel within the station, then forward within that channel to an unload berth. Vehicles are moved forward within a channel as the next-forward berth becomes available. After a vehicle arrives at the destination station unload berth, the vehicle door is cycled to enable passengers to depart the vehicle and enter the station platform area. After a vehicle has moved forward within the channel to the load berth and after a destination has been assigned to the vehicle, the software illuminates a boarding display and cycles the vehicle door to enable passengers to board.

Anomaly Management. The software provides for reaction to anomalies which are detected by the software and to faults which are reported by a vehicle. In addition, the software responds to operator initiation of anomaly reaction. Examples of anomaly reaction are stopping vehicle movement and removing guideway power. Anomaly recovery is provided to restart the system following an anomaly reaction.
OPERATING ALGORITHMS

This section describes the primary operating algorithm as implemented in the C&CS software. These algorithms are conveniently categorized as shown below. The first four items are used regardless of which operating mode, demand or schedule, is in use. The transition algorithm is used to redistribute vehicles when going from demand to schedule mode or between two dispatch schedules that are not specifically designed to work together. The anomaly management algorithm is a combination of automatic and operator actions designed to aid in the safe restart of the system following a failure or anomaly of any kind.

- SYNCHRONOUS VEHICLE CONTROL
- VEHICLE DISPATCH LOGIC
- VEHICLE ARRIVAL LOGIC
- CHANNEL MANAGEMENT
- DEMAND MODE
- SCHEDULE MODE
- TRANSITION ALGORITHM
- ANOMALY MANAGEMENT

SYNCHRONOUS VEHICLE CONTROL/MONITORING

The basic principles of the synchronous control algorithm are:

1) Imaginary (virtual) points circulate around the main guideway
2) These points are numbered and are 15 seconds apart
3) Vehicles are dispatched to the guideway so that they will closely follow a particular assigned moving point
4) The software, using presence detectors, monitors each vehicle relative to its assigned point and takes appropriate action when necessary.
Vehicle tracking is accomplished by monitoring the actual position of the vehicle relative to its assigned point. In order to meet its assigned point, each vehicle has a virtual point and a virtual path. Once a virtual path is assigned, the computer uses the actual point of each vehicle to read its position and movement. However, if the vehicle is stopped or idling, it uses the desired virtual point of each vehicle to read its position. If the vehicle is moving, the computer reads the actual position of each vehicle to track its movement. Additionally, the computer uses other virtual points to check the vehicle's position and movement.
VEHICLE ARRIVAL LOGIC

As vehicles approach their destination a switch command loop is set to cause the vehicles to enter the station via the station entrance ramp. A PD on the ramp must be hit in order for the vehicle's virtual point to be "cleared" for use by another vehicle downstream of the station.

CHANNEL MANAGEMENT

Each station channel contains 2 or 3 arrival or unload berths, and one dispatch or load berth. This chart shows the sequence of action taken as each vehicle moves through a station channel. An arriving vehicle stops in the forwardmost available unload berth, opens its doors for passengers debarking, and moves ahead. At the load berth the vehicle awaits its next assignment, cycles its doors for passenger loading, and is dispatched to the main guideway at the appropriate time as determined by guideway point occupancy and the current mode of operation, demand or schedule.
Demand Mode Macro Logic

Demand Mode Algorithm
VEHICLE REDISTRIBUTION ALGORITHM

Vehicles are redistributed in the system if a station is not capable of handling the passenger demand with vehicles on hand or on-way (i.e., expected arrivals) or if a station's inventory of vehicles falls below a preset minimum level. The minimum level assures vehicle availability for entering passengers during low demand periods.

SCHEDULE MODE ALGORITHM

In schedule mode vehicles travel between origin-destination pairs based on preset dispatch rates. A master schedule consists of a series of subschedules to be run at specified time intervals during the operating day. Each subschedule consists of dispatch rates for each origin-destination pair, platform assignments, side channel use rates, and inventory requirements. Each schedule must be balanced in order to prevent vehicle shortages or excesses at each station platform. The balancing process is accomplished by the analyst who generates the schedule. Schedule mode is meant primarily for use during very high, predictable, demand periods, where, if carefully constructed, it can outperform demand mode by a small margin.
Anomaly Management

Transition Algorithm

- 3) Stations with surplus dispatch all extra vehicles to the closest downstream station with a deficit
- 4) "End" stations redistribute the extra vehicles to the closest station with a deficit or to an "end" station
- 5) Station inventories are calculated. (station surplus/deficit are calculated, station requirements from this schedule are provided if necessary)

The algorithm works as follows: in response to an event of master schedule of a transition in a vehicle or a vehicle failure causes an interruption in the service. When a vehicle or a vehicle failure causes an interruption in the service, the algorithm dispatches the vehicles in the system to balance the demand.

