ATTACHMENT A

M-PRT 1-1 SYSTEM OPERATIONS DESCRIPTION MANUAL

To be provided

MORGANTOWN
PERSONAL RAPID TRANSIT SYSTEM

SYSTEM OPERATION
DESCRIPTION MANUAL
M-PRT-1-1

INTRODUCTION

This System Operation Description Manual is intended to provide persons unfamiliar with the Morgantown PRT System with an introduction to its operation and its major design features. This is the initial document in a series of manuals designed to instruct system personnel on the operation and maintenance of the Morgantown PRT System (refer to manual "tree" next page) on a daily basis.

This document is organized into two major sections

Part I	System Overview
Part II	System Description

Part II supplements the information contained in Part I and provides more technical detail. The Table of Contents shows this relationship and allows the reader to easily locate in depth detail as required.

OPERATIONS AND MAINTENANCE MANUAL DOCUMENT TREE

MORGANTOWN PRT SYSTEM O&M MANUALS

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)

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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:

- Demonstate 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

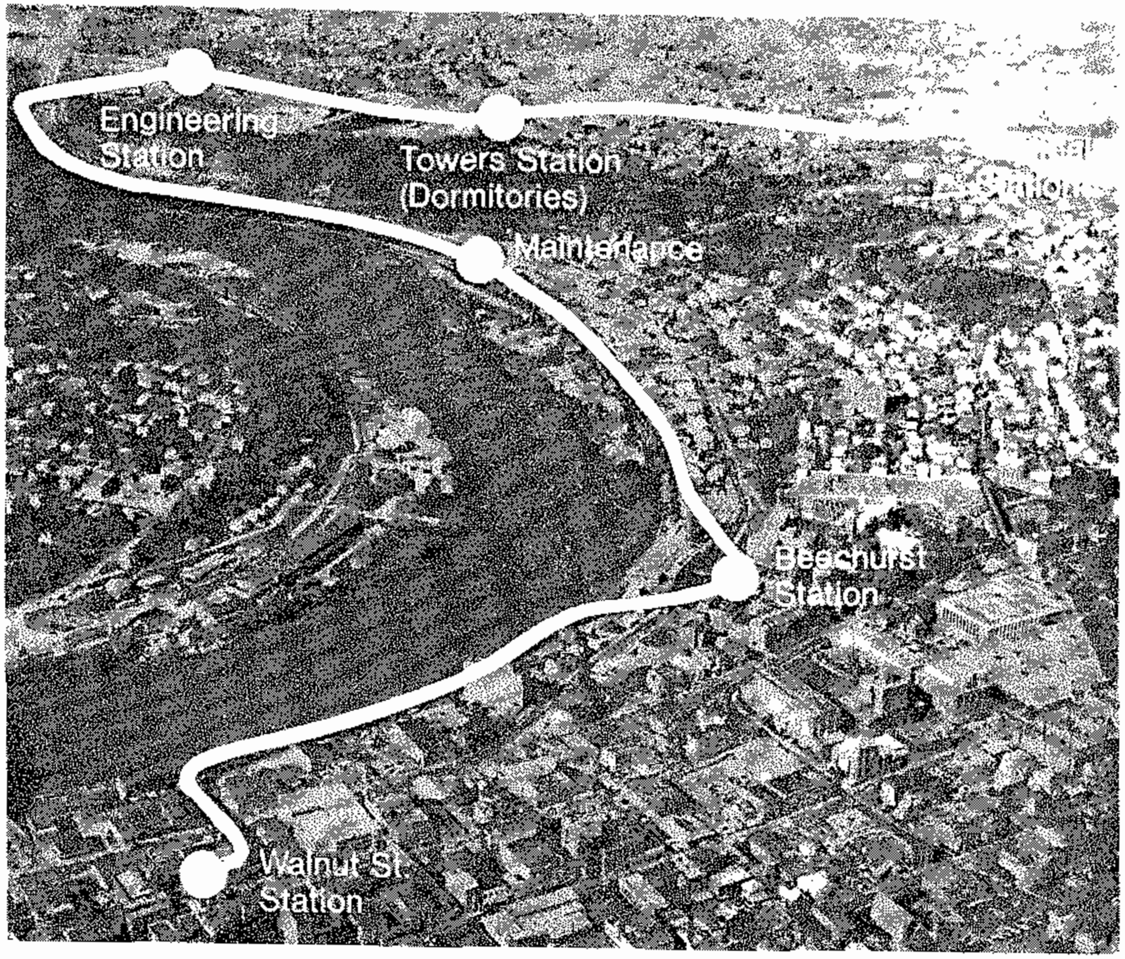
The Boeing Aerospace Co. - Station Electronics, Vehicles, Guideway & Station Equipment Installation, and System Checkout.

F.R. Harris - A & E Design

The Trumbull Corp. - General Contractor

Daniel, Mann, Johnson & Mendenhall (DMJM) - Consultants to WVBOR.

MORGANTOWN PRT ROUTE



SYSTEM OPERATIONAL DESCRIPTION

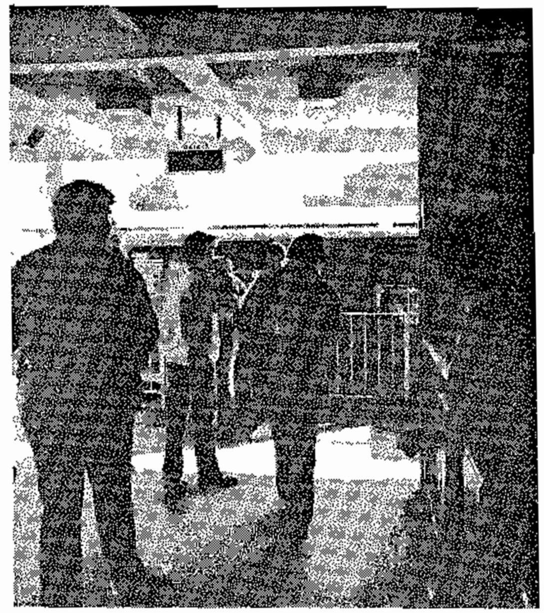
The Morgantown PRT system is operated in either schedule or demand mode. During those periods when passenger demand is highly predictable, the system is operated in schedule mode. Vehicles are dispatched between origin/destination pairs on a preset schedule. When passenger demand is less predictable, 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.

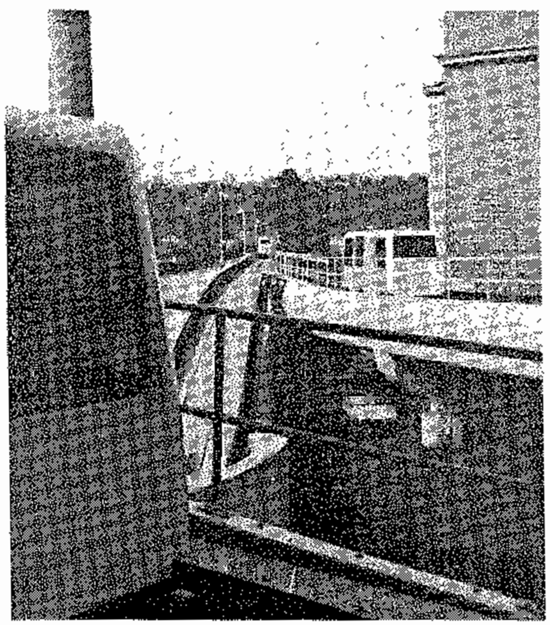
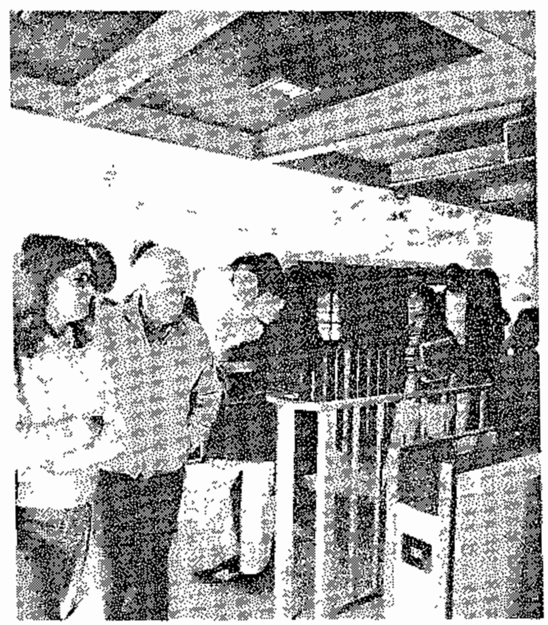
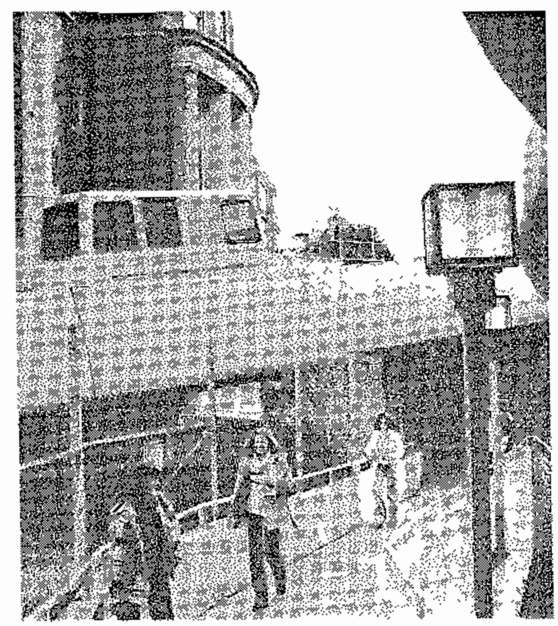
Operation of the PRT system, as summarized from a passenger's viewpoint, is as follows: arrive on concourse level of origin station where static and dynamic displays provide direction to the platform servicing his destination; proceed to the platform level; insert a coded card or exact change in a fare 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 handicapped 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

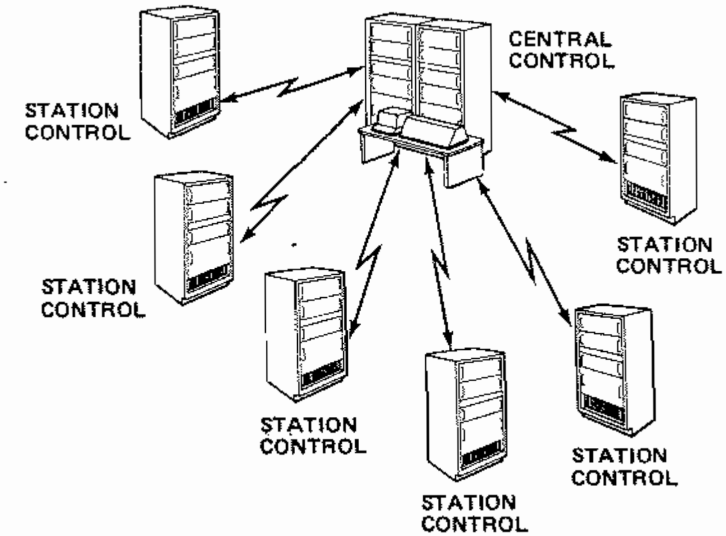
Includes the guideway structure, passenger stations, co-located maintenance and central control facilities, guideway heating, the electrical power distribution system, and a small auxiliary maintenance and wash facility.

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).

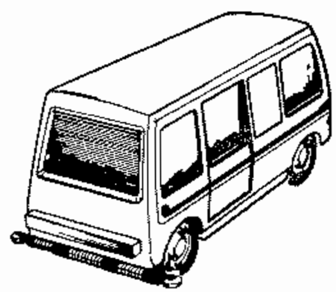
Vehicle System

Includes all the vehicles in the system.



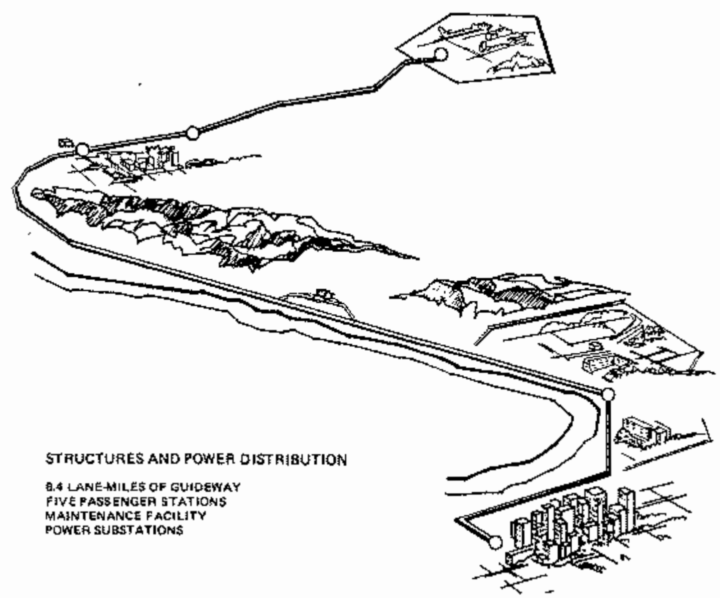
CONTROL AND COMMUNICATIONS

CENTRAL CONTROL
CENTRAL COMPUTER AND ELECTRONICS
SIX STATION COMPUTERS AND ELECTRONICS



VEHICLE

ELECTRIC POWERED
AIR CUSHIONED
21 PASSENGERS
8,700 LB EMPTY
15.5 FT LONG



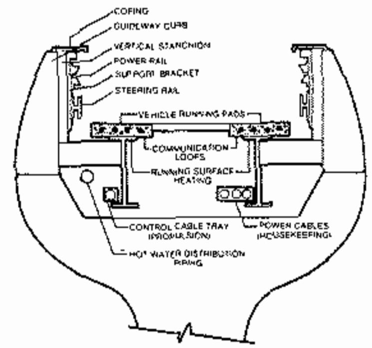
STRUCTURES AND POWER DISTRIBUTION

8.4 LANE-MILES OF GUIDEWAY
FIVE PASSENGER STATIONS
MAINTENANCE FACILITY
POWER SUBSTATIONS

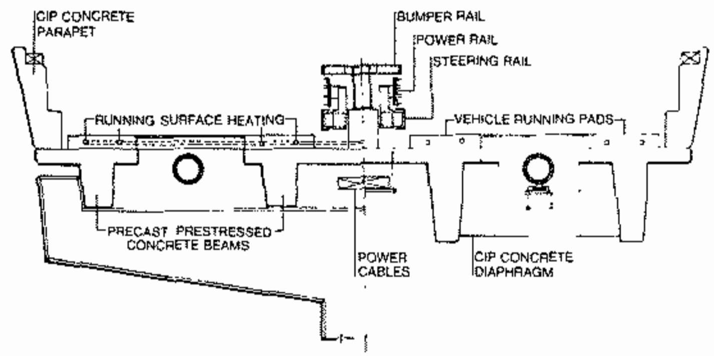
GUIDEWAY

The guideway structure is a limited access route connecting the PRT stations and the maintenance facility. Approximately 54% of the guideway is elevated, the remainder at ground level. Both single and double lane guideways exist. The running surface is concrete containing distribution piping for guideway heating to allow all-weather operation. Inductive communication loops, also contained in the running surface, enable messages to be transmitted and received between the vehicle and the control and communications equipment. Steering and electrical power rails are mounted vertically along the side of the guideway. Emergency walkways, handrails and guideway lighting are provided for passenger safety if egress is required.

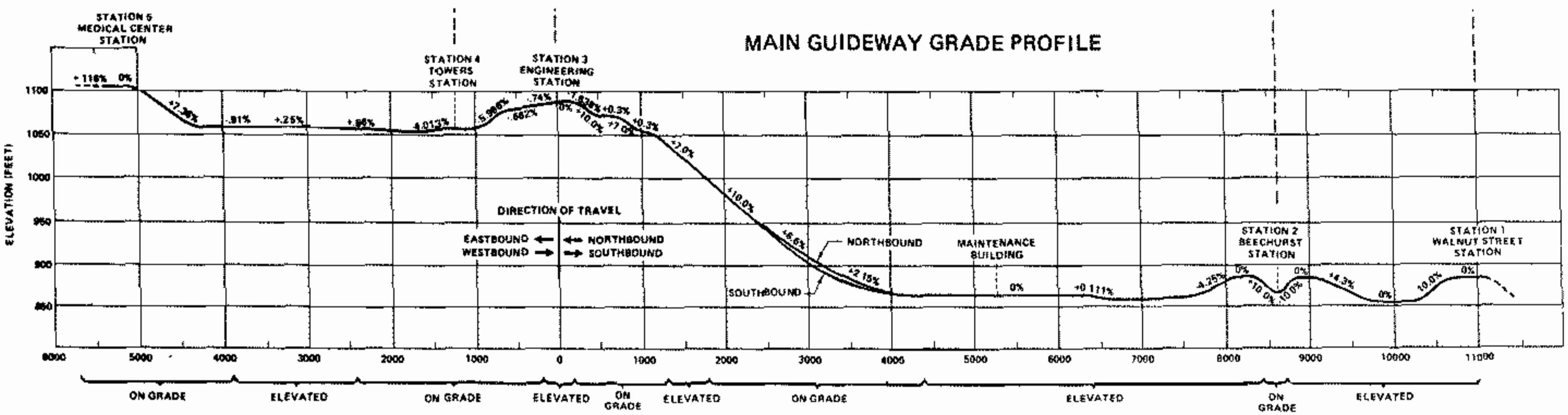
A total of 45,936 linear feet of guideway network is installed with grades up to 10%. Curves that are super-elevated as well as spiraled offer comfortable ride characteristics. Thirty-foot radius curves are used in station areas resulting in compact station design. Guideway speeds up to 30 miles per hour enable passengers to depart from downtown (Walnut Street Station) and arrive 10.5 minutes later at the Medical Center Station, a distance of 3.6 miles, any time of day or night. With an average speed of 14 miles per hour, a time savings up to 15 minutes is achieved.



TYPICAL GUIDEWAY CROSS SECTION (ELEVATED) – PHASE I



TYPICAL GUIDEWAY CROSS SECTION (ELEVATED) – PHASE II



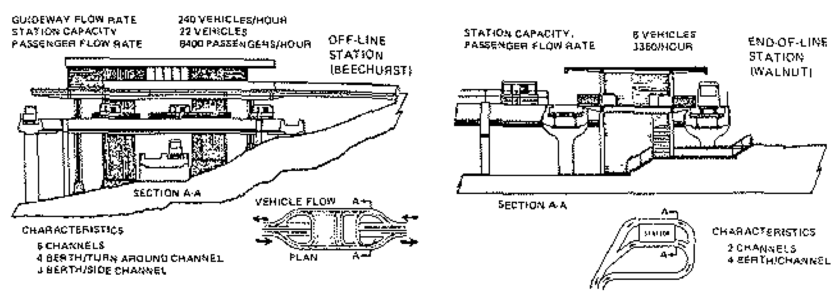
PASSENGER STATIONS

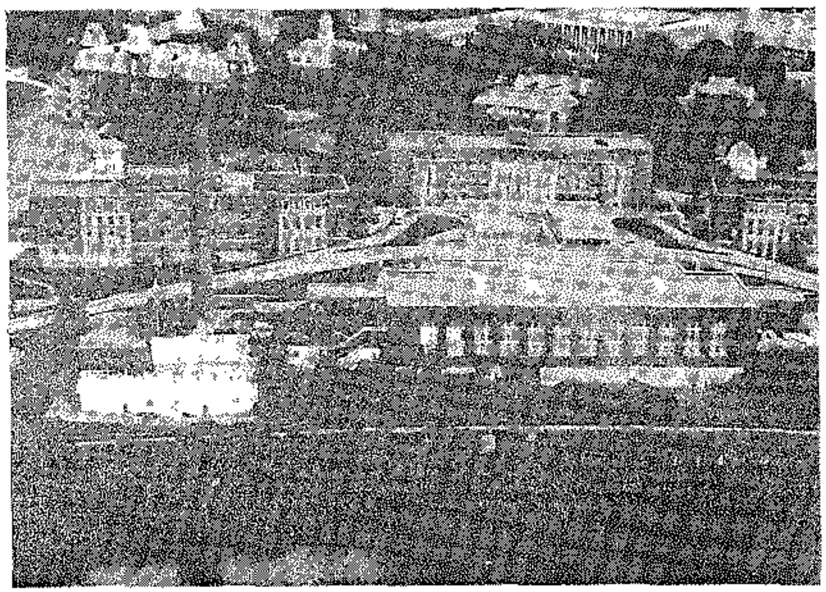
The station facilities provide access to the system, directing passengers to and from the vehicle loading areas. The facilities also house control and communications equipment required for controlling vehicle operations within the station area.

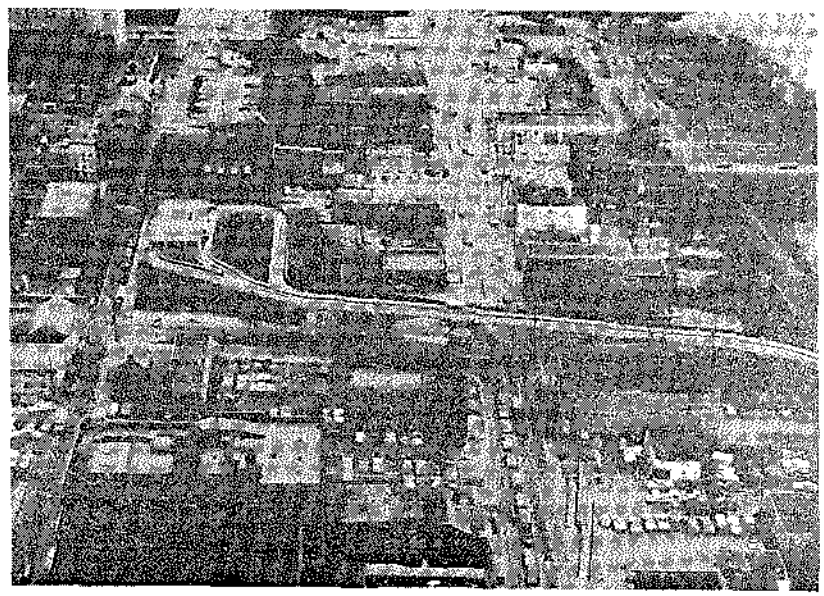
Two types of passenger stations are utilized, end-of-line and off-line. As the name indicates, end-of-line stations are located at the extremities of the system (Walnut and Medical Center). The off-line stations (Beechurst, Engineering & Towers), allow vehicles to either bypass or stop, providing passenger 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 PRT PASSENGER STATIONS







MAINTENANCE FACILITY

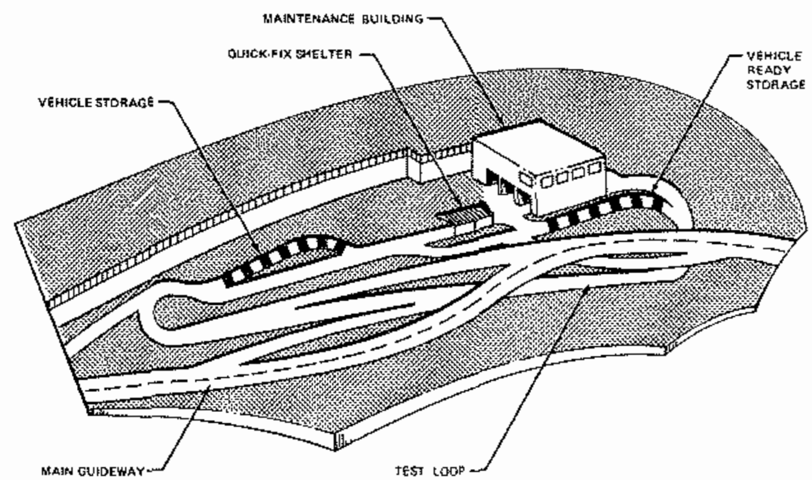
The maintenance facility provides for operation, maintenance, test, cleaning and storage of vehicles in the Morgantown PRT system. The facility consists of a maintenance building and associated guideway. The building houses maintenance shops, a central control room and the communications equipment and personnel necessary to operate and maintain the system. The associated maintenance guideway contains a test loop for post maintenance check.

The facility permits complete vehicle maintenance, repair, cleaning and test activities including: lubrication, detail inspection, vehicle repair, mechanical/electrical maintenance, functional testing, vehicle storage, etc. Repair of electronic and hydraulic/pneumatic equipment is accomplished in separate maintenance shops within the building. All vehicle subsystem components are maintained and repaired in the vehicle maintenance area with the exception of emergency repairs made at stations or on the guideway. Malfunctioning electrical and mechanical station equipment will be removed and transported to the maintenance facility for repair.

ENGINEERING MAINTENANCE FACILITY

This small facility is located at the engineering station. It contains an automatic car wash, a "quick-fix" location for minor vehicle repair and ECU repair shop. This facility has an associated guideway, providing 8 parking spaces for ready vehicles. The crew manning this facility responds to anomaly situations in the north end of the system, thus minimizing system impact (downtime).

MAINTENANCE FACILITY

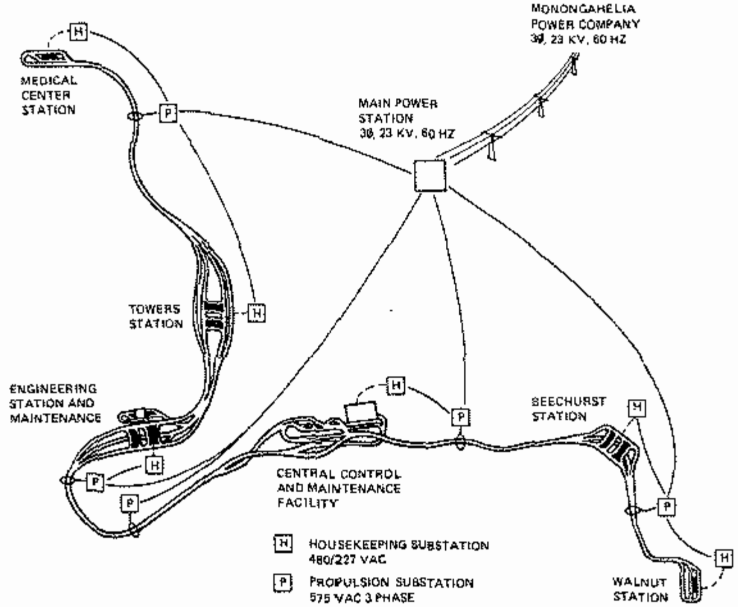


ELECTRICAL POWER DISTRIBUTION SYSTEM

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.



CONTROL AND COMMUNICATIONS SYSTEM

The primary purpose of the Control and Communications System (C&CS) is to provide automatic control, communications and monitoring of the movement of vehicles along the guideway.

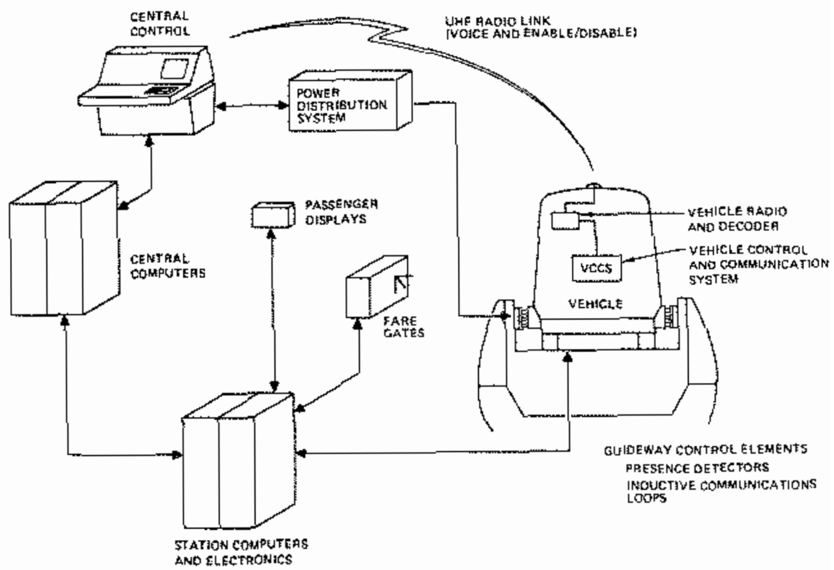
The C&CS controls vehicle movements on the main guideway, within each station area, at guideway and station interchanges and at the maintenance facilities. All communications, commands, station signals, and the management thereof are the responsibility of the C&CS which also provides dynamic graphics and other communications for passenger assistance.

The C&CS consists of dual central supervisory computers, dual station control computers, and the communication links between central control and each station. The C&CS also includes guideway and onboard vehicle control and communications equipment. The C&CS is divided into the following functional areas:

1) CCCS–Central Control and Communications Subsystem
2) SCCS–Station Control and Communications Subsystem
3) GCCS–Guideway Control and Communications Subsystem

The central computer carries out the automatic system management functions, receiving destination service requests from the stations and transmitting commands to the stations. Duplex communications with the stations is through asynchronous 2400 bit per second data lines. The interface between computers is through standard modems at both central control and the stations. The station computer receives inputs from the destination selection units and provides passenger instructions via the passenger advisory displays. The station computer manages vehicle movements and receives status information via the data handling unit. Speed commands, station stop commands, steering switch signals, and calibration signals are received by the vehicle through inductive communication loops buried in the guideway.

Redundant computers with automatic switch-over capability are provided at each computer location in the event of failure of a primary computer.



CENTRAL CONTROL AND COMMUNICATIONS CHARACTERISTICS

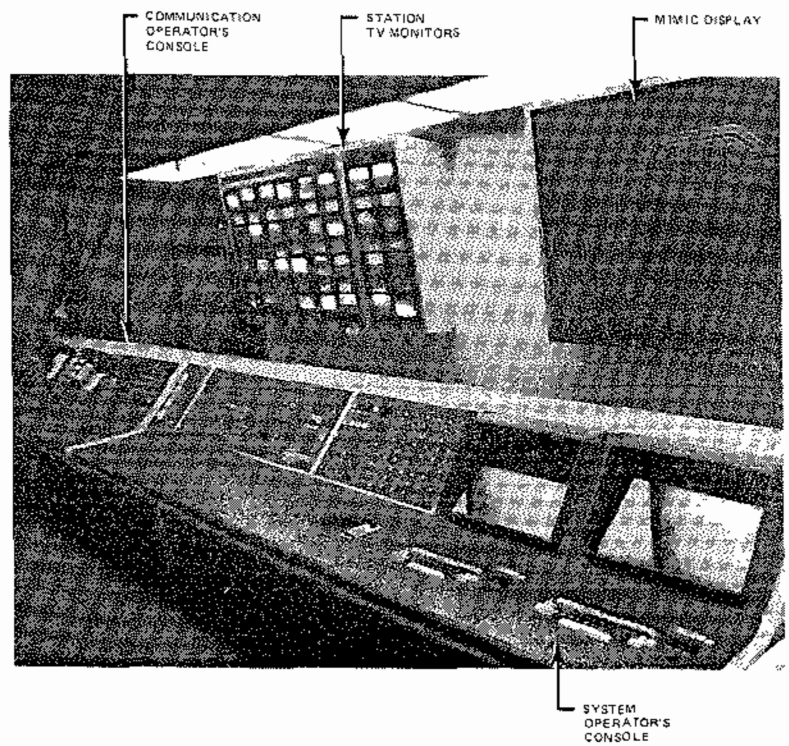
The central control equipment includes the central computers, peripherals, control console/displays, and communications equipment. The system operators, located at central control, monitor and exercise direct control over the system during conditions of initialization, failure, or shutdown. At all other 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.

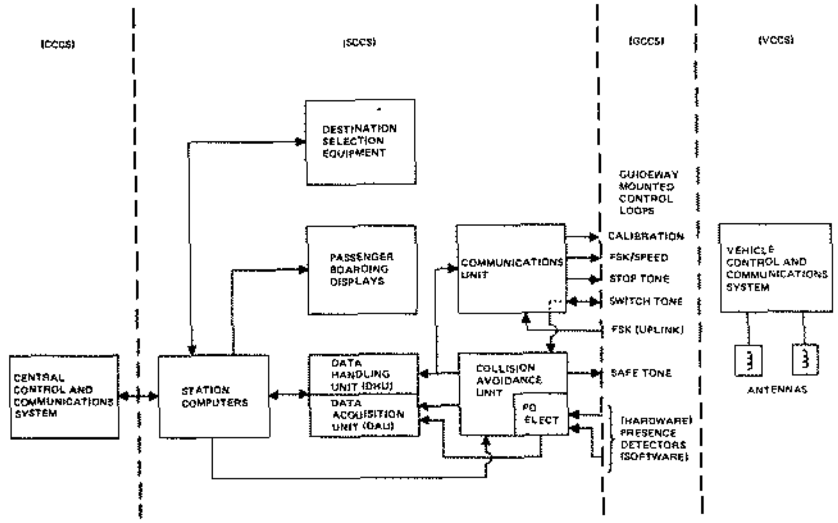
The central console equipment permits the operators to monitor and control the transit system. The consoles include display and control equipment, as well as communications equipment. The central control room also includes a mimic display which permits the operators to monitor the progress of each vehicle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

CENTRAL CONTROL ROOM



STATION CONTROL AND COMMUNICATIONS CHARACTERISTICS

The Station Control and Communications Subsystem (SCCS) controls vehicles and station operations in response to central supervisory commands. Communication of control signals to the vehicle is accomplished through inductive communication loops imbedded in the guideway. Communication is in the form of coded messages and fixed frequency control tones. The station computer controls vehicle switching, stopping, and door operations in the station. The station computer also operates the station dynamic boarding displays and responds to inputs from the passenger activated destination selection units. The computer in the maintenance facility performs the same types of functions as the station computer and also controls the test track and maintenance "ready" storage positions.



Each station has a Collision Avoidance System (CAS) which acts to prevent vehicle collisions in case the primary Vehicle Command and Control System should fail. The principal elements of CAS consist of redundant sensors which detect vehicle entry into a control block; inductive communication loops which transmit a safe tone to the vehicle in a block; and redundant control electronics (and software) which determine correct occupancy of the block. As a vehicle progresses along the guideway, the CAS control electronics removes safe tone from the block immediately behind. If a trailing vehicle violates the "OFF" block, it stops automatically by activation of emergency brakes. In each leg of a guideway merge area, one safe tone is normally off. This safe tone is turned on allowing a vehicle to proceed when vehicle priority at the merge is established by the CAS control electronics. At each switch point on the guideway, one safe tone is normally off. This safe tone is turned on allowing the vehicle to proceed when verification of proper switching action has been received.

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:

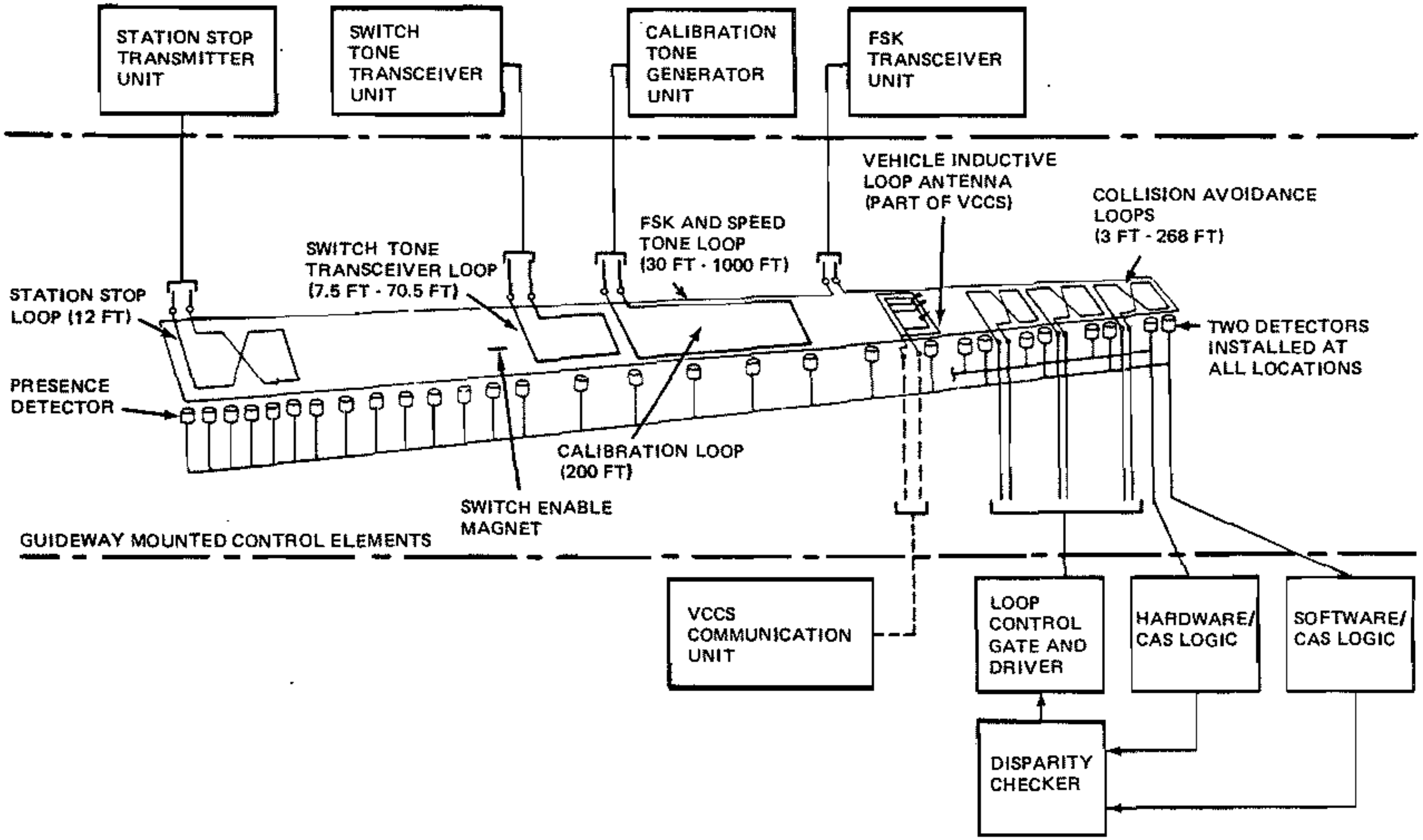
Station Stop Loops. The station stop tone transmitter generates a signal to decelerate and stop the vehicle ±6 inches from the center of the station platform unloading/loading gates. The vehicle enters the stop loop at 4 feet per second and is decelerated to a precise stop as brakes are applied.

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.

GUIDEWAY CONTROL AND COMMUNICATIONS CHARACTERISTICS



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).

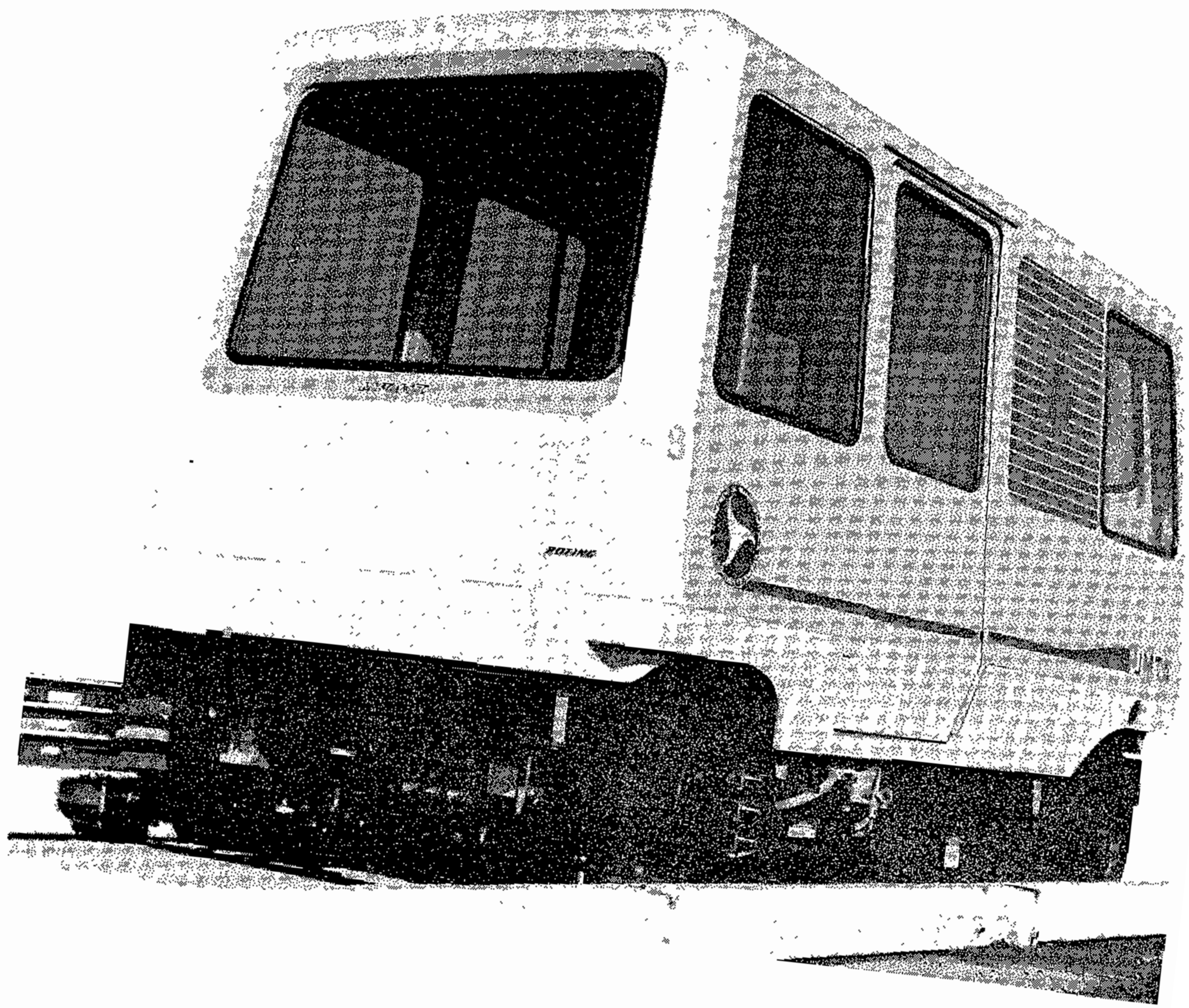
PHYSICAL CHARACTERISTICS

Length	15 Ft 6 In.
Height	8 Ft 9 In.
Width	6 Ft 8 In.
Weight	8,750 lbs Empty
Wheel Base	127 In.
Tread Width	62 In.
Accommodations	21 Passengers

PERFORMANCE CHARACTERISTICS

Control	Automatic-Remote
Propulsion	70 HP Electric Motor
Velocity	44 fps (30 mph) Max
Suspension	Air Bag-Automatic Leveling
Tires	Dual Chamber (1.5 In. Deflation)
Steering	Side Sensing (1.2 Sec Transfer)
Brakes	Redundant Dual-Piston Caliper
Conveniences	Environmentally Controlled, Quiet, Comfortable, Safe
Turning	30 Foot Radius

MORGANTOWN PRT VEHICLE



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.

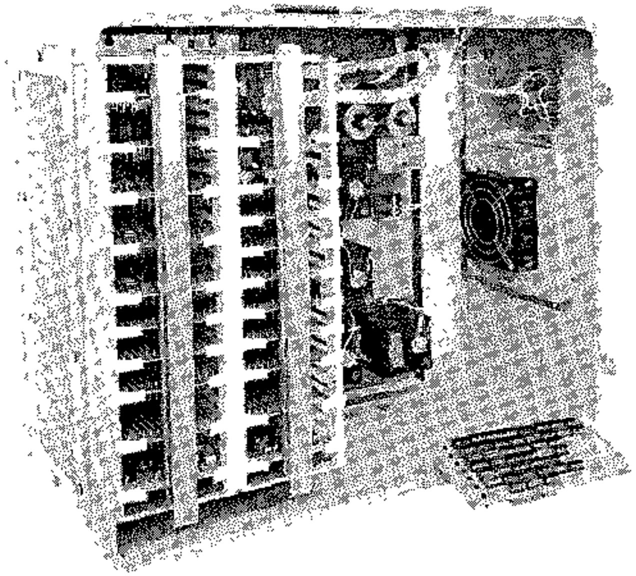
Data Handling Unit—The data handling unit (DHU) receives conditioned logic signals from the communications unit. The DHU decodes the signals and produces logical instruction and response sequences unique to the input. This unit will initiate logic commands and messages when vehicle conditions change.