Supplies/deficit = Station inventory - requirement

Since demand requests are used when necessary to balance the two sides of an office station, demand inventories include "in station" + "on way" vehicles.

In the presence of anomalies in the system, the operator uses the algorithm to dispatch vehicles to maintain service as much as possible. An operator is required to continue as much passenger service as possible in order to continue with the system to proceed at such an operator. The operator dispatches the system to proceed at such an operator. The system is required to maintain service as much passenger service as possible in order to continue with the system to process the anomalies in the system. The operator is required to continue as much passenger service as possible in order to continue with the system to process the anomalies in the system.

Directional Section:

- 1) Station inventory requirements from this schedule
- 2) Station inventory requirements from this schedule
- 3) Stations with surplus dispatch all extra vehicles to the closest downstream station with a deficit
- 4) "End" stations redistribute the extra vehicles to the closest station with a deficit or to an "end" station
- 5) Station inventories are calculated. (station surplus/deficit are calculated, station requirements from this schedule are provided if necessary)

The algorithm works as follows: in response to an event of master schedule of a transition in a vehicle or a vehicle failure causes an interruption in the service, the algorithm dispatches the vehicles in the system to balance the demand.
Central Control and Communications Subsystem (CCCS)

CENTRAL CONTROL AND COMMUNICATIONS
FUNCTIONAL DESCRIPTION

The system operators at central control monitor and directly control system operations during startup, failures, shutdown, and restart. At all other times, the central computer controls and supervises vehicles in stations, on the guideway, and at the maintenance facility. The system operators merely monitor transit system operations. All operator-initiated commands are routed from the control console through the central computer to the remote computer at each station.

Software routines allow the operator to restart the system (after an anomaly has forced the system into the non-normal state), run selected vehicles at reduced performance levels (running vehicles at speeds lower than normal for use during abnormal or emergency conditions), assign vehicles to various locations (remotely control vehicle destinations, e.g., dispatch a faulty vehicle to maintenance), and perform other control and override functions.
The operation of the vehicle's control system is divided into two main modes: manual and automated. The emergency mode is activated only in the event of a failure of the control system or in an emergency situation. The automated mode is activated when the operator is not present in the vehicle. The system operator is responsible for the overall management of the system.
CENTRAL SOFTWARE

The Central Segment software consists of the Central Executive and the Central Applications Program (CAP). The Executive program controls the processing performed by the Application program and provides the software interface with the computing system and external environment. CAP records system operational data, displays and logs system status data, executes operator commands, maintains the vehicle motion time base (virtual points) and coordinates and communicates with the station software to effect the contribution and movement of the vehicle fleet throughout the system.

CAP is modular in structure to facilitate development, testing, and maintenance. The structure includes five module groups which organize the applications modules along functional lines.

The Command Processing Module group enables system start-up, accepts operator inputs from the CRT keyboard, and executes operator commands.

The Data Collection Recording and Display Module group provides the following:

- **Data collection**—includes output of runtime information such as vehicle mileage to magnetic tape.
- **Event logging**—provides for printouts of vehicle locations, miles, and enabled hours.
- **Safe data recording**—provides periodic output of vehicle status information to cartridge and fixed-head discs.
- **System operator displays**—outputs system status and current anomalies to the CRT, along with the last requested display. Anomalies and displays are printed upon operator request.

- **MIMIC display**—periodically updated to reflect current vehicle locations.

The Communications Processing Module group accepts messages from the Passenger and Maintenance stations applications programs.

The Operations Management Module group provides for dispatch of vehicles and for maintenance of the virtual points and subpoints which it uses to synchronize dispatches. It also provides for management of vehicle inventories in demand mode, initiation of dispatch rate changes in schedule mode, and reaction to anomalous conditions.

The Operations Monitoring Module group maintains the current status of each vehicle in the system, as reported by the stations.

![Central Applications Program Organization Diagram](diagram-url)
**Central Control Computer Configuration**

- **Reader:** Can read an 80-column, 24 cards/min, punched card.
- **Impact printer:** Line printer—6 4-character set, 330 lines/min, 80 columns.
- **Magnetic tape transport:** A 9-track, 8000 characters/Sec, 10,000 characters/min, magnetic tape transport.
- **CRTs:** Terminal—non-modified Baudot terminal, with special capability.
- **Paper tape reader/punch:** 300 characters/sec, reader and punch, 128 columns, full 80 character set printer terminal.
CENTRAL CONTROL COMPUTER CONFIGURATION
(Continued)

*Special Purpose Equipment (SPE)*. SPE at Central is provided to enable manual switching of station computers and to interface with operator control and display equipment. Specific SPE interfaces are with:

- **MIMIC**—provides graphic visibility of vehicle location and status. This interface is controlled by the software to provide automatic switchover in the event of computer failures.

- **Electrification Control**—a relay output interface in each computer is wire “OR’ed” in the SPE. Either computer commanding a closure will remove guideway power from the associated section of the system.

- **Communications Link**—the primary communication is through the UNIBUS link; to provide the necessary arbitration in failure determination, a secondary link, consisting of 3 bits full duplex, is provided as part of the SPE MIMIC interface.

- **Modems**—the modems are 2400 BAUD, synchronous serial lines which are routed through the SPE to enable each station computer to be independently switched to either Central computer.

- **Remote Bootstrap**—a remotely controlled ROM used to bootstrap the disk and modem lines to load the system software.
CENTRAL CONTROL OPERATIONS

The central control room contains the equipment for monitoring and controlling system operation. There are two main consoles, one for the system operator and one for the communications operator, and a shift supervisor's station. Thus, operation of the system during peak traffic periods calls for three people to be on duty; a system operator, a communications operator, and a shift supervisor.

The system operator's console contains two keyboard terminals and related cathode ray tube (CRT) displays, a Guideway/Station Electrification Panel, and an intercom unit linked to maintenance operations in the Maintenance Control Room. The keyboard and CRT displays permit the operator to control the system whenever required, such as during start-up, restart, shutdown, anomaly recovery, and even during normal operations. Each keyboard and CRT display is linked to one computer string. The A string computer interfaces with the left keyboard and the B string computer interfaces with the right unit. Each keyboard and CRT display consists of an alphanumeric and function coded keyboard, a 12-inch cathode ray tube monitor, and associated electronics.

The MIMIC Display, which is a small-scale software-controlled replica of the M-PRT guideway, is mounted slightly above eye level on the wall directly in front of the system operator's console. Through a series of yellow lights, the display shows the location of all vehicles between presence detectors in the system. Each light on the MIMIC Display corresponds to a PD. The light is illuminated when the loop associated with that PD is occupied and is turned off as the vehicle passes on to the next loop.

Lights in each berth position indicate vehicle status: a red light means that the vehicle is disabled, a yellow light indicates occupied and available. Vehicle-related anomalies cause the yellow MIMIC Display lights to flash at the PD locations of the anomalous vehicles. A slow flash (60 per minute) indicates a minor anomaly, a fast flash (180 per minute) means a more serious one.
The station control and monitor panel and monitor the following:

- Station Control Panel
- Monitor Panel

The System Operator Console contains the following:

1. Console Screen Control Panel
2. Display Panel Assy
3. Station Control & Monitor Panel Assy
4. Two Keyboard Terminals and Related Cables
5. Maintenance Radio
6. Maintenance Equipment Panel
7. Station Equipment Panel
8. Power Supply (UPS) Outputs
9. Uttar Pradesh
10. Uttar Pradesh
11. Uttar Pradesh
12. Uttar Pradesh
13. Uttar Pradesh
14. Uttar Pradesh
15. Uttar Pradesh
16. Uttar Pradesh
17. Uttar Pradesh
COMMUNICATION OPERATOR’S CONSOLE

The communications operator is responsible for communications to and from passengers in the PRT system, and to and from the public outside the PRT system. He does this from the communications operator’s console, which has:

1) Station public address selector panel
2) Control/monitor panel
3) Vehicle radio control unit
4) Public and passenger service phones
5) Maintenance radio unit
6) Video monitor display unit (closed-circuit TV)

The communications operator also enables or disables vehicles (to conserve energy and vehicle wear) as required over the vehicle radio control unit, and is responsible for maintaining station security by monitoring the TV displays that show all the station platforms. These are fixed-focus non-multiplexing cameras mounted at strategic points in each station. The operator can address any station over the public address system.