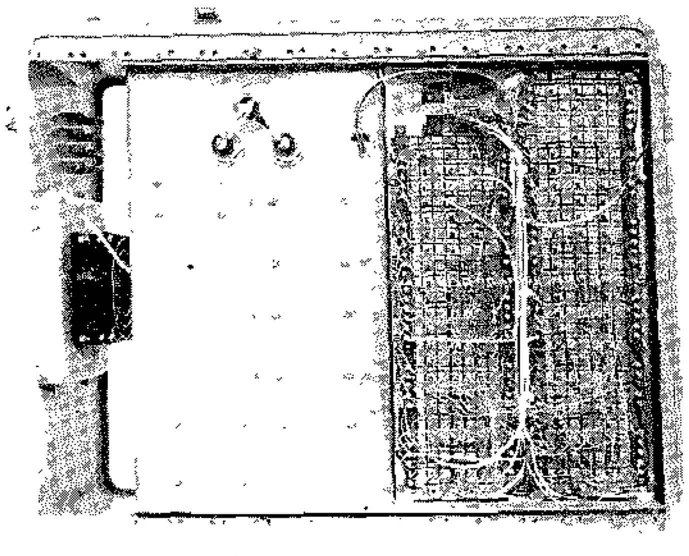
Control Unit—The control unit reacts to signals from the vehicle and the DHU to control the following vehicle functions:

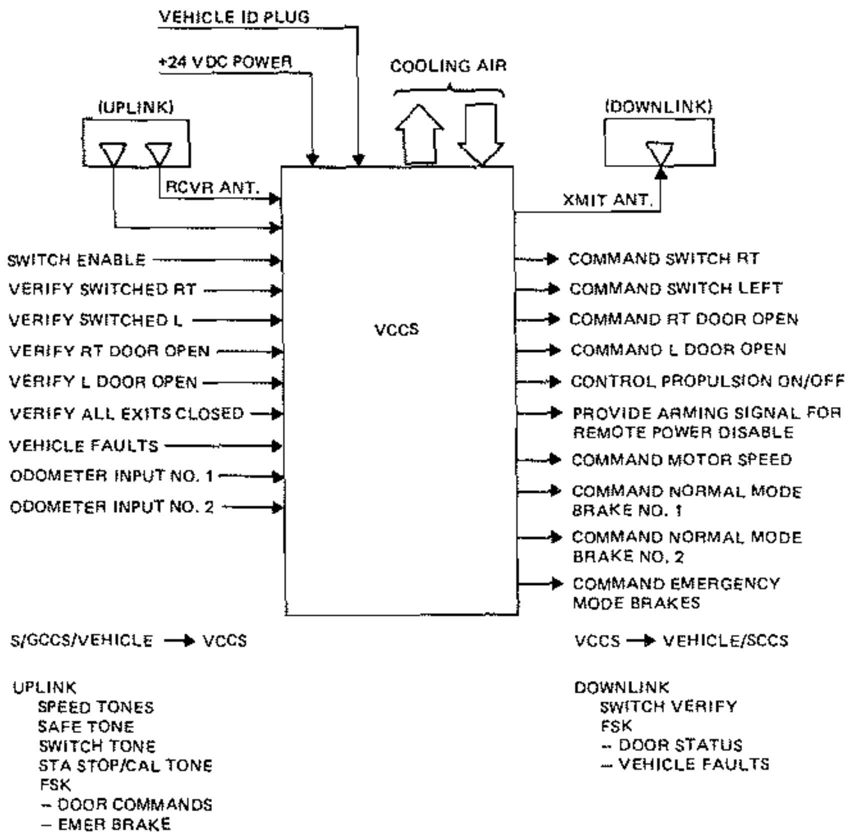
1) Brakes
2) Steering
3) Doors
4) Propulsion

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

VEHICLE CONTROL AND COMMUNICATIONS CHARACTERISTICS

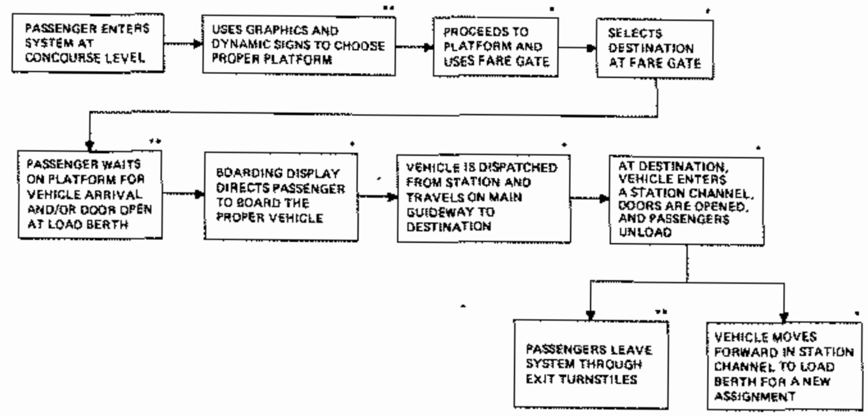






SYSTEM OPERATIONAL LOGIC

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 CONTROL/TV SURVEILLANCE

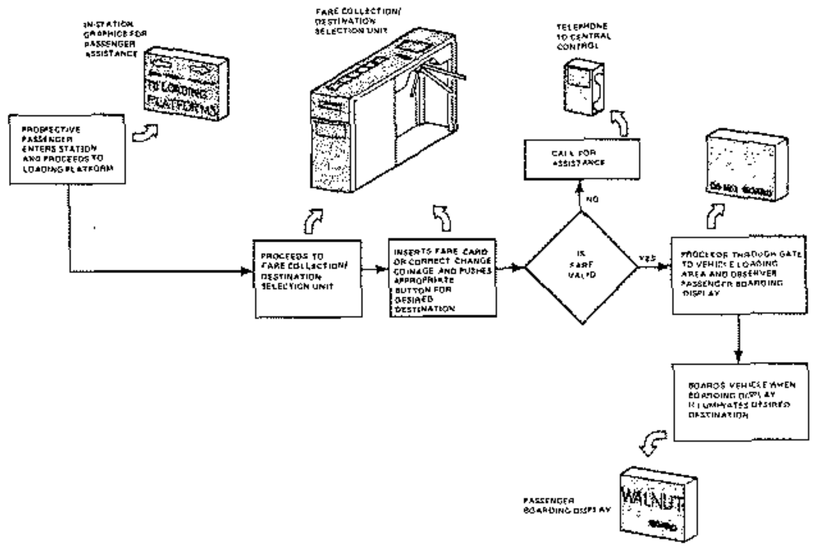
PASSENGER DESTINATION REQUEST

At single platform stations, i.e., Walnut Street and Medical Center, a passenger enters the station on a concourse level and proceeds to a platform level. At Beechurst, Towers and Engineering stations, which have two platforms, a lighted Platform Assignment Display on the concourse level directs the passenger to the proper platform to obtain service to his desired destination. The Platform Assignment Display is controlled by the system operator.

Use of a coded magnetic card or correct change coins are required at the Fare Collection Unit for passage through the entrance gate. A multi-trip card is issued periodically to students, or may be purchased from West Virginia University. The Fare Collection Unit is initialized periodically to recognize valid coded cards and to reject obsolete cards. A valid fare enables the Destination Selection Unit and the entrance gate.

After the passenger has inserted his card or fare into the Fare Collection Unit, he pushes the button for his desired destination. A legend lights to acknowledge the selection. The passenger proceeds through the gate to the vehicle loading area. The Fare Collection and Destination Selection Unit is reset when the passenger proceeds through the entrance gate.

Station computer response to the destination request depends on the operating mode. During the scheduled mode the requests are forwarded to central for off-line improvement of the schedule. The passenger boards the next vehicle scheduled to his destination. During the demand mode the station computer begins a sequence of searches. The computer looks for an empty vehicle currently in the station loading position. If a vehicle is not available, the computer looks for an empty vehicle in the station and directs it to the loading position. Otherwise, the computer finds the nearest available vehicle and directs it to the loading position.



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. Nominally, 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.

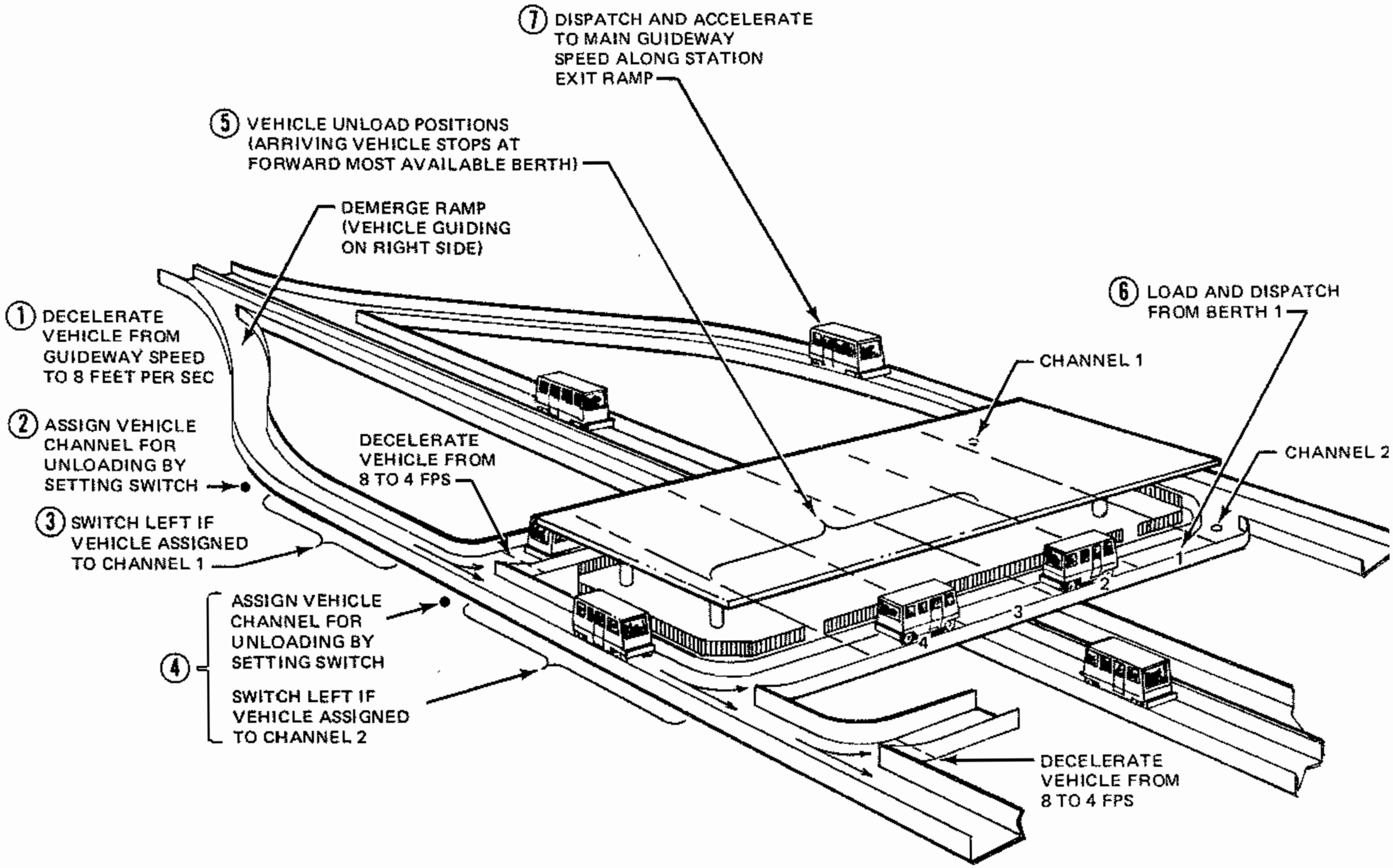
After the switching region is cleared, the vehicle is decelerated to the 4 ft/sec velocity from which a vehicle can execute a precise stop (±6 inch accuracy). Stopping deceleration is controlled by an on-board speed profile. The vehicle initiates the precise stop in response to an energized guideway 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/sec^2 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.

IN-STATION VEHICLE MANAGEMENT



VEHICLES ON MAIN GUIDEWAY

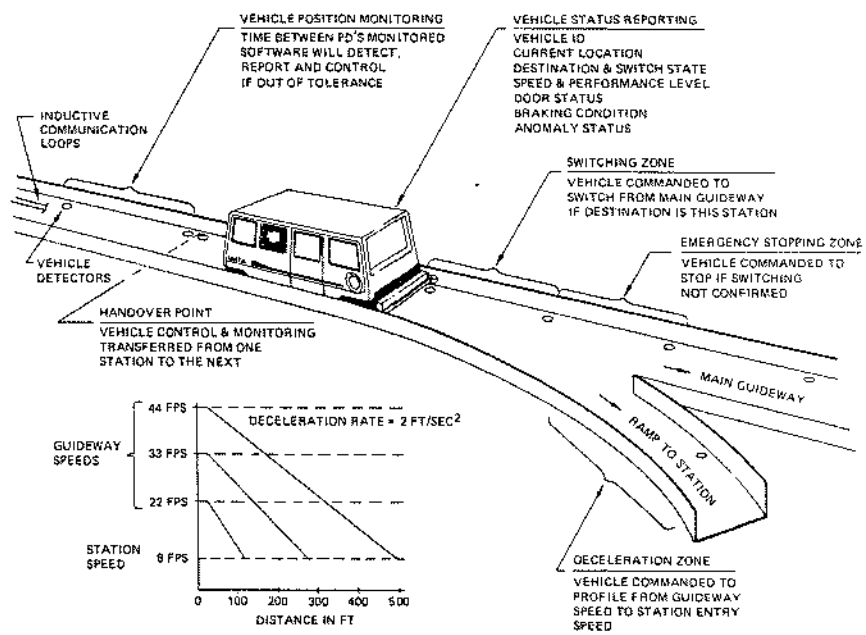
Vehicle progress on the guideway is monitored by the station control computer by observing the time of actuation of presence detectors. Vehicle status is also monitored by station control. A vehicle status report includes: 1) vehicle ID, 2) current location, 3) current destination and switch condition, 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/sec^2 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.

GUIDEWAY CONTROL AND MONITORING



SYSTEM OPERATIONS AND MAINTENANCE

System operations and maintenance activities are performed at the two maintenance facilities. A team of highly trained engineers and technicians operates and maintains the system to the highest standards of safety and passenger service.

The organizational concept for this team is shown below along with the functional allocation of their duties.

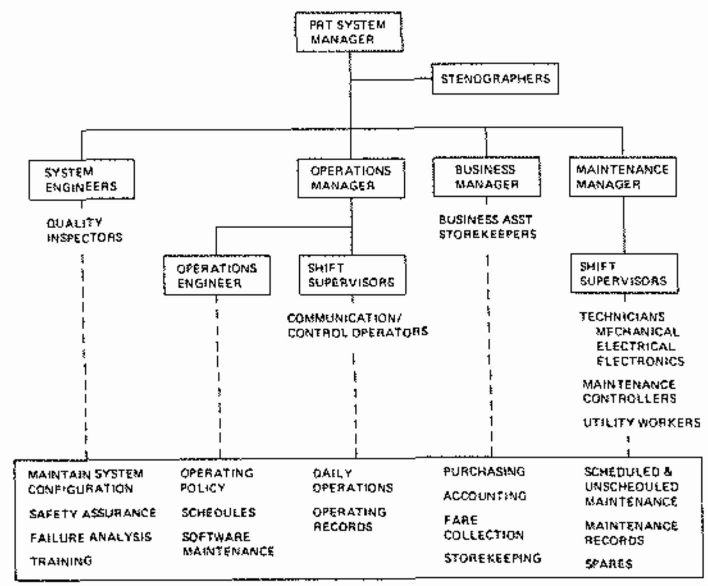
The System engineers are responsible for overall cognizance of system operational readiness, safety, and quality inspection.

The Operations crew provides daily operations through teams of two operators and one shift supervisor who constantly monitor system performance and manage the system's recovery from anomalous events.

The Maintenance crew performs scheduled maintenance on all system elements and provides the troubleshooting and repair function for unexpected failures (unscheduled maintenance).

The Business Manager's office provides the accounting and purchasing functions, as well as fare collection, and spare parts storekeeping.

OPERATIONS AND MAINTENANCE ORGANIZATIONAL CONCEPT



FUNCTIONAL ALLOCATION

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.

SYSTEM SAFETY FEATURES

INDEPENDENT, CHECKED REDUNDANT, COLLISION AVOIDANCE SYSTEM (CAS)
- SOFTWARE CAS
- HARDWARE CAS

} AGREE ~ VEHICLES PROCEED } DISAGREE ~ VEHICLES STOP

REDUNDANT VEHICLE CONTROL AND BRAKING ELEMENTS

AUTOMATIC AND MANUAL POWER TRIP FOR GUIDEWAY SAFETY
- DOORS OPEN ON GUIDEWAY CAUSES IMMEDIATE POWER TRIP

VEHICLE SWITCHING PROTECTION
- ON-BOARD CHECK
- GUIDEWAY CONTROL CHECK

VEHICLE OR GUIDEWAY CONTROL MALFUNCTIONS CAUSE VEHICLE TO STOP
- RUNAWAY VEHICLE
- PROPULSION SYSTEM DISCREPANCIES
- HYDRAULIC AND ELECTRICAL DISCREPANCIES
- LOSS OF COMMUNICATION
- LOSS OF COMPUTER CONTROL OR STATION ELECTRONICS

PART II SYSTEM DESCRIPTION

Structures and Power Distribution System (S&PDS)

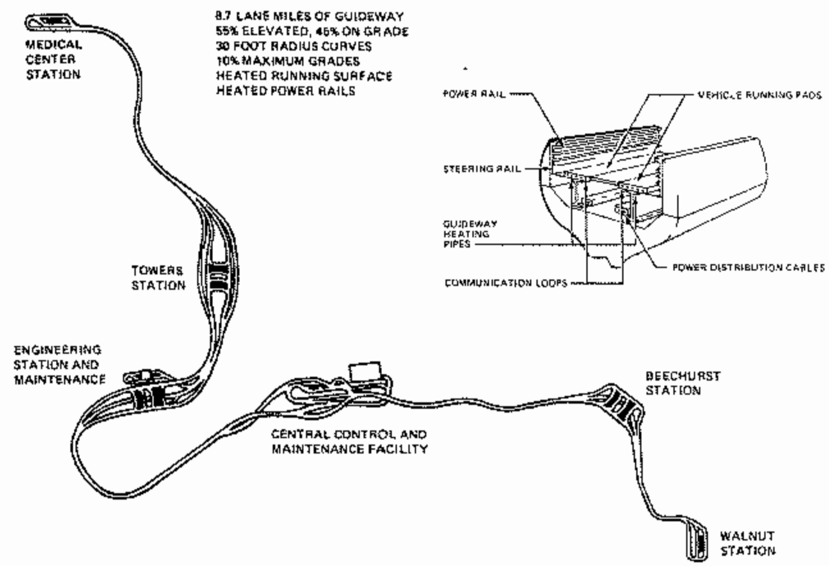
GUIDEWAY CHARACTERISTICS

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 inthe 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.

GUIDEWAY NETWORK

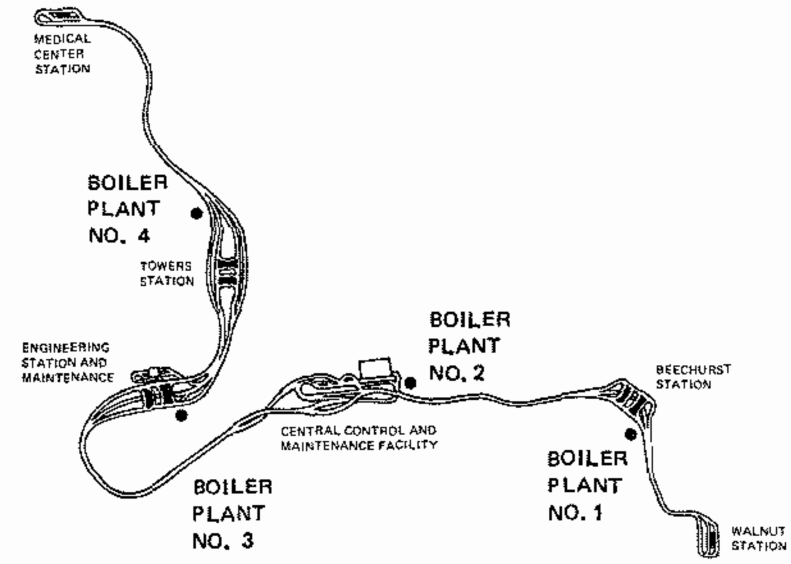


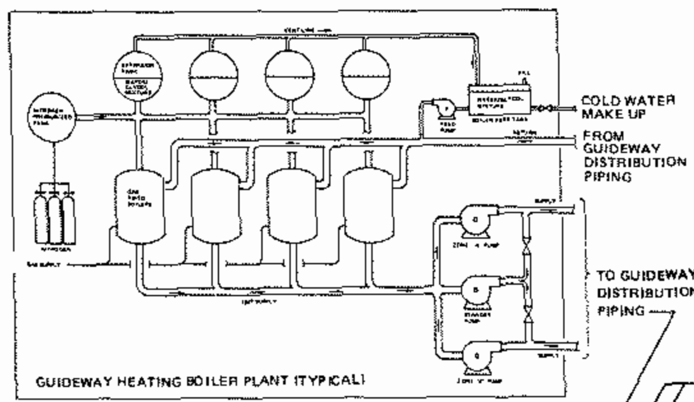
GUIDEWAY HEATING SYSTEM

The guideway has pipes embedded within the concrete where hot water/glycol can be circulated to melt ice or snow to make the PRT system an all weather operation. On-grade sections of the guideway have heating pipes buried across the entire width of the guideway and elevated guideway sections have heating pipes buried in the two running pads. The guideway is divided into five heating zones serviced by three boiler plants. Each boiler plant services only the zone(s) in its area of control and is not manifolded into adjacent zones.