Passengers in PRT vehicles can summon the communications operator over the same unit. Each vehicle can be separately addressed or all vehicles can be addressed simultaneously. The means to open and close passenger gates remotely is also provided on the communications console.

The telephone/elevator control panel assembly enables the communications operator to assist passengers by means of the station elevator telephones.
The shop area of the maintenance building

maintenance control. Engineering Maintenance Facility

intercom units are also provided between central control

The UHF communication network allows

THE UHF Radios are handier to be located on top

the maintenance area.

Its primary ability is also provided so that all repair personnel

with provide contact with central from anywhere in the area.

There is a separate UHF radio system for the exclusive use of

Maintenance Personnel. The recovery and maintenance

Maintenance Personnel. The recovery and maintenance

emergency.

Each vehicle has its own radio, which can be activated in an

central or be connected by control over a UHF radio system.

by the PA system, personnel in the vehicles can contact

Passengers at the station platforms can pick up a hand-held

The system uses various methods for communication.
STATION/GUIDEWAY CONTROL AND
COMMUNICATIONS FUNCTIONAL DESCRIPTION

The S/GCCS equipment is located at each station in the
system and at the maintenance facility and consists of the
following:

1) dual station computers and modems
2) Data Handling Unit (DHU)
3) Inductive Communications Unit
4) Collision Avoidance System (CAS)
5) operational service equipment for passenger
   interface

The data link between the S/GCCS and the CCCS is a hard-
wired, fully duplex cable transmission system carrying serial
frequency-shift-keyed (FSK) modulated digital data. The
communications modem, consisting of a transmitter and
receiver station, connects the station computer to the cable
transmission system. The station computers process input
data from the CCCS to store the station operational soft-
ware programs, update stored programs, or generate the
required station and vehicle control data messages. Because
of the short distance between the CCCS computer and the
maintenance SCCS computer, a communications modem is
not required.

In addition to the communication modems, the station
computers interface with the station data handling and data
acquisition circuits, the CAS, and the station platform fare
collection/destination selection units and passenger boarding
displays. Each of these interfaces acts as a computer input/
output device under control of the station computers
(Central Processing Unit).

The data interface between each SCCS and the vehicles on
the guideway is an inductive communications link that
transmits vital signals by tones and nonvital signals by FSK
digital data message transmissions. Inductive communications
are accomplished by guideway-embedded loop antennas that
are connected to associated transmitter and receiving units in
the station equipment room, and by vehicle-borne receiving
and transmitting antennas that couple signals to the vehicle
VCCS electronics.
STATION COMPUTER CONFIGURATION

Two DEC computers are located at each of the six stations. A typical station computer configuration consists of two PDP 11/40's performing redundant processing, a floppy disk and teletype for each computer, Special Purpose Equipment (SPE) for controlling the non-standard computer interfaces, and the modems and boot switches enabling each station computer to communicate with one central computer.

Central Processor and Mainframe Logic (DEC PDP 11/40). The PDP 11/40 computer is a 16-bit machine with 48K of core memory, having a 980nsec cycle time. The mainframe contains a Memory Management Unit to provide memory mapping as well as executive and user mode memory read/write protection; a power failure monitor; a programmable real time clock; and all the Device I/O controllers for the standard peripherals, the Special Purpose Equipment, and the UNIBUS Link between the two processors.

Peripherals. The station peripherals are:

• Teletype - an LT33-DC terminal with paper tape reader/punch capability. The teletype performs all functions at 10 characters/sec

• Floppy Disk - a dual drive unit with 128K word capacity per drive, a 483 millisecond average access time, and a 36 microsecond per word transfer rate

• Remote Bootstrap - a ROM which is remotely controlled from Central used to bootstrap the modem lines to load system software

• Modems - the modems are 2400 BAUD synchronous serial line units

Special Purpose Equipment (SPE). The SPE is logic designed to provide dual system interface capability for simultaneous operation and/or automatic switching of the two computers with the system devices. The SPE interfaces with the following station electronic equipment:

• Data Handling Unit (DHU) - the DHU enables communication with the vehicles and control of the stop and switch tones. Two general device register interface controllers (DR11-C) are used - one for input, the second for output. The input functions the same as the DAU; the output data from only the prime processor is presented to the system device. Selection of the prime computer is automatic through software control