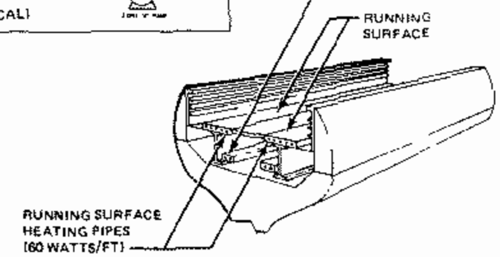
Each boiler plant is different in the number and capacity of the boilers, pumps, and expansion tanks it contains but the function of each plan is identical. Temperature transfer is accomplished by a 50 percent water/glycol solution pumped to the guideway at approximately 180°F and over 100 psig. Pump outlet temperature is maintained by an automatic lead-lag sequence control system. This system automatically adds or subtracts the number of boilers required to meet the load conditions and automatically modulates the boilers through two firing rates. Each boiler is natural gas fired and their sequencing can be altered to rotate their use in the lead-lag system. Normally one pump-motor combination is in a standby mode that can be substituted for either of the required pumps as necessary. Expansion tanks pressurized with nitrogen maintain a constant head on the boilers and an automatic boiler feed system maintains an acceptable fluid level in the expansion tanks.

The guideway heating system is under control of the system operator and he must turn each boiler plant "ON" or "OFF" from his console at Central Control. Once turned on, the boiler plant operation is automatic and normal operation will be indicated to Central Control unless a malfunction exists. An audible alarm will be sounded at Central Control if a boiler doesn't start when required because the water/glycol level is low, or a fire exists in the boiler plant. The system operator must then take appropriate action.





GUIDEWAY HEATING BOILER PLANT (TYPICAL)



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).

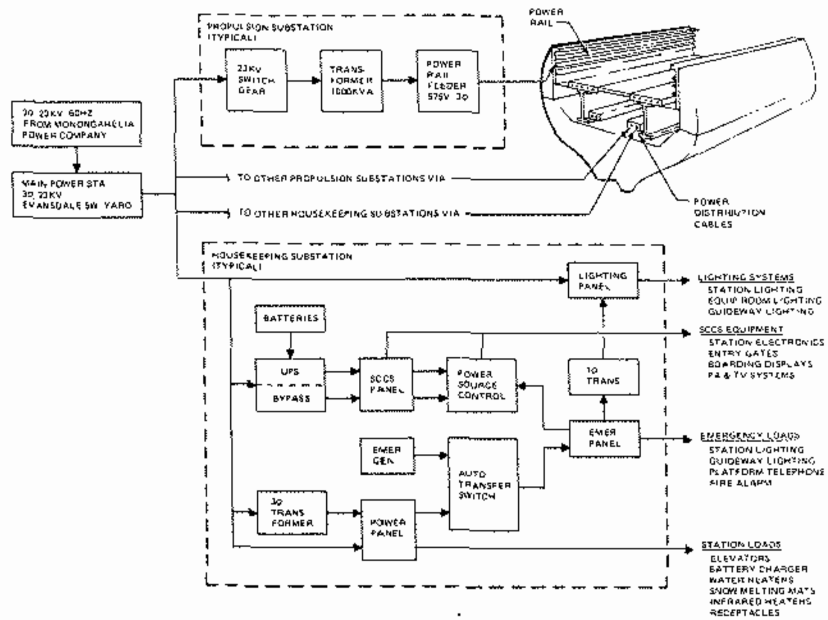
Five 1000kVA, three-phase transformers provide the power for the rails. The switch gear is equipped with electrically operated circuit breakers which are controlled from the System Operator Control Console located in the Central Control Room.

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.

POWER DISTRIBUTION AND FUNCTIONS



PROPULSION POWER DISTRIBUTION

Power rails along the guideway distribute the three-phase, 575 VAC, 60-Hz power to the vehicles. The rails are compatible with the maximum total current demand of the expected vehicles between propulsion substations.

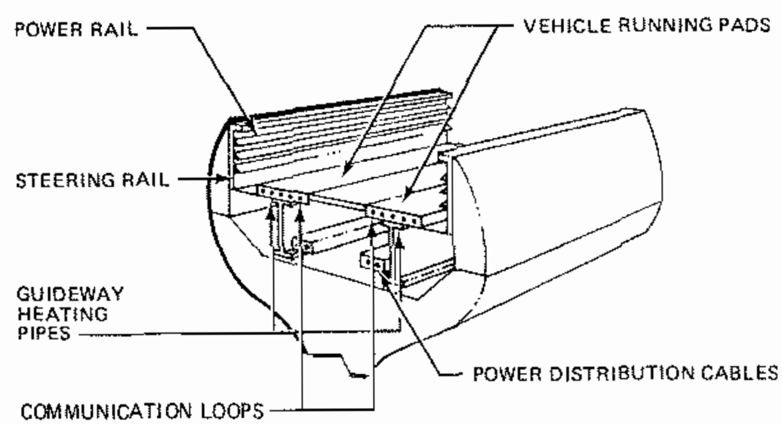
The power rails are securely anchored to the guideway. Rail joints every 90 feet allow thermal expansion of the rails. Electrical continuity is maintained across the expansion joints to avoid arcing of the collector brushes.

The guideway power rails are connected to the propulsion power substation transformer secondaries through remotely controlled circuit breakers operated from the control center. Independent circuit breakers are provided so that the main guideway on either side of a passenger station can be operated independently, and that the station guideways and the maintenance facility guideway can be removed from the main guideway power for maintenance and fault correction. The 575 VAC bus at each propulsion power substation is connected to the transformer secondary by a circuit breaker equipped with overcurrent trips, undervoltage trips, and reverse power sensing. This circuit breaker protects the propulsion power system from internal transformer faults fed from the other propulsion power substation transformers via the guideway power rails.

There are fourteen guideway segments which are automatically controlled by the central computer to power down the guideway. This is done if a vehicle is stopped on the guideway and a vehicle door is opened. Automatic power down is provided to protect passengers on the guideway. Power up can be accomplished manually, and only when the software senses that there are no doors open.

The 575 VAC power is distributed by aluminum conductor bars attached to the guideway wayside structure. A smooth stainless steel surface is provided to reduce brush wear and arcing. The power rail is enclosed in a polyvinylchloride cover (except for the brush conducting surface) and fastened to the guideway structure with glass-fitted polyester hangers. The rails have a resistance heater wire installed which will provide 15 watts per foot per phase which will provide an ice free rail for most operating temperatures. These heater wires are controlled through wayside switch boxes which are remotely switched on and off from Central Control. They are powered from the 575 VAC power rail power. Merge ramps are attached to the rails which guide the individual collector brushes during merge or demerge.

Vehicle power is picked up from the power rail by a passive run-on run-off power collector mounted on the vehicle front wheel spindle which rides on the power rail as the vehicle travels along the guideway. The power collector interfaces with the power rails and power is transferred by sintered carbon/copper brushes, one for each phase, that contact the steel strip in the aluminum power rail. The brushes are sprung so that they contour to the rails and maintain a constant force against the rails. The load of the collector assembly against the rails is approximately 7 pounds per rail. Each brush is equipped with a 15 watt, 110 volt heater for winter operation.



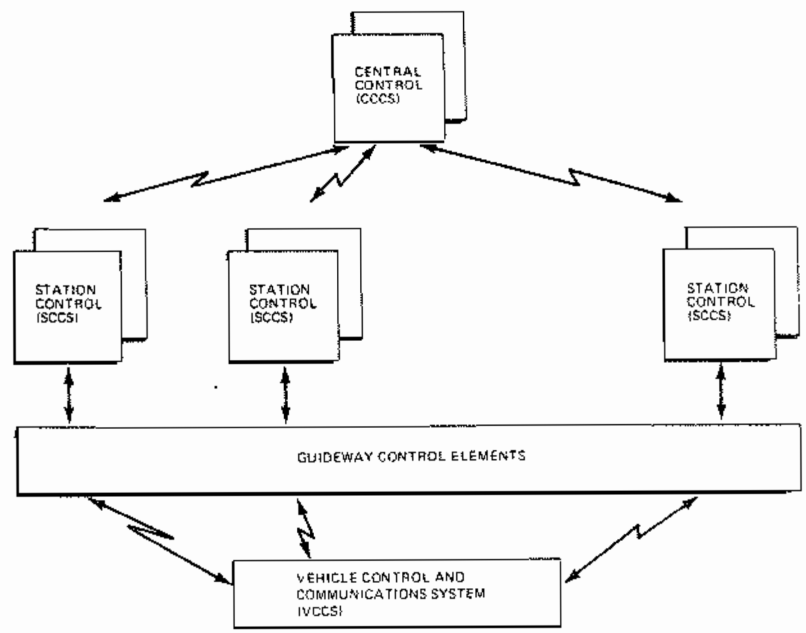
Control and Communications System (C&CS)

CONTROL AND COMMUNICATIONS SYSTEM CONFIGURATION

The primary purpose of the C&CS is to automatically control and monitor the Morgantown Personal Rapid Transit (M-PRT) system. The C&CS controls vehicle movements in each passenger station, along the main guideway, and at the maintenance facility, and provides graphics and other communications for passengers using the system. All communications, commands, and station signals, and their management, are the responsibility of the C&CS.

The C&CS automatically manages and controls the movement of vehicles operating between the five passenger stations, (Towers, Medical Center, Engineering, Beechurst, Walnut) and the maintenance facility in accordance with either a predetermined schedule or passenger-activated demand. This includes controlling and monitoring vehicle movements in the station areas, on the acceleration and deceleration ramps, and throughout the interconnecting guideway.

The C&CS controls the position of each vehicle by a synchronous point follower system. The point follower system consists of moving slots, and a fixed time base circulating in the central control and station control computers. The slots are established, a vehicle is assigned a slot, and the vehicle maintains the position in the slot during its trip. The vehicle is dispatched by the station computer in time to merge into an open slot. An onboard vehicle clock will maintain an accurate reference for the vehicle, to compare distance traveled and speed, as measured by an odometer in the vehicle. Periodic calibration loops will update any bias or random odometer errors. The slots are allocated by the central computer and they are monitored by the station computers; slot monitoring includes comparing the time a vehicle arrives at a presence detector (PD) with the expected time of arrival as determined by the station computer. Out-of-tolerance vehicle position is displayed for the system operator on his console.



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.

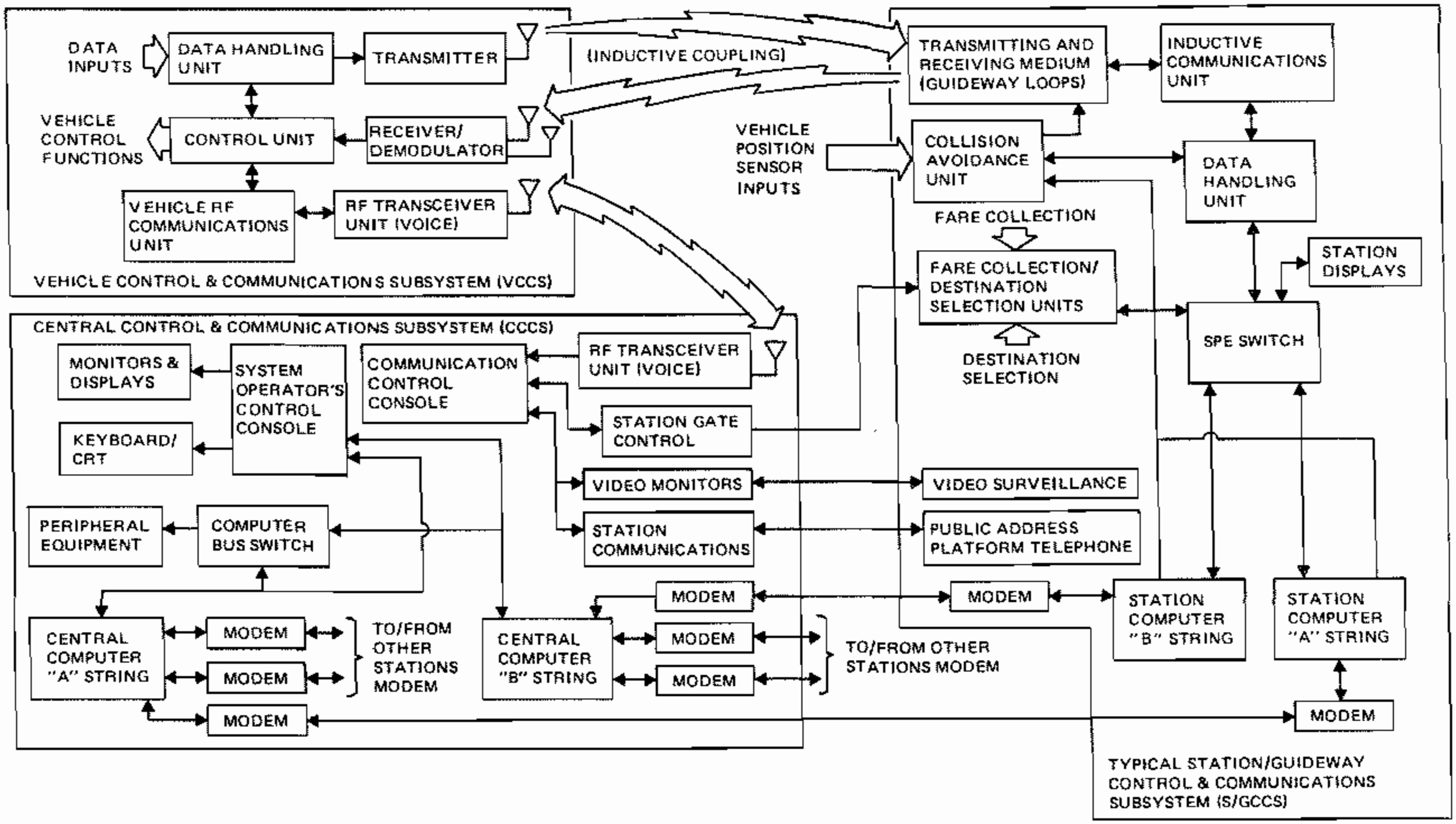
The C&CS software subsystem uses real-time operational programs to manage and control a fleet of vehicles between the five passenger stations and the maintenance facility. The software subsystem is modular and is readily adaptable to an expansion of the system.

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 FUNCTIONAL DIAGRAM



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.

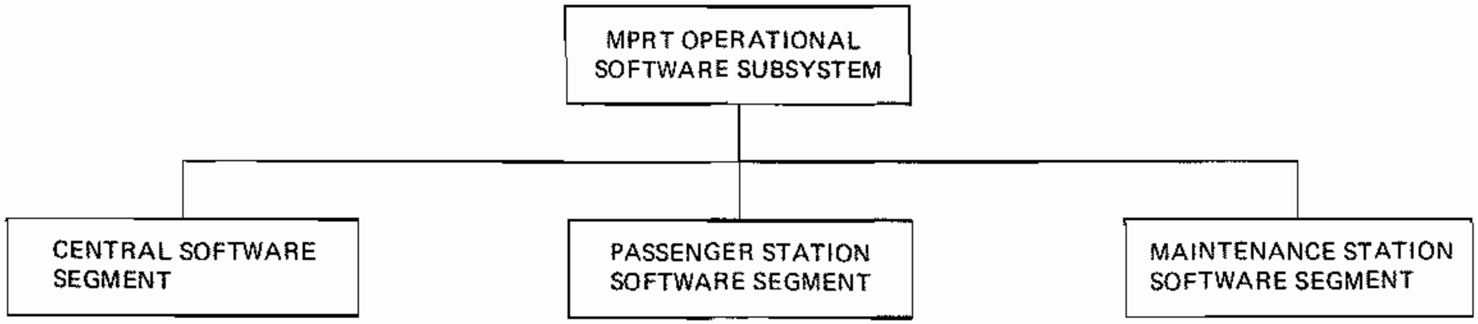
System Startup and Control. The software provides for loading of the computer network, for setting vehicle locations, and for initialization of variables to enable startup of the system. The software also controls the configuration of system elements, displays system status to the operator, processes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

MPRT OPERATIONAL SOFTWARE SUBSYSTEM ORGANIZATION



CENTRAL SOFTWARE SEGMENT

EXEC–EXECUTIVE PROGRAM
- CONFIGURATION MANAGEMENT
- INPUT/OUTPUT
- EXECUTIVE SERVICES

CAP – CENTRAL APPLICATIONS PROGRAM
- COMMAND PROCESSING
- DATA COLLECTION, RECORDING, & DISPLAY
- COMMUNICATIONS PROCESSING
- OPERATIONS MANAGEMENT
- OPERATIONS MONITORING

PASSENGER STATION SOFTWARE SEGMENT

EXEC–EXECUTIVE PROGRAM
- CONFIGURATION MANAGEMENT
- INPUT/OUTPUT
- EXECUTIVE SERVICES

PSAP – PASSENGER STATION APPLICATIONS PROGRAM
- COMMAND PROCESSING
- DATA COLLECTION
- COMMUNICATIONS PROCESSING
- STATION MANAGEMENT
- STATION MONITORING
- VEHICLE & GUIDEWAY CONTROL

MAINTENANCE STATION SOFTWARE SEGMENT

EXEC–EXECUTIVE PROGRAM
- CONFIGURATION MANAGEMENT
- INPUT/OUTPUT
- EXECUTIVE SERVICES

MSAP – MAINTENANCE STATION APPLICATIONS PROGRAM
- COMMAND PROCESSING
- DATA COLLECTION
- COMMUNICATIONS PROCESSING
- STATION MANAGEMENT
- STATION MONITORING
- VEHICLE & GUIDEWAY CONTROL

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.

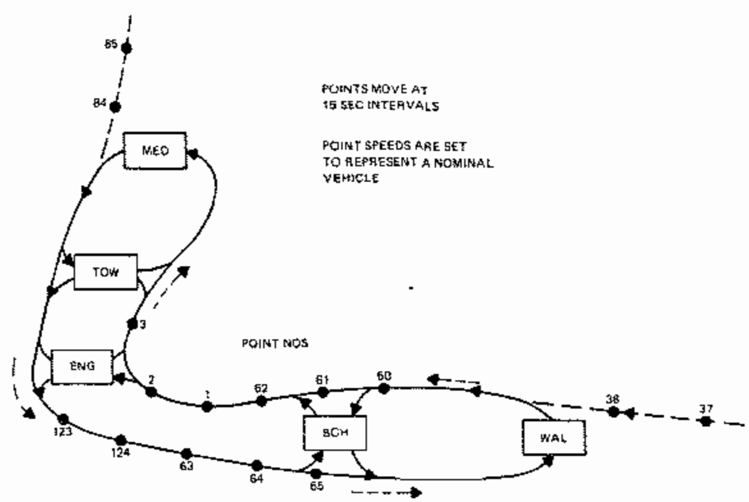
- SYNCHRONOUS VEHICLE CONTROL
- VEHICLE DISPATCH LOGIC
- VEHICLE ARRIVAL LOGIC
- CHANNEL MANANGEMENT
- DEMAND MODE
- SCHEDULE MODE
- TRANSITION ALGORITHM
- ANOMALY MANAGEMENT

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.

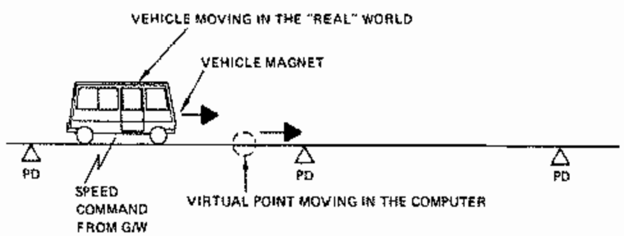
VIRTUAL POINT MOVEMENT



POINT NUMBERS ARE RECYCLED OR WRAPPED AROUND EACH SIDE

VEHICLE TRACKING

Vehicle tracking is accomplished by monitoring the actual position of the vehicle relative to its assigned moving or "virtual" point in the computer. Guideway mounted presence detectors (PD's) are used to track the motion of each vehicle in the system. Vehicles are reported "ahead of point" or "behind point" when they drift more than 1.1 seconds ahead or behind their assigned points. Vehicles are declared "runaway" if the time between successive PD hits becomes smaller than a fixed criteria. Such vehicles are stopped by application of emergency brakes and rail power dump by the system operator.



IF THE VEHICLE HITS A PD AFTER THE VIRTUAL POINT REACHES THE SAME PD, THE VEHICLE IS "BEHIND POINT"

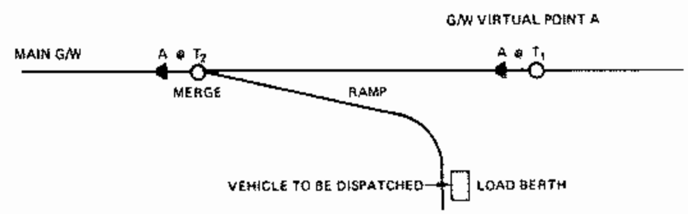
VICE VERSA FOR "AHEAD OF POINT"

ONLY ONE VEHICLE CAN OCCUPY A GIVEN POINT AT ANY GIVEN TIME.

VEHICLE DISPATCH LOGIC

In order to meet its assigned virtual point each vehicle leaving a station is commanded to start at a precise time calculated to accomplish a successful merge with this assigned point on the main guideway.

Central assigns each vehicle an available virtual point. The assigned point must be unoccupied or expected to be unoccupied at the merge. If the point is occupied but the occupant is expected to switch off the guideway before the merge, the point may be assigned to the departing vehicle. A check is made to be sure the occupying vehicle actually did switch off the guideway before allowing the merging vehicle to clear the station exit ramp.



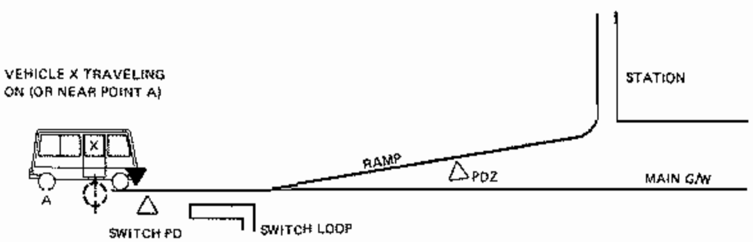
VEHICLES ARE ASSIGNED AN 'AVAILABLE' VIRTUAL POINT

'AVAILABLE' MEANS FAR ENOUGH BACK FOR A SUCCESSFUL MERGE & UNOCCUPIED, OR EXPECTED UNOCCUPIED AT T_2.

VEHICLES ARE RELEASED AT TIME T_1, SUCH THAT THE TRIP FROM THE LOAD BERTH TO MERGE TAKES THE TIME $T_2 - T_1$

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.



VEHICLE X HITS SWITCH PD

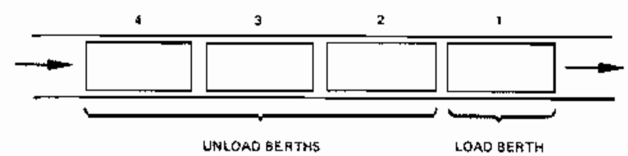
IF THIS STATION IS PROPER DESTINATION FOR VEHICLE X, SET SWITCH 'TOWARD' THE RAMP. IF NOT SET SWITCH 'TOWARD' THE MAIN G/W

WHEN VEHICLE HITS PDZ, CLEAR VIRTUAL POINT A (I.E. POINT A ON G/W IS UNOCCUPIED)

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.

CHANNEL ASSIGNMENT BASED ON CHANNEL OCCUPANCY AND OPERATING MODE



ARRIVING VEHICLES STOP IN FORWARDMOST AVAILABLE UNLOAD BERTH

VEHICLES MOVE FORWARD TO LOAD BERTH AS BERTHS AHEAD BECOME CLEAR

ONE DOOR CYCLE IS PERFORMED IN AN UNLOAD BERTH, AND ONE IN THE LOAD BERTH (UNLESS THE VEHICLE IS ASSIGNED TO MAINTENANCE)

DEMAND MODE ALGORITHM

The Phase II demand mode has been designed to provide the best possible passenger service at all demand levels in terms of average and maximum passenger wait time. It provides efficient trip management through an optional vehicle redistribution algorithm, thereby reducing total fleet miles to serve a particular demand level. Demand mode also provides operational flexibility during winter operations, unique demand situations, and maximizes performance during anomalies when portions of the system are temporarily shut down.

MAJOR FEATURES

COVERS WIDE DEMAND RANGE THROUGH VARIABLE CONTROL PARAMETERS

CONTROL PARAMETERS

- MAXIMUM WAIT ~ SET FROM 10 TO 600 SECONDS BY OPERATOR DEPENDING ON SYSTEM DEMAND LEVEL AND WEATHER. PREVENTS LONG WAITS BY INDIVIDUAL PASSENGERS ON LOW DEMAND ORIGIN/DESTINATION PAIRS
- VEHICLE LOADING ~ SET FROM 1 TO 21 PASSENGERS BY OPERATOR DEPENDING ON SYSTEM DEMAND LEVEL, AVAILABLE FLEET SIZE. AND DESIRED LOAD FACTOR/TRIP EFFICIENCY

VEHICLE REDISTRIBUTION MANAGEMENT

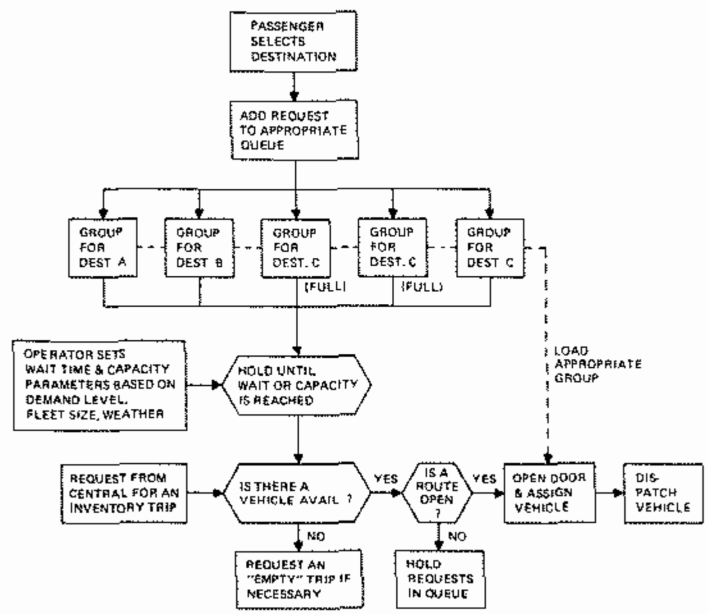
- VEHICLES ARE DISTRIBUTED BASED ON NUMBER OF PASSENGERS WAITING AND WAITING TIME ALL STATION PLATFORMS GIVEN A MINIMUM INVENTORY GOAL DURING LOW DEMAND PERIODS.

PROVIDES PARTIAL SYSTEM SERVICE DURING ANOMALIES

DEMAND MODE MACRO LOGIC

This chart shows the overall logic used in demand mode. Vehicles are assigned to groups of passengers based on the number of people waiting for a particular destination, and the length of time they have been waiting. The system operator has control over two parameters, and by setting them appropriately the operator can control average and maximum passenger wait time, vehicle occupancy or load factor, and fleet mileage required to serve the demand. These parameters are the group size at which a vehicle will be assigned. This is called the "vehicle capacity" and the wait time at which a vehicle will be assigned. Thus a group, large enough to fill a vehicle, will get immediate service, for which a smaller group will have to wait until the wait time has exceeded its preset value. This allows more passengers to enter the system and use the same vehicle. Even a single passenger will get good service, however, since it is anticipated that the wait time parameter will not be set in excess of 5 minutes.

DEMAND MODE MACRO LOGIC



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.

PASSENGER ACTIVATED VEHICLE REDISTRIBUTION REQUEST

– IF NO VEHICLE AVAILABLE WHEN PASSENGER REQUEST BECOMES ELIGIBLE.

1) CHECK ON-WAY & ASSIGNED VEHICLES FOR POSSIBLE CANDIDATE

2) IF NONE, REQUEST VEHICLE

3) VEHICLE REDISTRIBUTION TRIPS TAKE ANY WAITING PASSENGERS REGARDLESS OF THEIR 'READY' STATUS

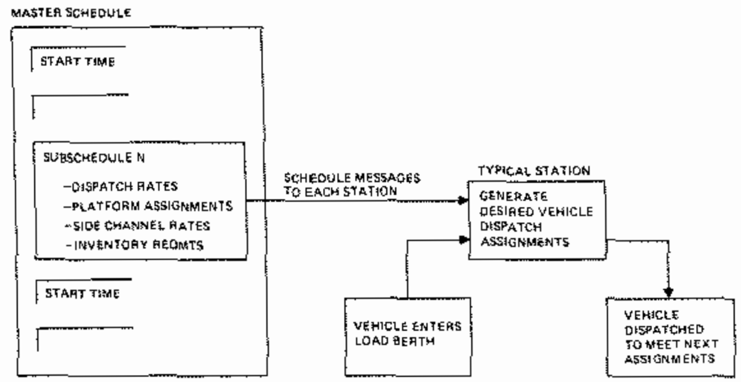
STATION MINIMUM INVENTORY VEHICLE REQUEST

–IF STATION PLATFORM INVENTORY FALLS BELOW 2 VEHICLES REQUEST VEHICLE

–PROVIDES GUARANTEED VEHICLE AVAILABILITY 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.



SCHEDULES MUST BE BALANCED

TRANSITION ALGORITHM

The Transition Algorithm redistributes vehicles in the system in response to a change of master schedule or a transition from demand to schedule mode. The algorithm works as follows:

1) Station* inventory requirements from 1st subschedule are prorated if necessary

2) Station* surpluses/deficits are calculated, (station inventories include "in station" + "on way" vehicles)

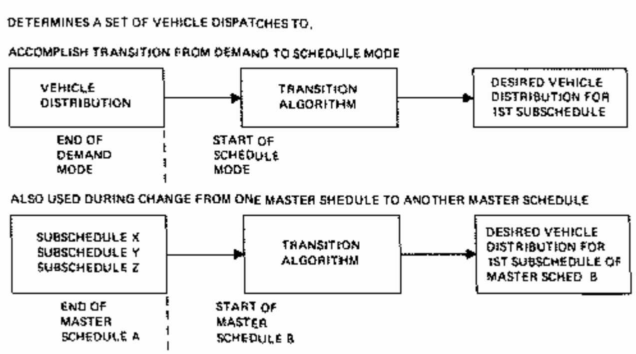
   Surplus/deficit = station inventory - requirement

3) Stations with surpluses dispatch all extra vehicles to the closest station with a deficit or to an "end" station

4) "End" stations redispatch the extra vehicles to the closest downstream station with a deficit

5) Side channel requests are used when necessary to balance the two sides of an offline station

* Directional station



ANOMALY MANAGEMENT

When a vehicle or wayside failure causes an interruption in normal service, an anomalous condition is said to exist. The first action that occurs during an anomaly is automatic and is taken to protect passenger safety. Vehicles are stopped through a process known as Trailing Vehicle Reaction (TVR). Once the system is brought to a safe, stable state, system operating procedures specify that the operator segment the system to the extent possible in order to continue as much passenger service as possible. As soon as the maintenance crew clears the problem the system is restarted in affected areas. Demand mode is generally used during these periods because of its inherent flexibility to work off any passenger demand accumulated during the anomaly.

TRAILING VEHICLE REACTION (TVR)

- STOPS VEHICLES ON NORMAL BRAKES
- AVOID EB STOP (CAS) WHEN POSSIBLE
- FACILITATES RESTART

SEGMENT SYSTEM WHEN POSSIBLE

- KEEP MAXIMUM O-D'S OPEN
- PREVENT G/W BACKUP PAST NEAREST STATION

SWITCH TO DEMAND MODE

- ALLOWS DYNAMIC SERVICE ADJUSTMENTS
- HIGH PRIORITY "WORK—OFF" OF WAITING PASSENGER AT END OF DOWNTIME

USE SYSTEMATIZED RECOVERY PROCEDURES

- OPERATOR OPTIONS FOR DISPATCH INHIBITS
- DOWNLINKS HELP DECIDE APPROPRIATE ACTION

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.

OPERATIONAL STATES AND MODES

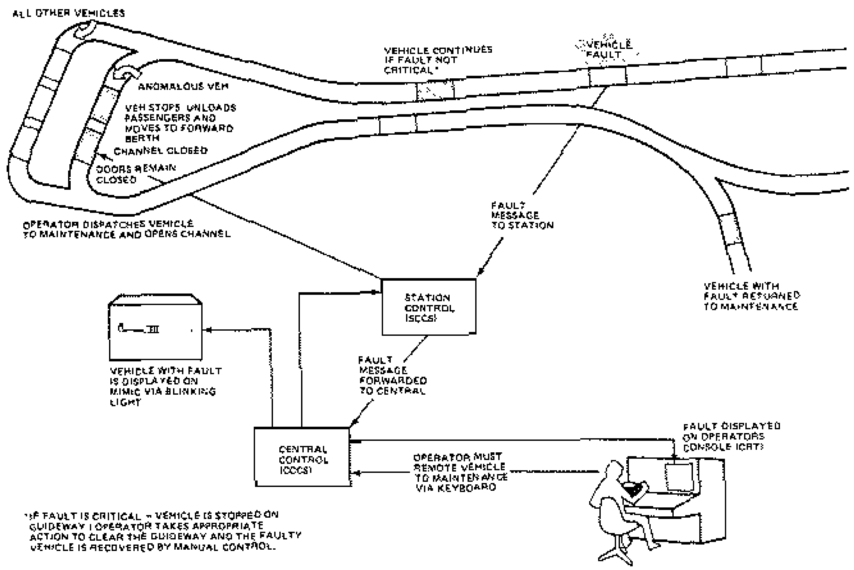
The system operator is responsible for the overall management of system operation. He obtains status information at his console and initializes the system for startup, input of operating parameters, and selection of the operating state and mode.

The Morgantown PRT system is operated in either of two states: normal and non-normal. These states include more than one mode of operation as defined below.

The system is in the normal state when its functions are under total automatic control. Normal state operations include the demand and scheduled modes. Transitions from the demand mode to the scheduled mode, or from the scheduled mode to the demand mode, are initiated by the system operator. The system is in the demand mode when the passenger selects his destination at the origin station and a vehicle is provided in accordance with his request. The vehicle will then transport the passenger non-stop to his destination. The demand mode is used primarily during off-peak traffic periods. The system is in the scheduled mode when the passenger is provided non-stop transportation in accordance with a predetermined origin/destination schedule that is based on expected traffic demands. The scheduled mode is used primarily during peak periods.

The system is in the non-normal state when its performance is less than normal because of a failure or other abnormal condition. Non-normal state operations include the reduced service mode, the remote mode, and the manual mode. The reduced service mode enables either the demand or scheduled mode to be continued in a non-normal state, but at a reduced performance. Reduced performance may include larger intervals between the vehicles, elimination of passenger service at one station, or lower speeds on the guideway. The remote mode enables the central control operator to remotely control vehicle movement. The manual mode enables system personnel to move the vehicles; means are provided for an on-board operator to control vehicle movement. The selection of the manual mode for a vehicle will preclude normal state operation of other vehicles in that section of the guideway.

NON-NORMAL STATE OF OPERATION



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 distribution 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.

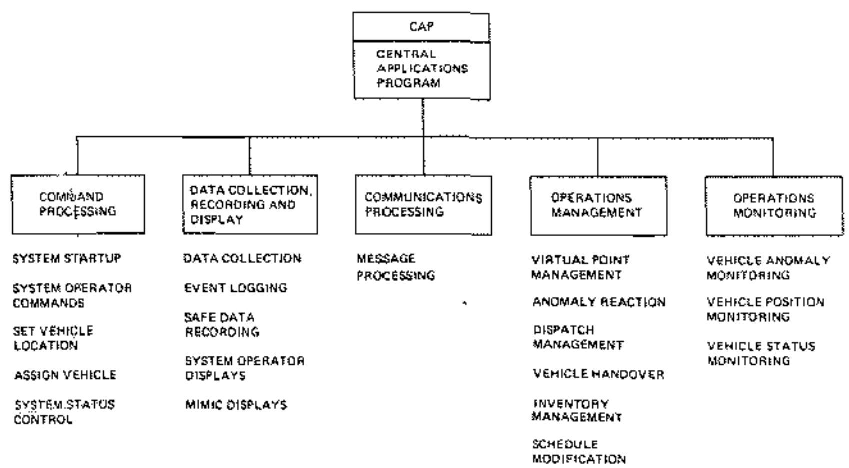
- Data collection–includes output of runtime information such as vehicle mileage to magnetic tape.
- Event logging-provides for printouts of vehicle locations, miles, and enabled hours.
- Safe data recording–provides periodic output of vehicle status information to cartridge and fixed-head discs.
- System 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 Mangement 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



CENTRAL CONTROL COMPUTER CONFIGURATION

The central computer configuration consists of two DEC PDP 11/55's performing redundant processing, a set of peripherals which is shared by both computers, two sets of dedicated peripherals (one for each computer), the MIMIC display indicating vehicle locations and anomalies, the electrification control panel enabling control of guideway power, Special Purpose Equipment (SPE) to accommodate non-standard computer interfaces, and the modems and boot switches enabling communication with the station computers.

Central Processors and Main Frame Logic (DEC PDP 11/55). The PDP 11/55 computer is a 16-bit machine which operates with a 300nsec cycle time. It contains 32K words of 300nsec bipolar memory, plus 32K of core memory with 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
- both real time and programmable clocks which are used to synchronize the system by use of the common line frequency
- Device I/O Controllers for the standard peripherals, the Special Purpose Equipment, a UNIBUS switch to enable sharing of peripherals by the two mainframes, and a UNIBUS link between the two processors

Dedicated Peripherals. Two sets provide functions vital to system operation:

- Fixed Head Disk (RF11/RS11)–a 256K word disk with an average access time of 16.9 milliseconds, and a 16 microsecond per word data transfer rate
- Cartridge Disk (RK11/RK05)–this unit has a 1.2 million word capacity, a 70 millisecond average access time, and an 11 microsecond per word data transfer rate
- DEC-writer II–a 128 character set printer terminal with 132 column print at 30 characters/sec
- Paper Tape Reader/Punch–a 300 characters/sec reader and a 50 characters/sec paper tape punch
- Electrostatic Line Printer–a direct Memory Access Block Mode printer with 500 lines/min and 100 characters/line capability
- CRT Terminal–a modified Beehive II terminal with special key caps to optimize operator input. Data transfer is 240 characters/sec.

Shared Peripherals. The following peripherals are switched manually and controlled only by the prime computer:

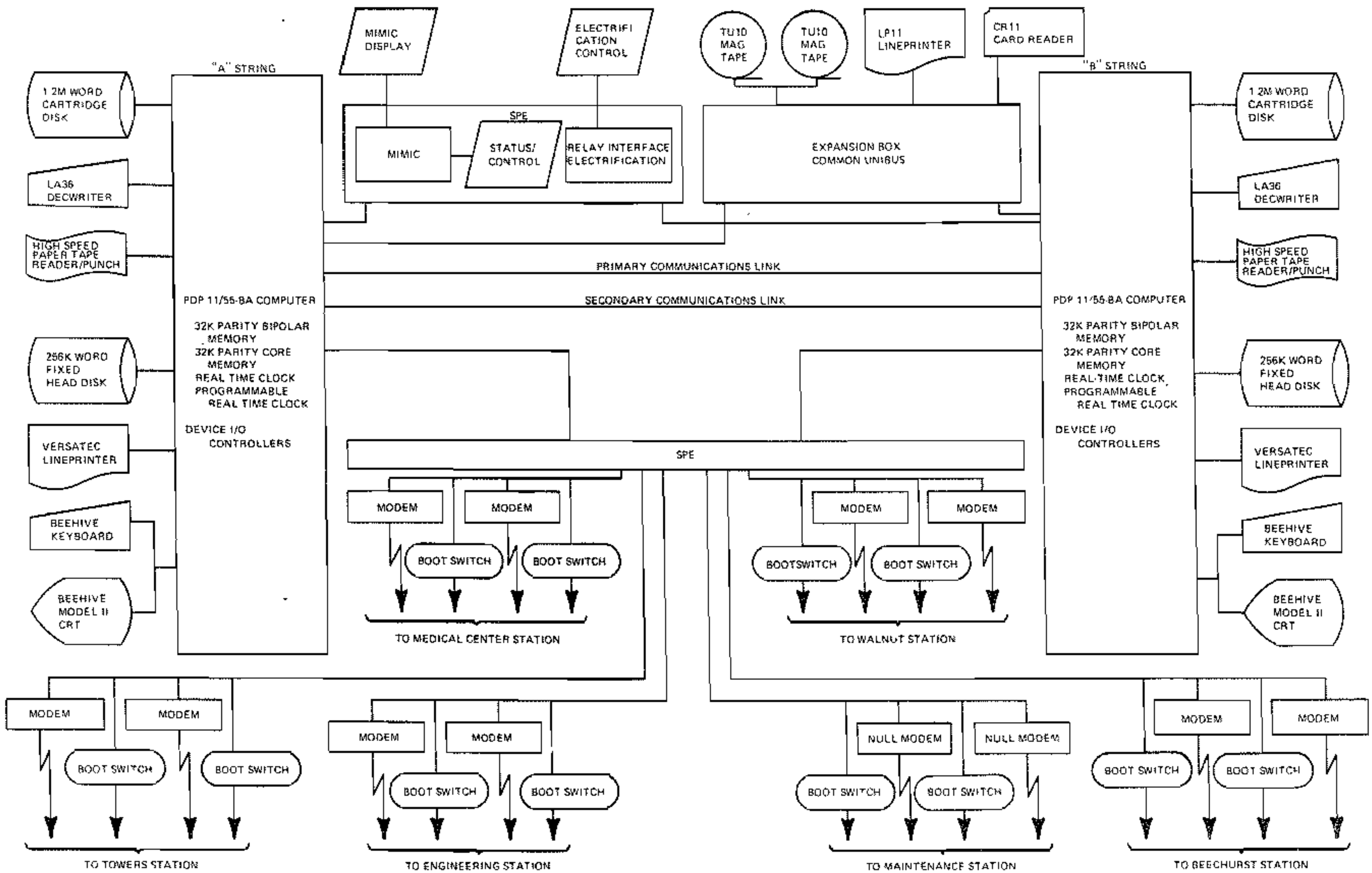
- a 9-track, 800 characters/inch, 10,000 characters/sec magnetic tape transport
- Line Printer–a 64 character set, 350 line/min, 80 column impact printer
- Card Reader–an 80-column, 284 card/min, punched card reader

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 visability 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.

MPRT CENTRAL COMPUTER CONFIGURATION



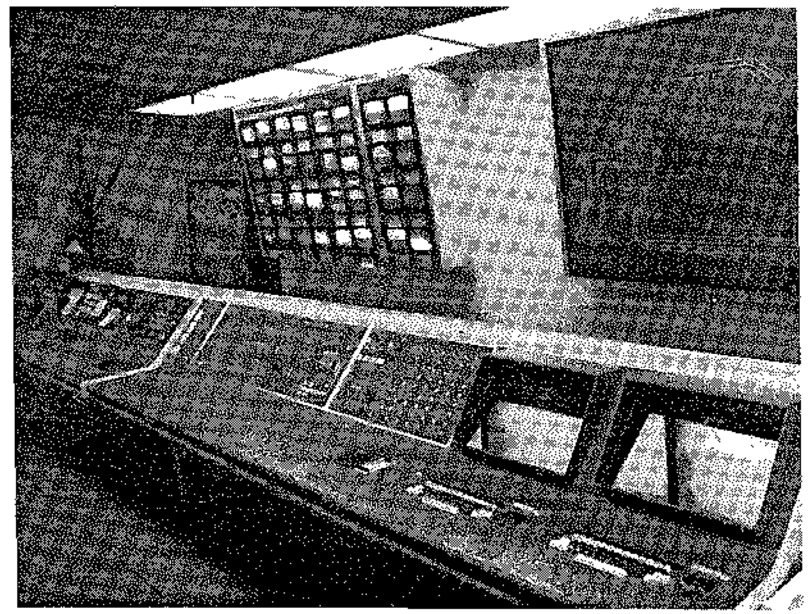
CENTRAL CONTROL OPERATIONS

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.



SYSTEM OPERATOR'S CONTROL CONSOLE

The Systems Operator Control Console contains the following control and monitor panels.

1) Concourse Sign Control Panel & Display Panel Assy
2) Electrification Control & Display Panel Assy
3) Station Control & Monitor Control and Monitor Panel Assy
4) Two Keyboard Terminals and related Cathode Ray Tube (CRT)
5) Maintenance Radio
6) Maintenance Intercom

The concourse sign control panel enables the system operator to control the concourse displays in the five passenger stations. These signs give the passengers the open and closed condition of each station on the M-PRT system and the platform to use to board the cars for their selected destination.