• Data Acquisition Unit (DAU) - the DAU provides monitoring of Presence Detector hits, switch verify signals, and CAS disparities. A general device register interface controller (DR11-C) is used in each processor to control data flow. In dual mode, data is presented simultaneously to both processors, and both must respond before the next data word is presented. Handshake signals are monitored by the SPE and discrepancies result in timeout signals. These timeout signals and other error data determine when SPE switching is required. The SPE can then be switched to single string mode where both the data and handshake signals are only presented to one processor

• Collision Avoidance System (CAS) - the CAS enables control of safe tone loop signals; through one or more Bus Output Interface modules (M1502), each a 16-bit open collector high voltage driver. Data is only routed from the prime processor just as with the DHU output

• Destination Selection Unit (DSU) - the DSU presents passenger requests from the entry gates. Data and handshake signal flow is the same as for the DAU

• Passenger Boarding Display (PBD) - the PBD informs the passengers of the status of the channel and the boarding status and destination of the vehicle. Interface is through a relay output interface (M1801) and is wire "OR"ed from both processors.
MRT Typical Station Computer Configuration
The Station Management module group provides for the updating of virtual points, reaction to vehicle and station electronics anomalies, dispatching and handover of vehicles, and the assignment of vehicles to provide passenger service.

The Station Monitoring module group monitors vehicle reported faults, detects other anomalous conditions of the vehicles, monitors all vehicle positions within the station control zone, and verifies proper vehicle switching for vehicles entering or bypassing a station.

The Vehicle and Guideway Control module group controls vehicle switching on the guideway and within station ramps and channels, controls vehicle movement and door operations within the station channels, verifies proper vehicle merging onto the main guideway, and controls the software Collision Avoidance System (CAS).
VEHICLE CALIBRATION

Because of tire wear, rolling radius variations between tires, and other minor deviations, the vehicle odometer signals are periodically updated as the vehicles travel the guideway. Vehicle corrections are made so vehicle position can be maintained within the tolerance. Corrections are calculated by the VCCS from inputs provided by the calibration loop signals along the guideway.

The calibration tone generator transmits a signal to the Vehicle Communications Control System (VCCS) to provide speed and distance reference. This nonvital signal is used by the VCCS as a reference for calibrating the vehicle's odometer. Vehicle speed calibration is taken from the loop length and vehicle position information from loop position. Calibration tone loops are 200 feet in length and are positioned approximately every 800 feet along the guideway. Calibration tone units are comprised of a calibration tone transmitter and its associated loop driver. The output from a 36.3 kHz oscillator in the calibration tone transmitter is applied to the loop driver. The loop driver output is connected to the associated calibration tone transmitting loop antenna via the station junction box.

Loop drivers provide the signal interface between each station's inductive communications transmitting unit and its associated loop antenna. A double push-pull circuit provides the signal gain and current drive required for each loop. Input signals from the related transmitter unit are gain-adjusted at the input stage of the loop driver and the differential output signals are applied through two open gain amplifiers to separate push-pull current amplifiers. The output of each push-pull current amplifier is connected to the associated loop antenna terminals via the station junction box. A crossover distortion adjustment in each current gain amplifier helps ensure a smooth sinusoidal output.

A high-power integrated-circuit amplifier provides the current drive for each loop. Input signals to this amplifier from the related transmitter unit are buffered in a unity-gain amplifier. Application is then made thru a gain-control potentiometer, to the high-power amplifier. This provides a balanced drive to the loop, thru an output transformer.
The presence of higher speed commands in a section of guardway is monitored by the guardway
receiver. The vehicle response to the higher speed commands is initiated by those positions of the guardway which
are an additional safety precaution. "High-speed enable"

The FSK transmitter is designed to provide a single or a multi-channel configuration.

The FSK data and speed tone signals have separate gain adjustment. In a single-channel configuration, the signals are always

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So 2 Hz the FSK receiver will produce a signal in a 2 Hz tone. In this manner, speed commands are always

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STATION STOP TONE CONTROL

When a vehicle enters a station channel, it is commanded to stop or proceed by the presence or absence of a stop tone. This tone is a 36.3 kHz unmodulated tone applied to the stop loops at the platforms.