The Electrification Panel enables the system operator to control and monitor the Guideway Propulsion Power and 23kV power to the complete M-PRT system. The 23kV high voltage power is controlled by the in-line and HV-1 circuit breakers located on the upper right hand side of the panel. An emergency clump switch that controls the in-line circuit breaker receives its power from a 48 volt battery located in the Systems Operator Console. The station control and monitor panel controls and/or monitors the status of the secondary and emergency power sources which consists of:

1) Housekeeping power
2) Uninterruptable Power Supply (UPS) outputs
3) Guideway lighting
4) UPS Bypassed
5) UPS Fault
6) Standby Generator "ON"
7) Housekeeping Power "OFF"
8) Temperature & Equipment Blower
9) Humidity

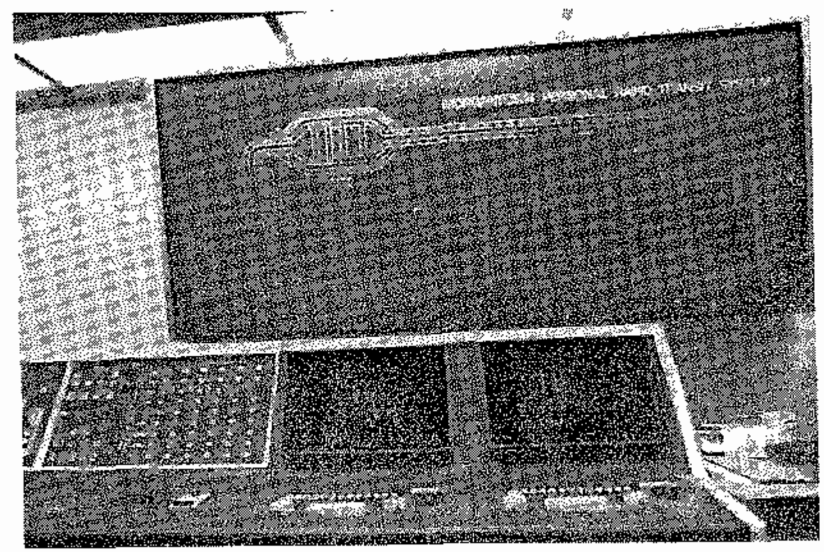
The station control and monitor panel also controls & monitors the following:

1) Station and Boiler House Fire Alarms
2) Guideway Heating Boiler Controls
3) Platform Heating Control
4) Snow Mat Heating Control
5) Guideway Power Rail Heating Control

The two keyboard terminals and CRT displays enable the system operator to address the Control computer and to monitor the automatic operation of the system.

The maintenance radio provides the system operator with a means of communication with the maintenance personnel in the field and the vehicle recovery team.

The maintenance intercom provides the system operator a means of communication with the maintenance personnel within the Maintenance and Engineering Maintenance facilities.



COMMUNICATION OPERATOR'S CONSOLE

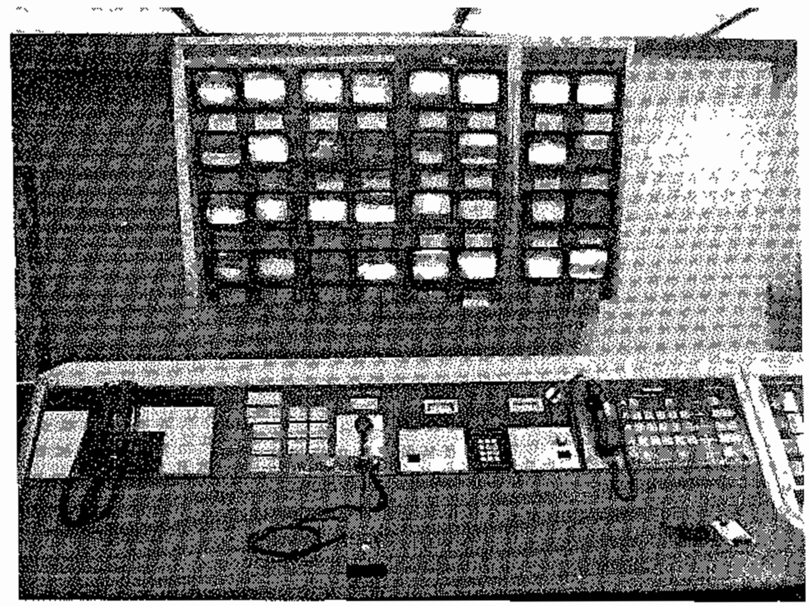
The communications operator is responsible for communications to and from passengers in the PRT system, and to and from the public outside the PRT system. He does this from the communications operator's console, which has:

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.



VOICE COMMUNICATIONS NETWORK

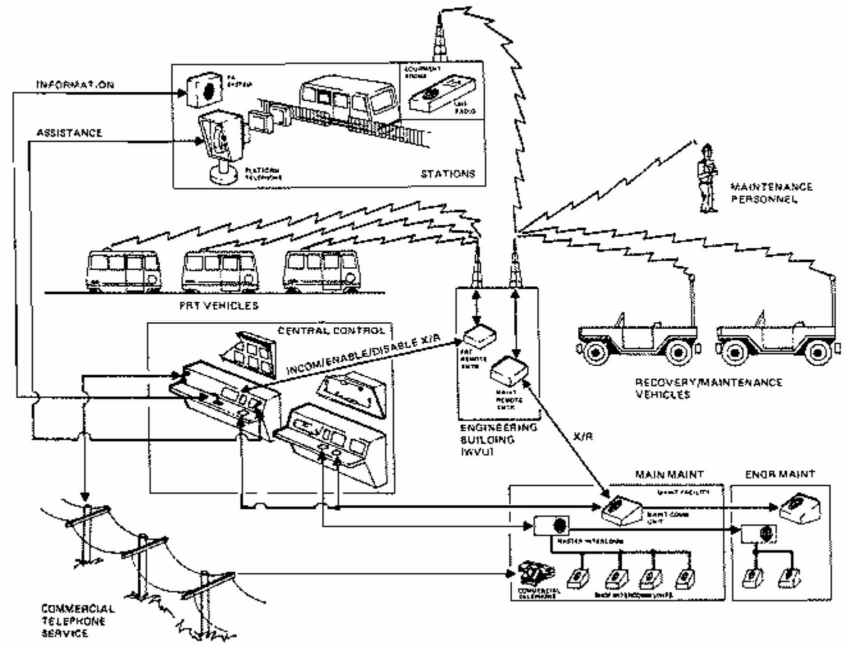
The PRT system uses various methods for communication from central control and maintenance control. Normal telephone communications are provided to each of these areas as well as to the normal office area. The central control area has one unlisted number that has been given to local police, fire, and university security officials.

Passengers at the station platforms can pick up a handset and be in instant contact with central control. One-way communications or paging to the station areas can be accomplished by the PA system. Passengers in the vehicles can contact central or be contacted by central over a UHF radio system. Each vehicle has its own radio, which can be activated in an emergency.

There is a separate UHF radio system for the exclusive use of maintenance personnel. The recovery and maintenance vehicles are equipped with two-way radios, and hand-held units provide contact with central from anywhere in the system. Paging ability is also provided so that off-duty personnel can be summoned anywhere in the Morgantown area.

The UHF radios are hardwired to remote transceivers on top of the WVU Engineering Building. Separate control allows two-way communication over the maintenance frequency. Intercom units are also provided between central control, maintenance control, Engineering Maintenance facility and the shop area of the maintenance building.

PRT VOICE COMMUNICATIONS NETWORK



Station and Guideway Control and Communications Subsystem (S/GCCS)

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:

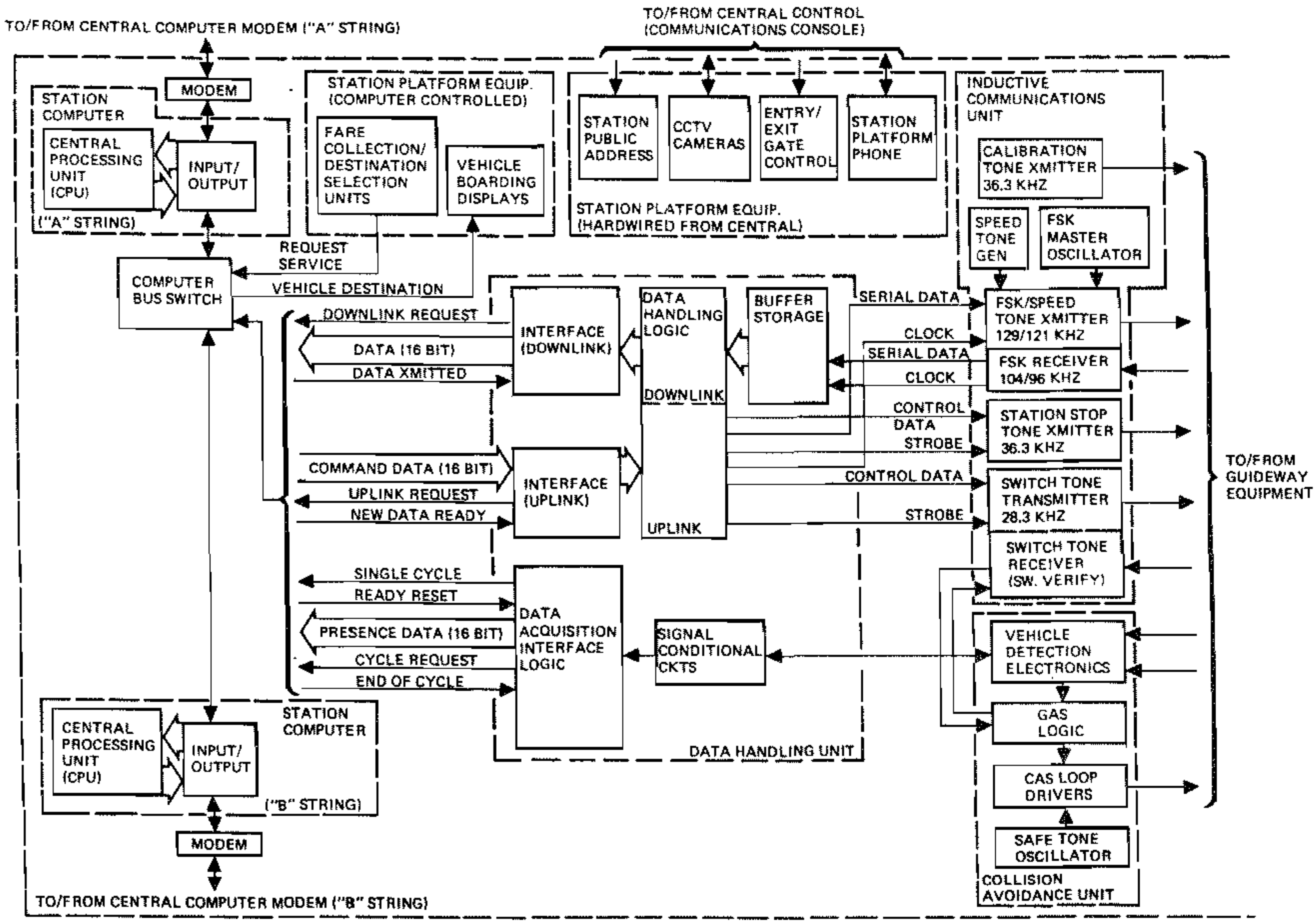
1) dual station computers and modems
2) Data Handling Unit (DHU)
3) Inductive Communications Unit
4) Collision Avoidance System (CAS)
5) operational service equipment for passenger interface

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 software 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/GUIDEWAY CONTROL AND COMMUNICATIONS FUNCTIONAL DIAGRAM



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

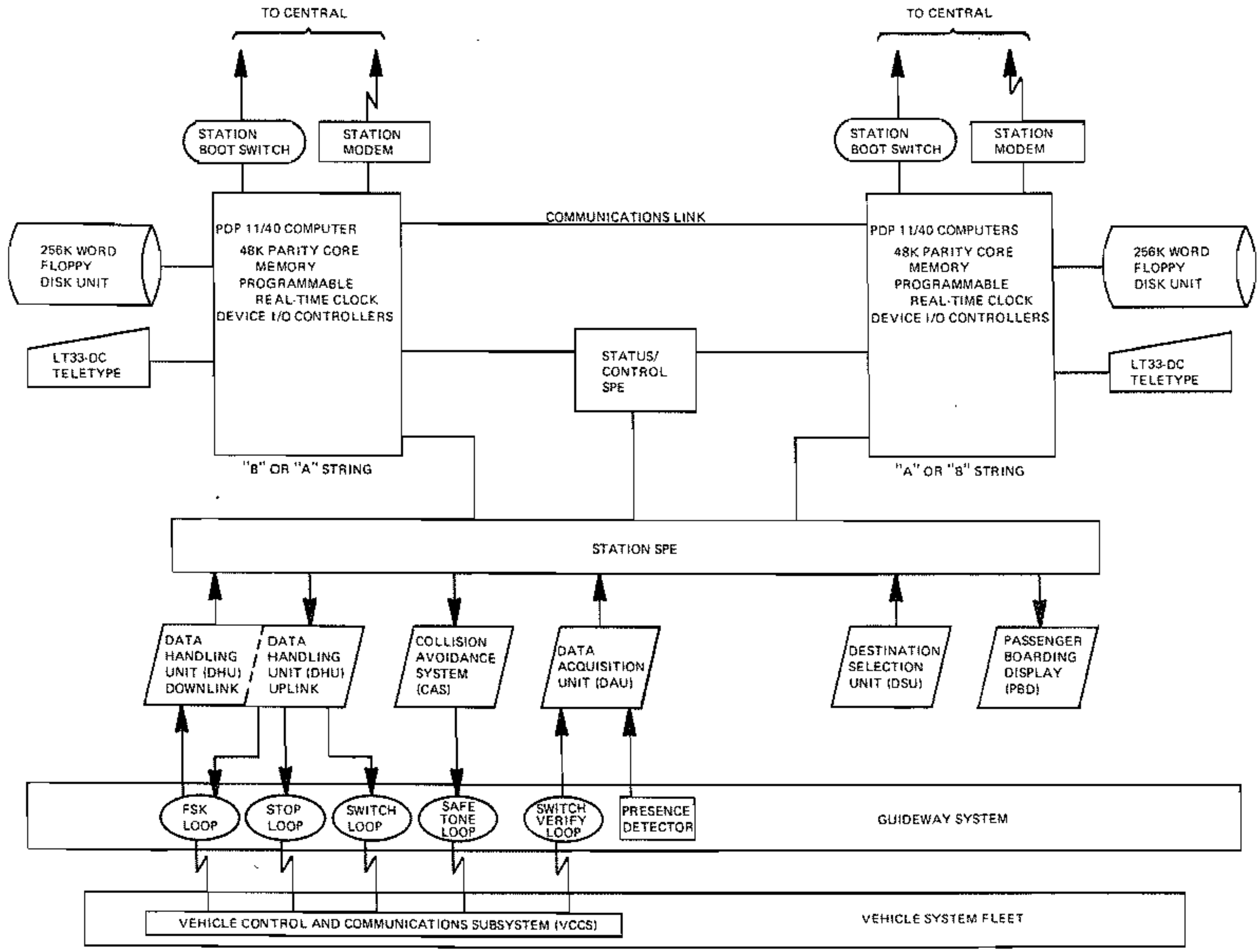
- Data Acquisition Unit (DAU) - the DAU provides monitoring of Presence Detector hits, switch verify signals, and CAS disparities. A general device register interface controller (DR11-C) is used in each processor to control data flow. In dual mode, data is presented simultaneously to both processors 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.

MPRT TYPICAL STATION COMPUTER CONFIGURATION



PASSENGER STATION SOFTWARE

The Passenger Station Segment software consists of the Passenger Station Executive Program and the Passenger Station Applications Program (PSAP). The Executive Program controls the processing performed by the Applications Program and provides the software interface with the computing system and external environment. PSAP controls the movement of individual vehicles on the main guideway within the control zone of a single station, on station merge and demerge ramps, and in station channels. This includes ramp and channel switching and door control at load and unload berths. PSAP also accepts passenger destination requests, controls passenger boarding displays, and commuicates with central to coordinate timing and vehicle movement. PSAP also receives commands, reports station and vehicle status.

PSAP is modular in structure to facilitate development, testing, and maintenance. This structure includes six module groups which organize the applications modules along functional lines.

The Command Processing module group supports processing for commands and data originating from system operator keyboard and from CAP.

Data Collection consists of one module which supports the collection of vehicle trip and passenger request data for recording and display by CAP.

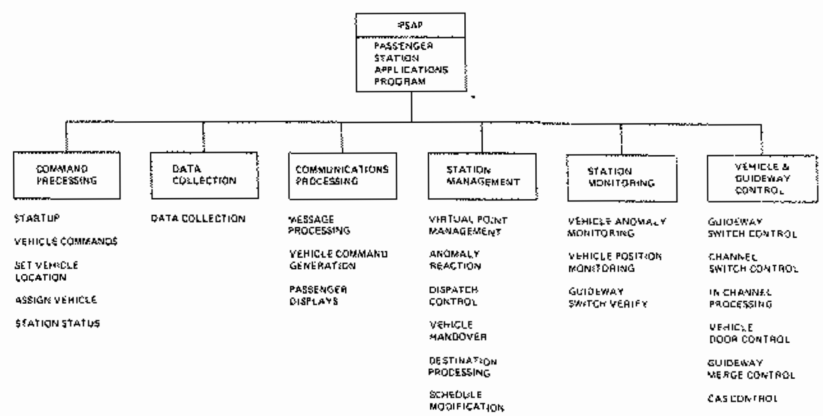
The Communications Processing module group accepts messages from CAP, the Data Handling Unit (DHU), and the Destination Selection Unit (DSU) and initiates the appropriate processing of these messages. It also provides for the preparation of vehicle messages to be transmitted through the DHU and for the illumination of appropriate Passenger Boarding Displays.

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).

PASSENGER STATION APPLICATIONS PROGRAM ORGANIZATION



MAINTENANCE STATION SOFTWARE

The Maintenance Station Segment software consists of the Maintenance Station Executive Program and the Maintenance Station Applications Program (MSAP). The Executive Program controls the processing performed by the Applications Program and provides the software interface with the computing system and external environment. MSAP functions are similar to those of PSAP in providing vehicle control and communications with central. In addition, vehicle control is provided for a test loop at maintenance which is used for checking vehicle operations and performance. There is no passenger interface at maintenance.

MSAP is modular in structure to facilitate development, testing, and maintenance. This structure includes six module groups which organize the applications modules along functional lines. The composition of the six module groups is similar to that described for PSAP. The differences are noted below.

The Command Processing module group supports processing of commands to control the looping of vehicles on the Maintenance Test Loop, in addition to the other functions described.

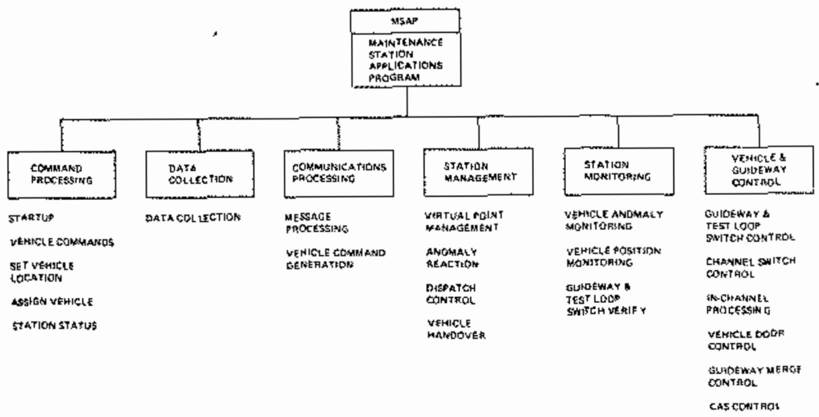
The Communications Processing module group is not required to process DSU inputs or to output data to the Passenger Boarding Displays, since those devices are not included in the Maintenance Station environment.

The Station Management module group provides the functions as described for PSAP except for the assignment of vehicles to provide passenger service.

In addition to the functions listed for the PSAP Station Monitoring module group, MSAP also monitors vehicle switching on the Maintenance Test Loop.

The Vehicle and Guideway Control module group includes control of test loop switching and monitoring of merge positions on the test loop in addition to the functions described for PSAP.

MAINTENANCE STATION APPLICATIONS PROGRAM ORGANIZATION



VEHICLE CALIBRATION

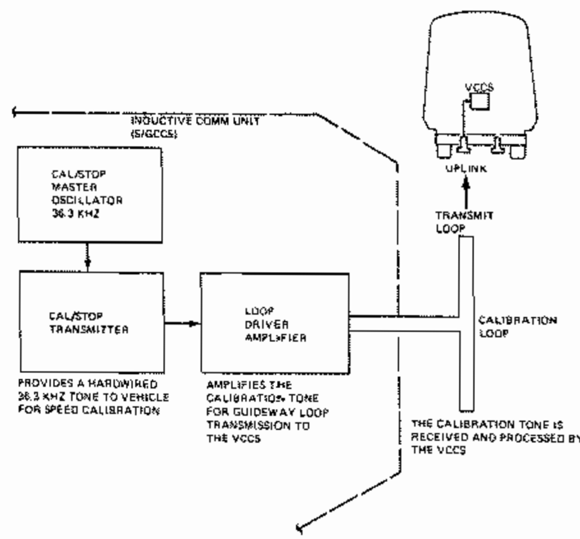
Because of tire wear, rolling radius variations between tires, and other minor deviations, the vehicle odometer signals are periodically updated as the vehicles travel the guideway. Vehicle corrections are made so vehicle position can be maintained within the tolerance. Corrections are calculated by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

CALIBRATION LOOP CONTROL



FSK AND SPEED TONE CONTROL

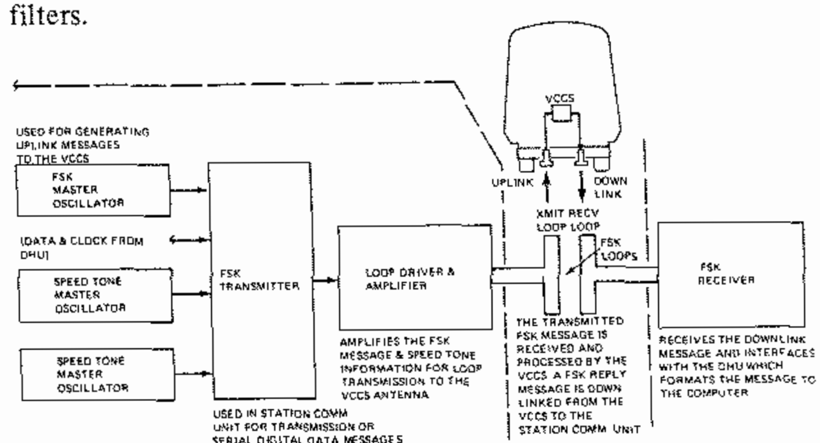
The FSK transmitter provides brake commands, speed commands, and identification requests. The FSK receiver is used to receive vehicle-generated messages. The master oscillator, which is common to several FSK transmitters, provides two continuous sinusoidal outputs which are detected in narrowband filters by the FSK transmitters. The filter outputs are applied to analog switches in the FSK transmitters, the switches being turned on and off by the serial data and clock from the DHU. When the serial data contains a logic "1", the control logic switches 120 kHz carrier, during the gated clock period, to one input of a mixing amplifier. When the serial data contains a logic "0", 121 kHz carrier is switched to the mixing amplifier and the 129 kHz is turned off. In the absence of a clock pulse, however, neither carrier is switched, no matter what the state of the serial data.

The speed command tone signal inputs are generated in one of 6 possible speed tone circuit configurations, which provide signal outputs corresponding to common speeds of 44, 33, 22, 8, 6, and 4 feet per second. The higher command speeds use circuit configurations that provide signal outputs in a combination of two of three possible tones alternately chopped at a 50 Hz rate. The lower command speeds use circuit configurations that provide a single one of these same three tones which is also chopped at a 50 Hz rate. In this manner, speed combinations were selected so that any oscillator failure always results in a lower speed for safety.

The FSK data and speed tone signals have separate gain adjustments in the FSK transmitter, followed by an overall gain adjustment in the mixing amplifier; the composite output is wired to the input of the loop driver, which provides the correct drive for the particular FSK-speed tone loop.

As an additional safety precaution, "high-speed enable" magnets are buried in those portions of the guideway which activate vehicle mounted read switches and higher speed commands. As the vehicle progresses along the guideway the presence of higher speed commands in a section of guideway will be recognized and acted upon by the vehicle only if it has encountered a "high-speed enable" switch at the start of that portion of the guideway. If the vehicle detects higher speed commands without a high-speed enable, or detects a high-speed enable without higher speed commands, it slows to 4 feet per second and gives notification of the discrepancy via the FSK downlink.

The receiver of the FSK and speed tone unit receives serial FSK data via the associated FSK receiving loop antenna from vehicles transmitting status messages. The FSK status data signal is gated sinusoidal signal occurring at data bit rate of 1000 Hz. The data content of the gated sinusoidal signal is characterized by a signal frequency of 104 kHz representing a logic "1" and a signal frequency of 96 kHz representing a logic "0". The signal received is applied to two amplifier stages and a band pass filter, which removes any extraneous crosstalk signals appearing on the receiving loop antenna. Finally, it is applied to a limiting amplifier that shapes the input signal before application to the 96 and 104 kHz pass filters.



1 = TONE PRESENT   0 = TONE ABSENT

FAILURE MODES ONLY INVALID COMBINATIONS COMMAND 4 FPS

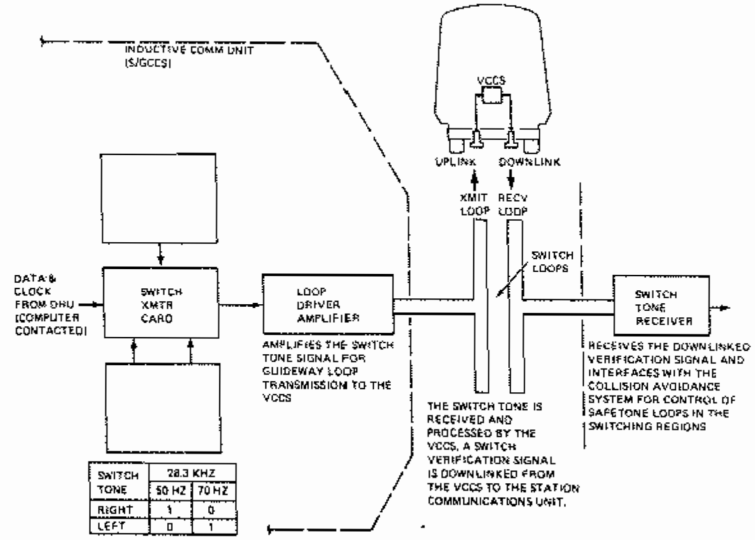
CIVIL SPEED	FREQUENCIES		
	6.1 KHZ	13.3 KHZ	17.2 KHZ
44 FPS	1	1	0
33 FPS	0	1	1
22 FPS	1	0	1
8 FPS	1	0	0
6 FPS	0	1	0
4 FPS	0	0	1
4 FPS	0	0	0
4 FPS	1	1	1

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.



COLLISION AVOIDANCE SYSTEM CONCEPT

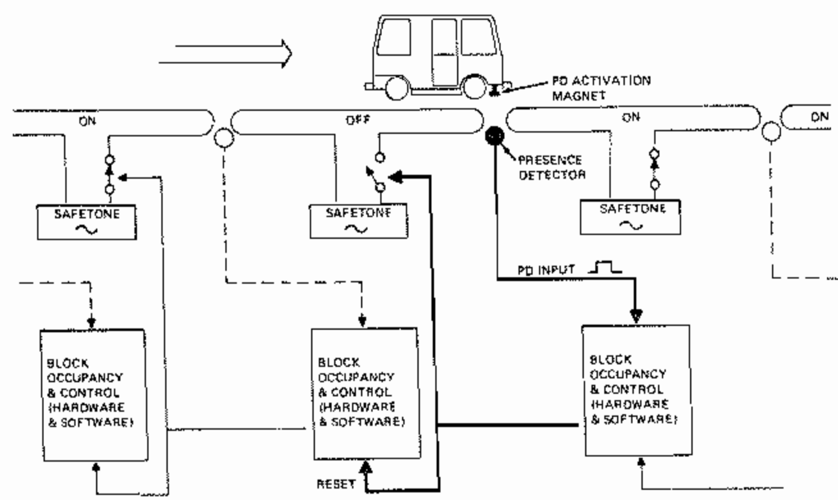
An independent Collision Avoidance System (CAS) is used to prevent collisions in the event of failure of the primary vehicle controls. The CAS is a block control system which transmits a safe tone to the vehicle in a block if it is safe to proceed. Protection is provided by turning off safe tone in the block immediately to the rear of a block that is occupied. Another vehicle encroaching from the rear will encounter the "OFF" block and will apply emergency brakes.

"Normally-off" and "normally-on" blocks are special purpose blocks which occur at all switch points and merge points on the guideway, and "normally-on" blocks are used in all other areas. In "normally-on" sections of the guideway, as a vehicle enters a block and activates a presence detector, the control electronics removes safe tone from the block just vacated. This provides an "off" block behind each vehicle at all times. As occupancy of each block occurs, a reset signal is generated to restore safe tone two blocks to the rear. At switch points the "normally-off" block is turned on to allow a vehicle to proceed as soon as the vehicle verifies a proper switch. If a switch failure occurs, the block will remain off causing the failed vehicle to stop on emergency brakes.

At merge locations a "normally-off" block exists in each leg of the merge. As a vehicle approaches the merge, it will be granted priority based on first arrival, and its "normally-off" block will be turned on. If a vehicle is out of position as it approaches the merge, and priority has already been granted to a vehicle in the other leg, the "normally-off" block will remain off for the vehicle in violation, and a merge conflict will be avoided.

The CAS is a redundant system utilizing two different logic paths. One logic path interfaces with the station computer, and software accomplishes block control. The other logic path (hardware) utilizes special purpose logic circuits to accomplish maintenance, a microprocessor is used to implement this "hardware" logic. Both logic paths must agree on block-occupancy or safe tones are turned off and the system operator is notified. In practice, the entire guideway is divided into CAS control zones. If a disparity occurs between the logic paths, safe tones are turned off in only the affected zone, thus minimizing the number of vehicles that will stop on emergency brakes. Other portions of the system not affected by the zone disparity can continue to operate normally.

CAS BLOCK CONTROL CONCEPT



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.

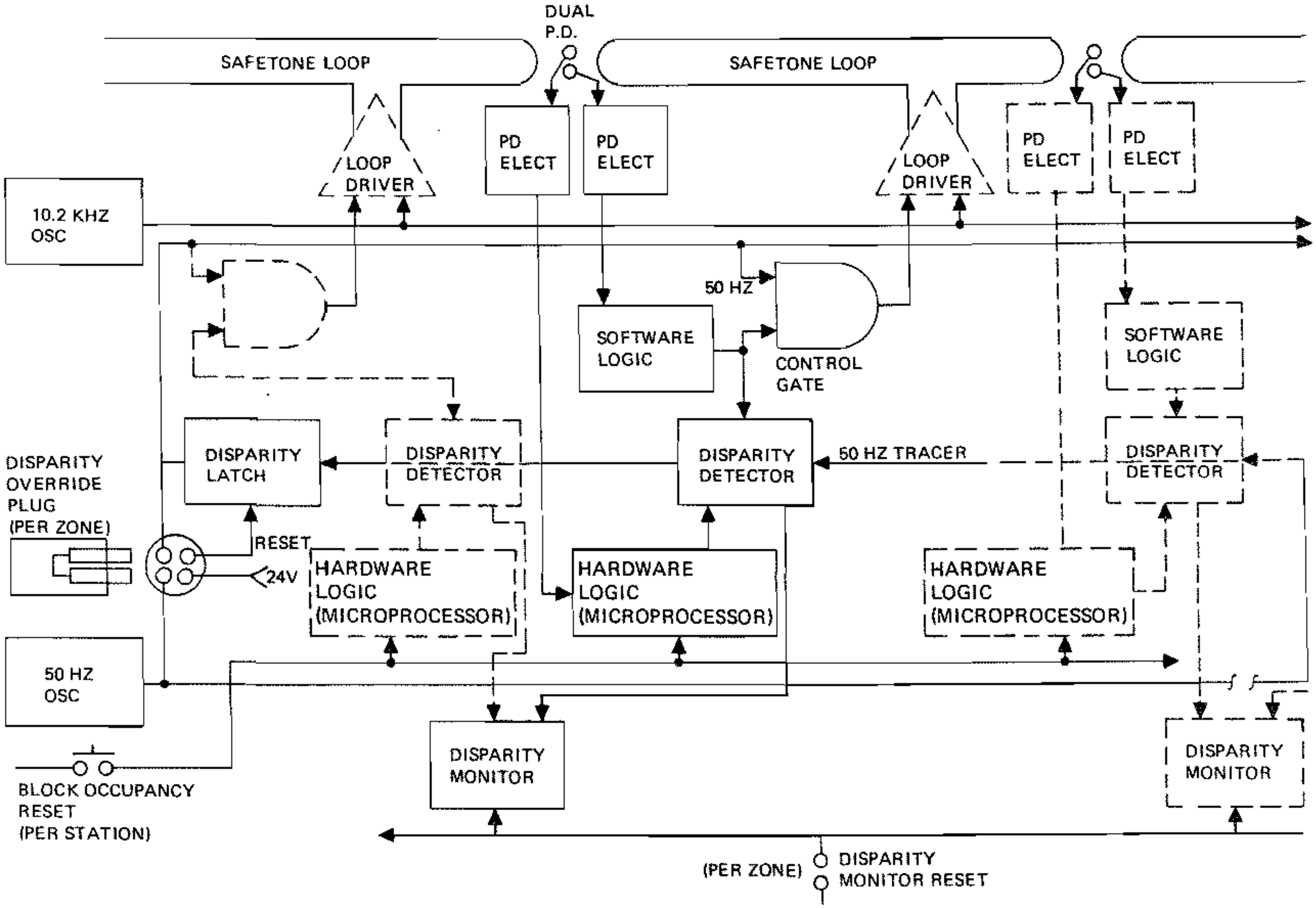
The CAS is redundant for block logic functions up to the interface with the disparity checkers. One CAS logic path enters the station computer where software computes the proper block occupancy, and commands safe tones on or off. The other logic path is accomplished in special logic hardware, (microprocessor) 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.

CAS FUNCTIONAL DIAGRAM



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.

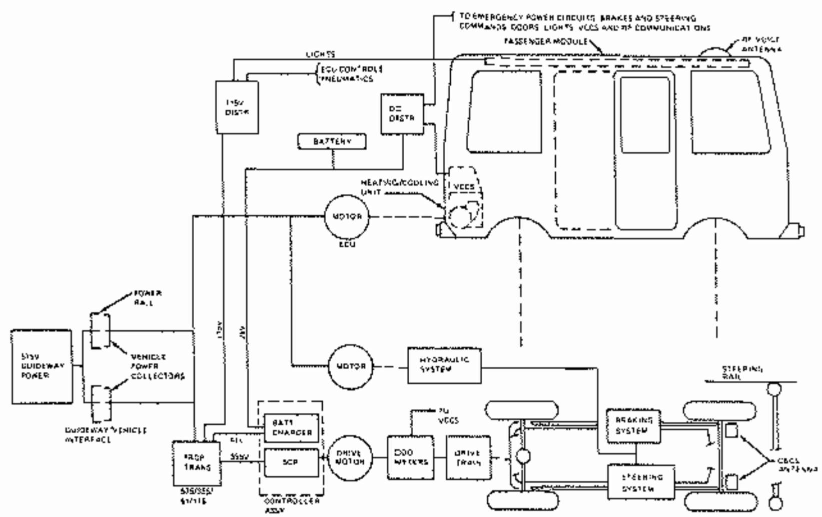
7) Braking–provides redundant normal and emergency rate stopping and a mechanical parking brake.

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

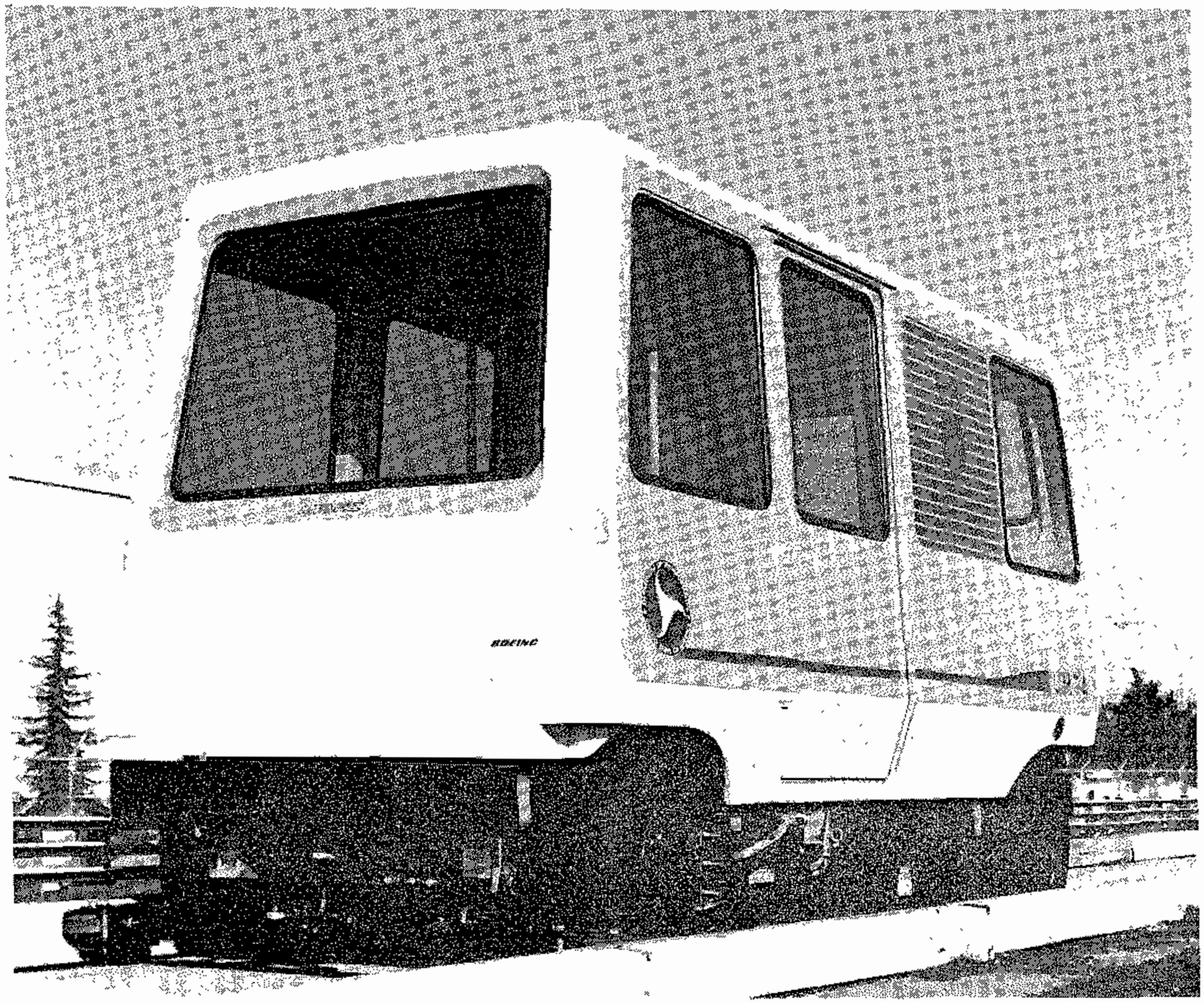
9) Electrical–picks up electrical power from the guideway power rails and converts it to 355/120/61 VAC and 26 VDC for vehicle functions.

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.

MORGANTOWN PRT VEHICLE FUNCTIONAL SCHEMATIC



MORGANTOWN PRT VEHICLE



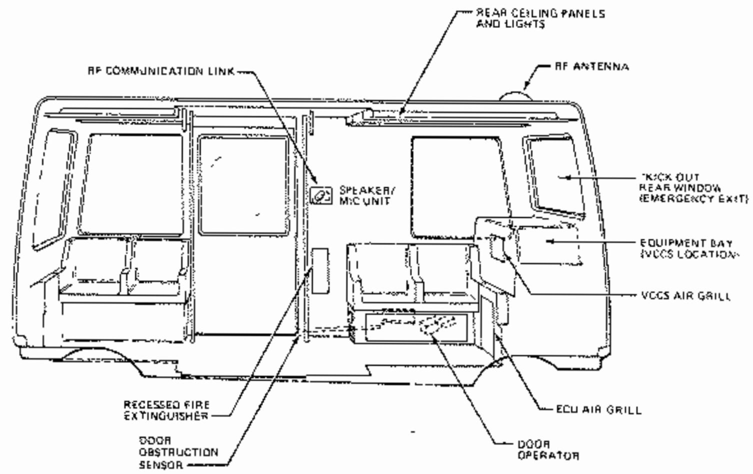
PASSENGER MODULE

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.

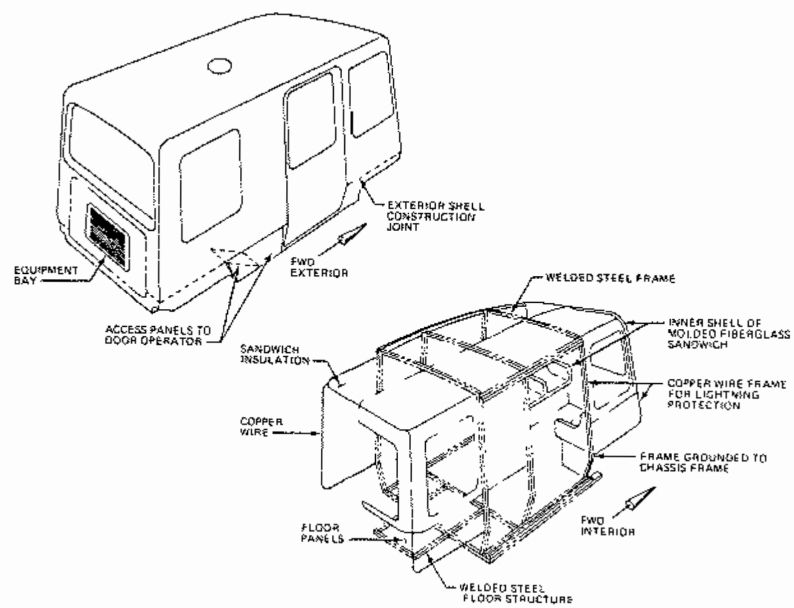
Fluorescent lighting is inset in the ceiling for normal module lighting. However, in case of a power failure, 24VDC lights that are powered by on-board batteries are automatically activated. The doors are also powered by 24VDC mechanisms, one for each door. The left door may be opened from inside the 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.

PASSENGER MODULE INTERIOR



PASSENGER MODULE CONSTRUCTION

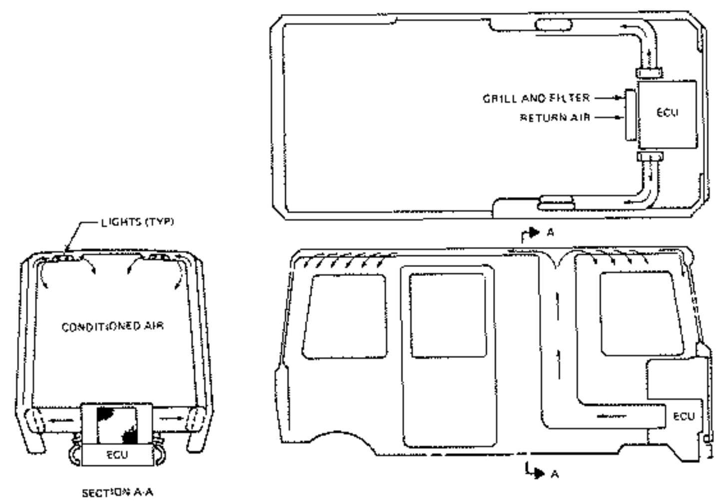


ENVIRONMENTAL CONTROL UNIT (ECU)

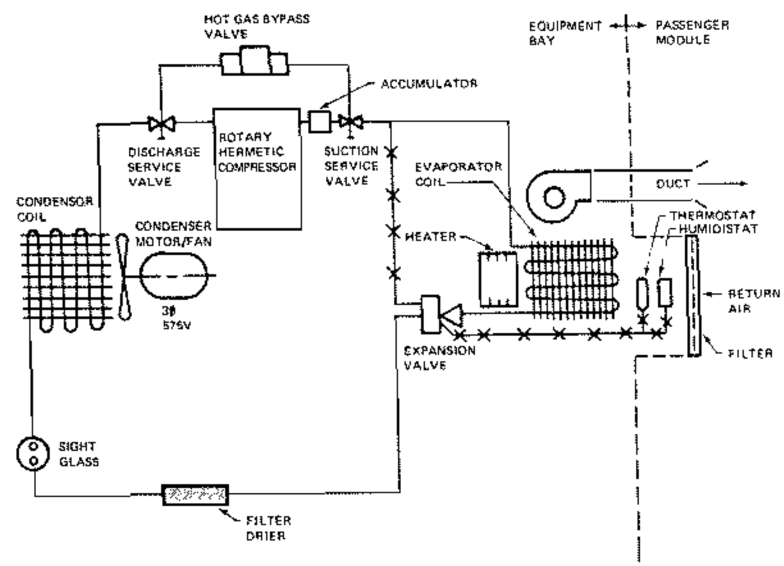
The ECU is mounted in the aft equipment compartment of the vehicle and provides conditioned air to the passengers. Cooling air is provided when the module air goes above 75°F, and heated air is provided when the module temperature is below 65°F. The cooling capacity is approximately equivalent to two tons at 100°F ambient. The heaters are electrical units (575VAC) with a heating capacity of approximately 4.5kW.