The vehicle must be receiving a 4 fps commanded speed and the stop tone in the VCCS in order to follow a fixed deceleration profile. This allows the vehicle to apply brakes, decelerate, and come to a rest ±6 inches from the station platform loading/unloading gates. Once the vehicle has stopped a “0” performance command sets the brakes in the full normal position.

Station stop tone units are comprised of a CAL/STOP transmitter circuit and its associated loop driver. The station CAL/STOP transmitter is controlled by a computer-generated command data word that is decoded by the DHU to provide a control data and strobe signal input to the addressed unit.
An independent Collision Avoidance System (CAS) is used to prevent collisions in the event of failure of the primary brake system. Normally-Off blocks are used on the speedometer and normally-Off blocks are used on the handbrake. When a vehicle encounters a normally-Off block, it will stop the vehicle immediately to the rear of a block that is normally-Off. If a vehicle is parked and the handbrake is applied, the vehicle will stop at the normally-Off block. When a vehicle enters a block and accelerates, the vehicle will accelerate and go through a normally-Off block. The CAS is a redundant system utilizing two different logic paths. One logic path interfaces with the mission computer, and the other logic path interfaces with the mission computer.
CAS FUNCTIONAL DESCRIPTION

As mentioned, a vehicle on the guideway must receive a safe tone or emergency brakes will be applied and the vehicle will stop. Safe tones are 10.2 kHz carriers modulated at 50 Hz. The modulated carrier allows the vehicle to proceed; absence of the carrier or its modulation will cause the vehicle to stop.

The CAS is redundant for block logic functions up to the interface with the disparity checkers. One CAS logic path enters the station computer where software computes the proper block occupancy, and commands safe tones on or off. The other logic path is accomplished in special logic hardware, (microprocessor) which computes the same occupancy, but provides an output only to the disparity checker. Inputs to the two paths are provided by independent presence detectors (PD) located on the guideway at the beginning of each block. Presence detector signals are converted to appropriate logic levels by redundant PD electronics circuits. After processing by the station computer, the safe tone command is routed to a control gate which passes the 50 Hz modulation signal to the safe tone loop driver. The 50 Hz modulation keys the loop driver producing a 10.2 kHz signal chopped at a 50 Hz rate. The 10.2 kHz carrier frequency is always present at the loop driver input, but is cut off until the modulation frequency appears.

The 50 Hz safe tone modulation frequency is obtained from a master oscillator in the Maintenance facility. This 50 Hz frequency is first distributed to each station, then to the various CAS control zones. Within a zone, the 50 Hz signal passes through each disparity checker, then through the zone disparity latch, and finally appears as the modulation input to each control gate. When the corresponding hardware and software logic signals are compared by a disparity checker, the tracer signal is allowed to pass, or is cut off, depending on whether the two logic paths agree. If a disparity occurs, the 50 Hz tracer is interrupted, causing the zone disparity latch to latch open, and the modulation is removed from the loop drivers in that zone. This causes loss of safe tone on the guideway, and vehicles in the zone will stop on emergency brakes. The disparity latch can be reset by insertion and removal of the disparity override plug after the cause of disparity has been corrected. At the time of disparity, the disparity latch circuit issues a signal to notify the system operator. Disparity monitor circuits are provided to assist in troubleshooting, and switches are provided to reset the monitors and the hardware block occupancy logic if required.

At switch points and merge points on the guideway, additional block control circuitry is required. A switch verification receiver detects the verification signal transmitted by a vehicle which has just completed switching. The detected signal is fed to redundant latch circuits for the software and hardware logic. When the latch occurs in both paths, and proper block occupancy has been computed, the "normally-off" safe tone at the switch is activated allowing the vehicle to pass. The latches are reset when the vehicle triggers the next PD's clearing the switching block.

At merges, a special purpose block control circuit receives PD inputs from both legs of the merge. This circuit establishes priority for a vehicle entering the merge, and sets a flip-flop which retains that priority until the vehicle has cleared the merge blocks. The "normally-off" safe tone in either leg of the merge is activated only when priority has been established for that leg. The priority logic function is duplicated in the software path, as with other block logic, and computation of safe tone state must be in agreement with the hardware path or zone disparity will occur.
Vehicle System

VEHICLE SUBSYSTEMS

Each Morgantown PRT vehicle consists of ten subsystems. These ten subsystems, identified below, are described in detail on the following pages.

1) Passenger Module—the envelope that houses the passengers.

2) Environmental Control Unit (ECU)—provides heated or refrigerated air to the passengers as required.

3) Chassis—the structural support and running gear.

4) Hydraulic—provides energy for braking and steering.

5) Pneumatic—provides automatic vehicle leveling.

6) Steering—allows the vehicle to follow a guiderail mounted on either side of the guideway.

7) Braking—provides redundant normal and emergency rate stopping and a mechanical parking brake.

8) Propulsion—turns the rear wheels at the commanded rate.

9) Electrical—picks up electrical power from the guideway power rails and converts it to 355/120/61 VAC and 26 VDC for vehicle functions.

10) Vehicle Control and Communications System (VCCS)—receives guideway and on-board commands and commands the motor, brakes, switching and the doors to perform as prescribed.
The passenger module is a fiberglass structure containing lights, doors, windows, and seats, all of which provide a pleasant surrounding for passengers. There are eight molded fiberglass seats and four floor-to-ceiling stanchions for standing passengers. The floor is carpeted to provide a pleasing non-skid surface, and all interior access panels are held closed with tamper-proof locks. A portable fire extinguisher is also provided to handle potential flammables brought aboard by passengers.

Fluorescent lighting is inset in the ceiling for normal module lighting. However, in case of a power failure, 24VDC lights that are powered by on-board batteries are automatically activated. The doors are also powered by 24VDC mechanisms, one for each door. The left door may be opened from inside the module when the vehicle is not moving. The rear window also serves as an emergency exit and, when opened, causes the vehicle to apply brakes and come to a stop. Either door may be opened from outside the vehicle by emergency handles on the rear corners of the vehicle.

The module windows are tinted to reduce glare, and are constructed from a special tempered safety glass. The large windows offer excellent viewing and yet provide security for the passengers. A UHF radio is provided for emergency voice communication to and from central control.
The high purity air is exhausted into the passenger module through a number of vents and outlets. Air drawn into the module is conditioned by the ECU, ECU Control Unit, and the Exhaust Control Unit. The majority of the air is drawn in through the floor in the all passenger compartment, the remainder (4%) from the exhaust system near the seat base. Air is then drawn into the module, through the ECU, and finally exhausted through the vents and outlets.
CHASSIS

The chassis consists of the frame, axles, wheels, and suspension system. The frame is a weldment with four integral jack pads for ease in lifting the vehicle. The front bumper is an impact-collapsible type, designed to withstand impacts up to 4 fps. The rear bumper is rigidly mounted to the frame. The axles are specially designed from basic truck-type commercial units. The front axle is a rigid box frame with steerable hub ends from truck-type four-wheel drive units. The rear axle drives the vehicle through a heavy-duty differential with a 7.17:1 ratio. The rear wheels are also steerable with an axle yoke universal at each hub assembly.

Suspension is provided by air springs at each wheel with standard shock absorbers. The air springs are self-inflating and regulating to provide a constant sprung-to-unsprung separation distance. This provides a constant floor height for ease of entry and exit at station platforms.

The wheels are heavy-duty 16.5, 8-stud, and the tires are 16.5, by 9.5, 10-ply. Each tire has an inner tube and liner that provide two independent air chambers for puncture protection.
The hydraulic subsystem supplies energy to the steering sub-system.
PNEUMATIC SUBSYSTEM

The pneumatic subsystem provides air to the top airsprings which support the passenger module. The vehicle is supported at the proper height and level by four airsprings, one near each wheel. The forward two airsprings are controlled by a height control valve and a pilot operated valve. Each rear airspring is controlled by its own height control valve. These valves, through a control linkage, measure the distance between the sprung and unprung portions of the chassis and meter air in or out of the airsprings to maintain the floor height and levelness.

If the pressure in the forward airspring or both rear airsprings rises above a limit, the overload warning system is actuated. Under these conditions, a warning horn sounds and the vehicle cannot be dispatched until a sufficient number of passengers exit.

Filtered air (25 microns nominal) is supplied to the electric motor driven compressor. This air is spin dried and refiltered (5 micron nominal) and stored in a 10 gallon receiver. Before going to the height control valves, the air is again spin dried, filtered, and lubricated.

System pressure is controlled between 92 and 104 psig. Relief valves on the compressor and in the system prevent pressure buildup under failure conditions. A low pressure switch provides a warning if the pressure drops to 65 psig.
STANDARD STEERIN G SYSTEM

- Cylinder is positioned to the left or the right.
- The vehicle will follow a guide rail or steering rail on either guide axle.

The steering force of approximately 240 pounds is transmitted to the steering wheel through a series of links and a fork-and-pinion action.

To negotiate 30-foot-radius turns, the vehicle is equipped with four-wheel steerin g.
BRAKE SYSTEM

The vehicle is equipped with a dual brake system, either of which can stop the vehicle safely. Every component of the dual systems is redundant and independent up to the brake pads. All four wheels have disc brakes with a unique caliper at each wheel and a single rotor.

The calipers contain tandem piston actuators with independent hydraulic actuation. Either piston in the caliper assembly is able to actuate the brakes at full capacity, but, when both pistons are actuated, which is normal, the braking results are not additive. This is a unique design; however, the brake pads, two with each caliper, are standard automotive practice.

Braking signals come from the VCCS to the brake amplifiers. The brake amplifiers command the servo valves to respond, and the servo valves apply the proper pressure (25 to 1000 psig) to the calipers. There are two braking modes: normal and emergency. In the normal mode, the VCCS provides an analog voltage of 9±10VDC to the brake amplifier and the servo responds with 25 to 800 psig. The emergency mode is created by an absence of a 28VDC signal to the brake amplifier, which causes the servo valve to release up to 1000 psig to the calipers. Normal rate braking provides up to .062g deceleration and emergency rate braking is limited to 0.45g deceleration.

Brake energy and control are provided by the hydraulic and the electrical systems respectively. In the absence of either or both, hydraulic energy is provided from the accumulators and energy for control is provided from the batteries. In an extreme case, when loss of power and failure of the batteries might occur, a special emergency braking system would be activated. Two solenoid valves in the system would open because of the absence of DC voltage; the servo valves would be bypassed, and all the energy in the accumulators dumped directly into the brake calipers.

The parking brake calipers are mounted on the front wheels and are spring-loaded assemblies that are held off by hydraulic pressure. If hydraulic pressure should decay to an unsafe pressure, the parking brakes would automatically activate. The pressure can be dumped, and the parking brakes applied manually from the maintenance panel on the front of the vehicle.
The propulsion motor is a compound-wound DC motor rated at 7 hp at 2700 rpm, with 420VAC on the armature and 250VDC on the field. It has an integral fan opposite the motor.

The propulsion system is running only when the propulsion system is running.

The system will be shut down automatically if the temperature becomes critical.

These sensors warn the system operator, through fault condition.

The motor controller includes a three-phase full-wave SCR, which provides the voltage needed to drive the motor.

The vehicle is driven by the propulsion system, which consists of a transformer, a motor controller, and a drive motor.
ELECTRICAL SYSTEM

The electrical system receives the guideway 575VAC power through either the left or right power collector and distributes several different voltages throughout the vehicle. The vehicle requires 575VAC, three phase, 120VAC, single phase, and 26-28VDC. The main autotransformer also outputs 355VAC, three phase and 61 VAC, three phase for the propulsion drive and control circuits respectively.

The 575VAC serves as the primary of the main transformer, as well as power for the hydraulic pump motor and the ECU system. The 120VAC circuit powers the normal module lighting, the pneumatic air compressor motor, power collectors, heaters, the battery heater, and the auxiliary receptacle. The 28VDC system charges the emergency batteries (two 12 VDC batteries in series) and powers the VCCS, the emergency module lights, the door operators, the brake amplifiers, and miscellaneous valves and control relays.

There are two DC buses for safety. Normally, both buses are fed from the DC power supply with the batteries floated on bus 1. All of the critical loads, i.e., one-half the normal brake system, the steering control valve solenoid, the propulsion cut-off, the VCCS, and the emergency brakes, are fed from bus 1. A circuit breaker ties the two buses together so that a fault on the power line to bus 2 or on the bus itself will cause the bus-tie breaker to open. If this happens, the critical loads are isolated from the fault and will be powered by the battery, and a fault message will be sent to the system operator.
VEHICLE CONTROL AND COMMUNICATIONS SYSTEM

The ACCS is a vehicle control and communications system designed to manage various aspects of vehicle operations. It sends and receives signals to control functions such as door activation, power management, and communication with other systems. The ACCS is typically integrated into the vehicle's electrical and mechanical systems to ensure seamless operation. Integration with other systems, such as the body control module (BCM), ensures a cohesive control environment for the vehicle.