There are two air source entries into the module. The majority of the air is drawn in through the grill in the aft end of the passenger compartment; the remainder (approximately 20 percent), enters through a small grill on the outside of the vehicle near the left rear wheel cutout. Air drawn into the module is conditioned by the ECU. Conditioned air is exhausted into the passenger module through the light fixtures in the ceiling of the vehicle.

ECU LOCATION AND DUCTING



ECU SCHEMATIC

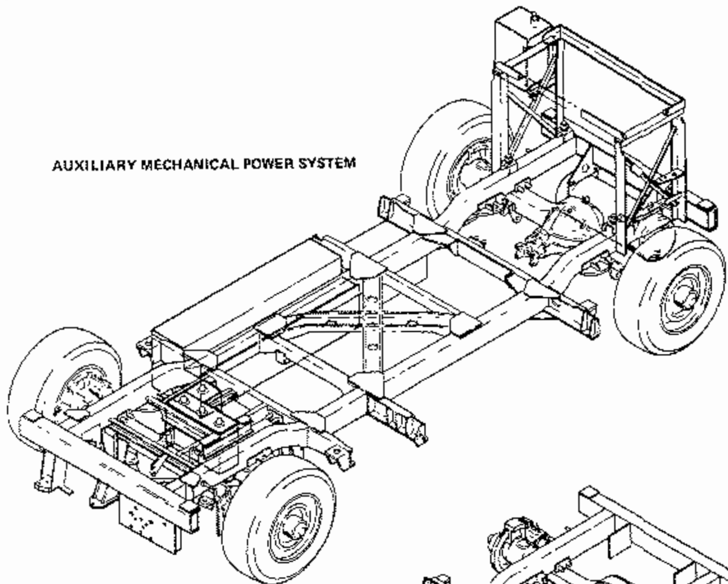


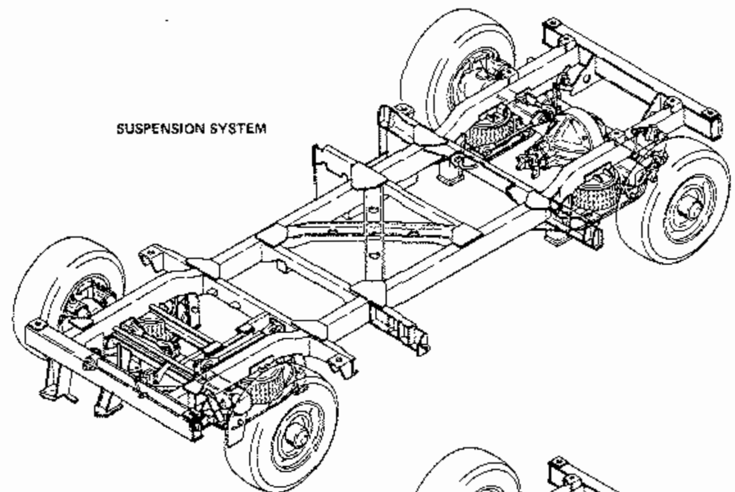
CHASSIS

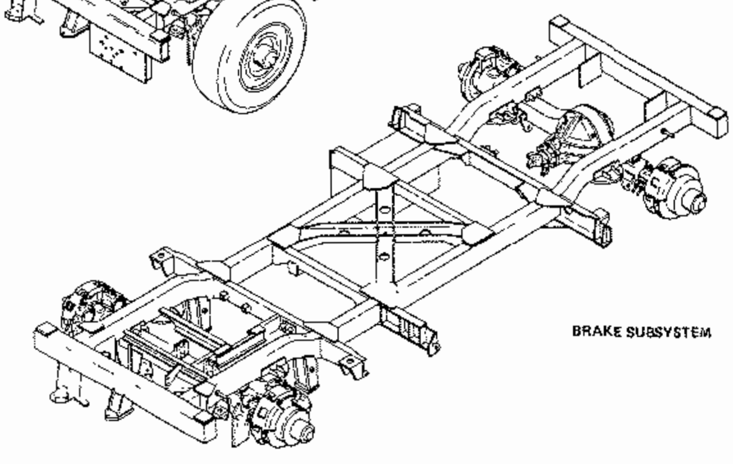
The chassis consists of the frame, axles, wheels, and suspension system. The frame is a weldment with four integral jack pads for ease in lifting the vehicle. The front bumper is an impact-collapsible type, designed to withstand impacts up to 4 fps. The rear bumper is rigidly mounted to the frame. The 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.

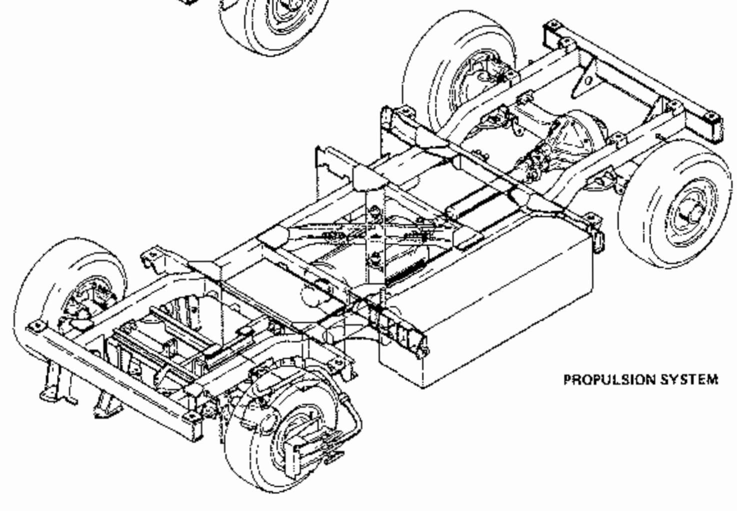
Suspension is provided by air springs at each wheel with standard shock absorbers. The air springs are self-inflating and regulating to provide a constant sprung-to-unsprung separation distance. This provides a constant floor height for ease of entry and exit at station platforms.

The wheels are heavy-duty 16.5, 8-stud, and the tires are 16.5, by 9.5, 10-ply. Each tire has an innertube and liner that provide two independent air chambers for puncture protection.









HYDRAULIC SUBSYSTEM

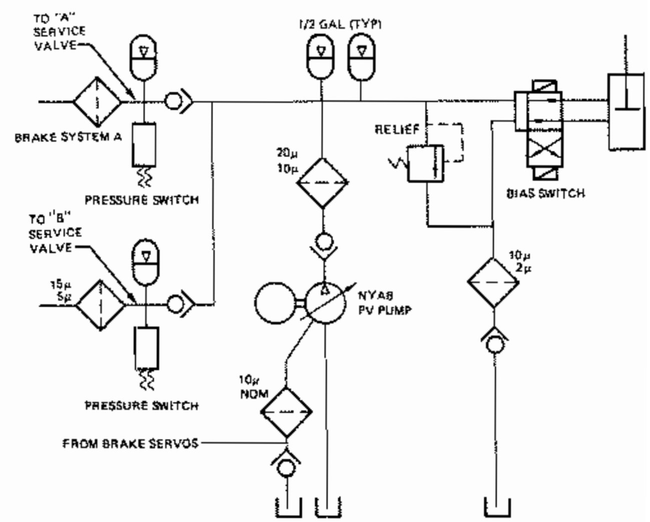
The hydraulic subsystem supplies energy to the steering subsystem for bias switching and to the braking subsystem for brake application. The hydraulic subsystem is powered from a 2 hp electric motor which drives a variable displacement pressure compensated pump. Operating pressure varies between 950 and 1000 psig for normal use. Under failure conditions, a relief valve limits pressure to 1250 psig.

The subsystem incorporates four hydro-pneumatic accumulators: a ½ gallon accumulator reserved for the exclusive use of each brake system and 2 ½ gallon accumulators for general system use. Pressure switches in the braking systems will apply brakes if pressure within the brake system drops to 800 psig.

The MIL-H-5606 petroleum-based hydraulic fluid is filtered to 20 microns absolute as it leaves the pump. Fluid going to the brakes is subsequently filtered to 15 microns absolute. Return fluid from the bias switch function is filtered to 10 microns absolute and fluid returning in the pump by-pass line is filtered to 10 microns nominal.

The bias switch is powered by a cylinder which is controlled by a high-performance solenoid-operated four way valve.

HYDRAULIC SUBSYSTEM SCHEMATIC



PNEUMATIC SUBSYSTEM

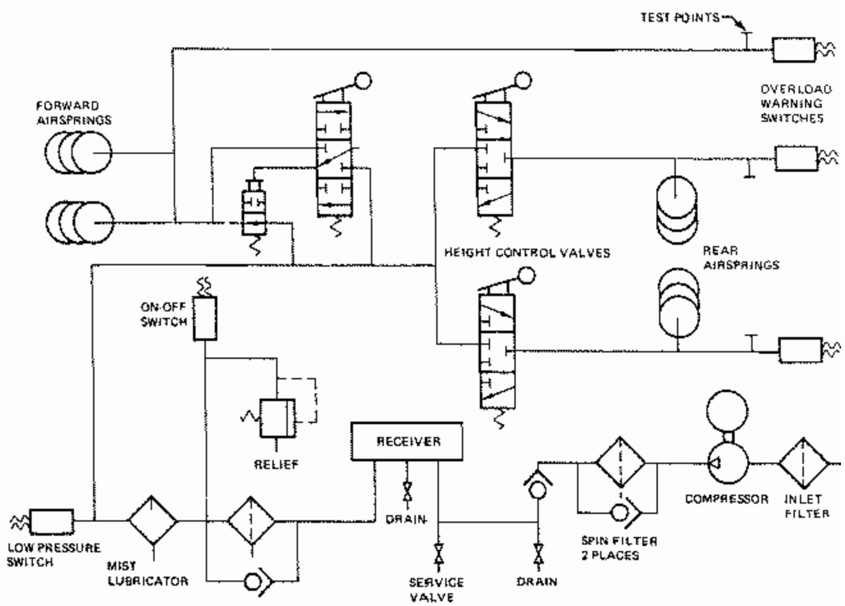
The pneumatic subsystem provides air to the top airsprings which support the passenger module. The vehicle is supported at the proper height and held level by four airsprings, one near each wheel. The forward two airsprings are controlled by a height control valve and a pilot operated valve. Each rear airspring is controlled by its own height control valve. These valves, through a control linkage, measure the distance between the sprung and unsprung 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.

PNEUMATIC SUBSYSTEM SCHEMATIC



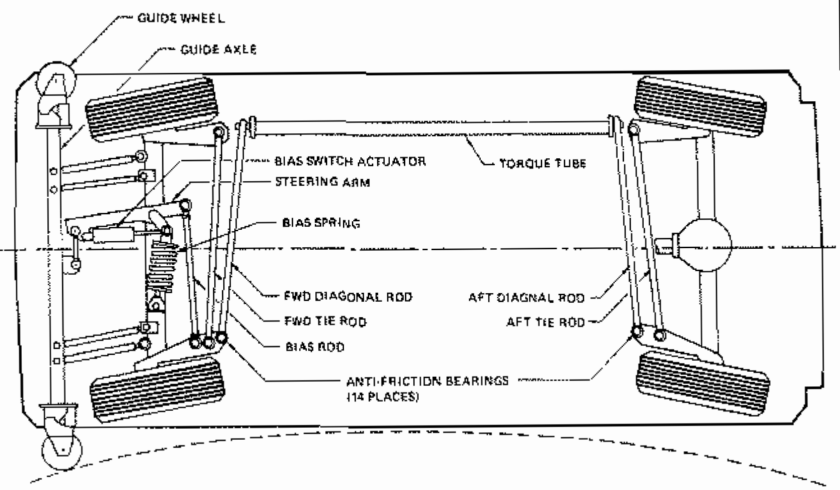
STEERING SYSTEM

To negotiate 30-foot-radius turns, the vehicle is equipped with four-wheel steering. The steering is applied to the left front wheel hub and then to the other three wheels through transverse links and a fore-and-aft torque tube.

Steering forces of approximately 240 pounds are transmitted from the mechanical bias going to the guidewheel of the guide axle.

The vehicle will follow a guide rail or steering rail on either side of the vehicle depending on whether the bias switch cylinder is positioned to the left or to the right.

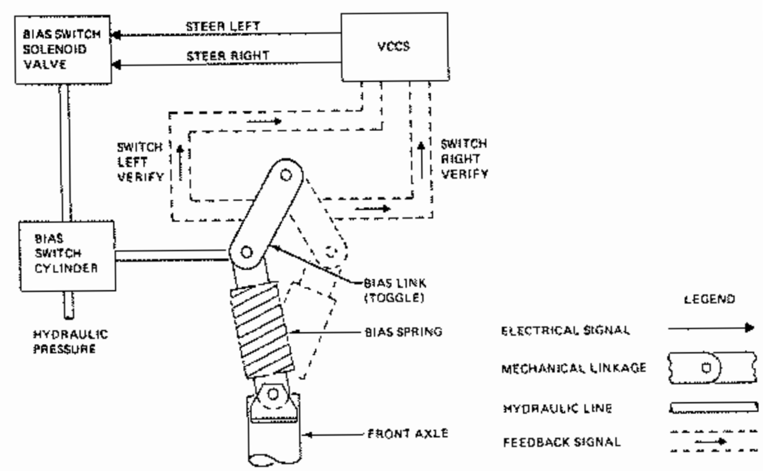
VEHICLE STEERING SYSTEM



STEERING SYSTEM CONTROL

Upon command to switch bias, a steer left or steer right command is issued by the VCCS. This command causes the Bias Switch Actuator to move the bias link over center thereby reversing the torque applied to the guideaxle linkage by the bias spring. Successful switching is verified by a set of magnetic reed switches mounted near the bias link.

STEERING CONTROL SCHEMATIC



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.

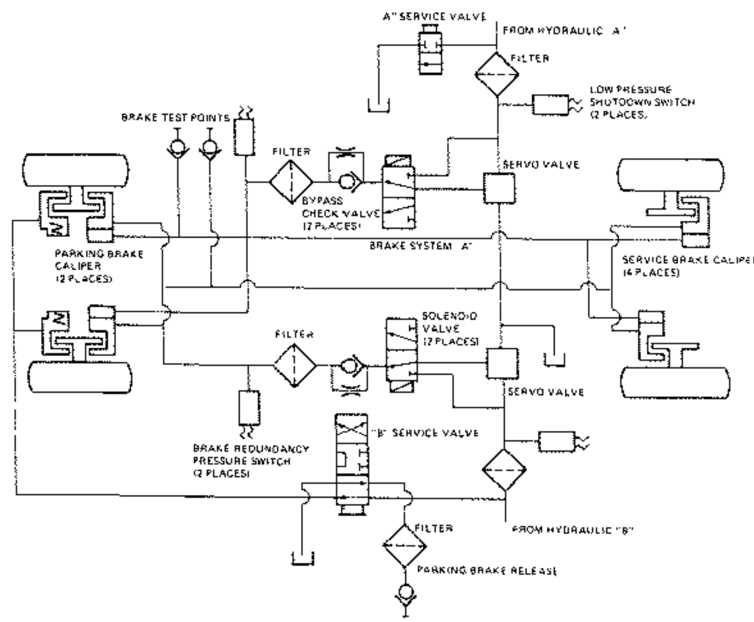
The calipers contain tandem piston actuators with independent hydraulic actuation. Either piston in the caliper assembly is able to actuate the brakes at full capacity, but, when both pistons are actuated, which is normal, the braking results are not additive. This is a unique design; however, the brake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

BRAKE SYSTEM SCHEMATIC



PROPULSION SYSTEM

The vehicle is driven by the propulsion system, which consists of a transformer, a motor controller, and a drive motor. The transformer converts the 575VAC, three-phase power to 355VAC, 61VAC, and 120VAC. Temperature sensors are buried in the transformer windings, the Silicon Control Rectifier (SCR) heat sinks, and the drive motor.

The motor controller includes a three-phase full-wave SCR converter for DC motor armature current. The controller regulates the vehicle speed, as well as jerk and acceleration, in response to speed command inputs. Speed commands are differential inputs (0 to 10VDC) provided by the VCCS, the motor controller responds with from 0 to 3168 rpm respectively. The SCR control contains the snubber circuits (to limit the rate of change of voltage to the SCRs), the controller turn-on circuits, the current rate limiters and amplifiers, and the brake generator circuits for firing the SCRs. The logic and control assembly contains the safety interlocks, the relay logic, the tach-digital to analog converter, the signal conditioning circuits, the controller turn-on circuits, the field current regulator, and the power supplies.

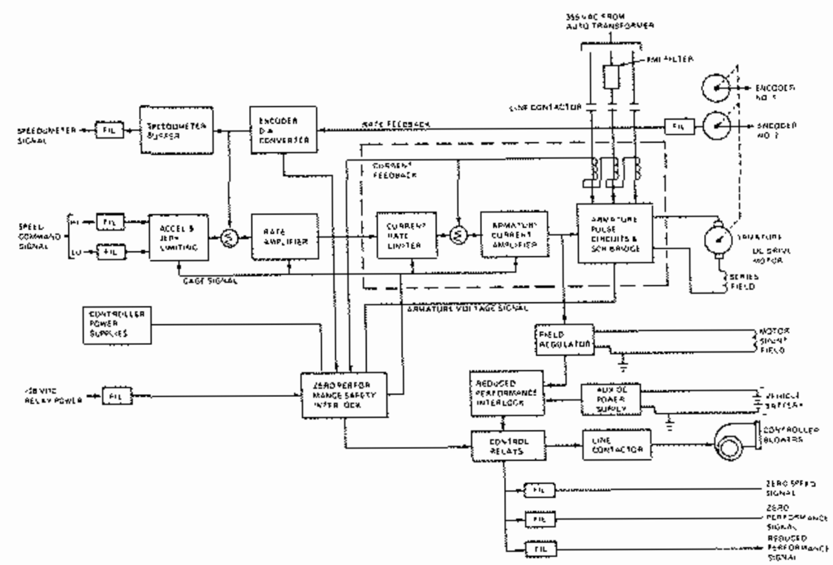
These sensors warn the system operator, through fault downlinking, when the temperature rises beyond a safe limit. The system will be shut down automatically if the temperature becomes critical.

The main 28VDC power supply and battery charger for the vehicle is located in the motor controller cabinet. This furnishes all DC loads for the vehicle and is activated whenever power is applied to the vehicle. Cooling is provided by a small fan, independent of the main blowers, which will operate only when the propulsion system is running.

The propulsion motor is a compound-wound DC motor rated at 70 hp, at 2730 rpm, with 420VAC on the armature and 25VDC on the shunt field. It has an internal fan opposite the commutator and a duct that accepts air from the controller cabinet blowers at the commutator end. Cooling air cools the motor controller first and then passes through the motor.

The tachometer drive units consist of motor shaft-mounted discs that spin through an optical transducer. The signals are conditioned in the tachometer enclosure and are then fed to the VCCS and motor controller. The motor shaft is spline-mounted to the drive shaft and drives the rear wheels.

PROPULSION SYSTEM SCHEMATIC

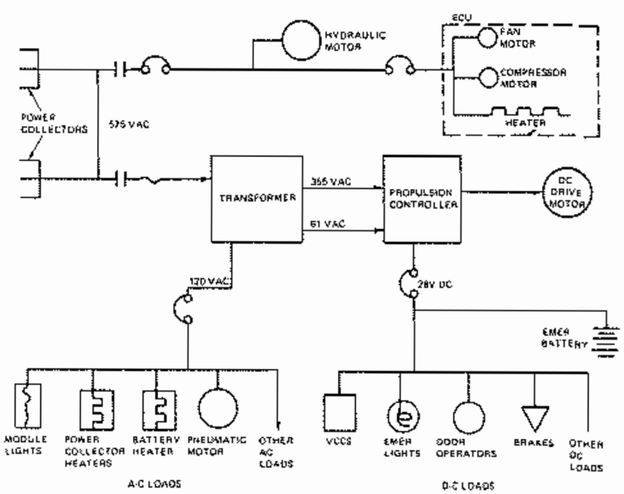


ELECTRICAL SYSTEM

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.

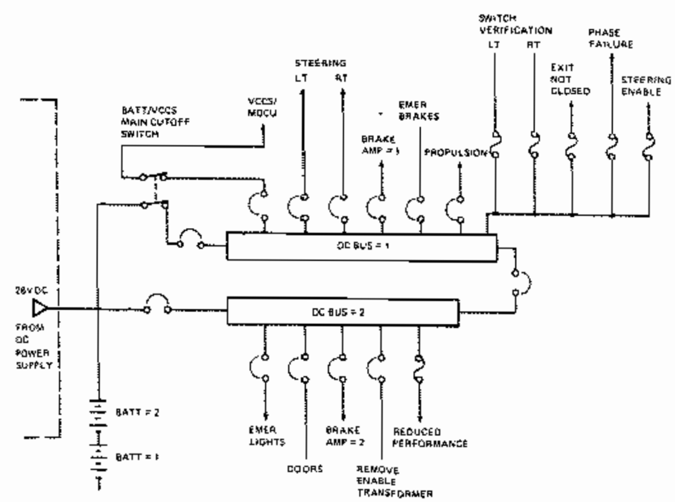
The 575VAC serves as the primary of the main transformer, as well as power for the hydraulic pump motor and the ECU system. The 120VAC circuit powers the normal module lighting, the pneumatic air compressor motor, power collectors, heaters, the battery heater, and the auxiliary receptacle. The 28VDC 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.

ELECTRICAL SYSTEM FUNCTIONAL DIAGRAM



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.

DC POWER DISTRIBUTION SCHEMATIC



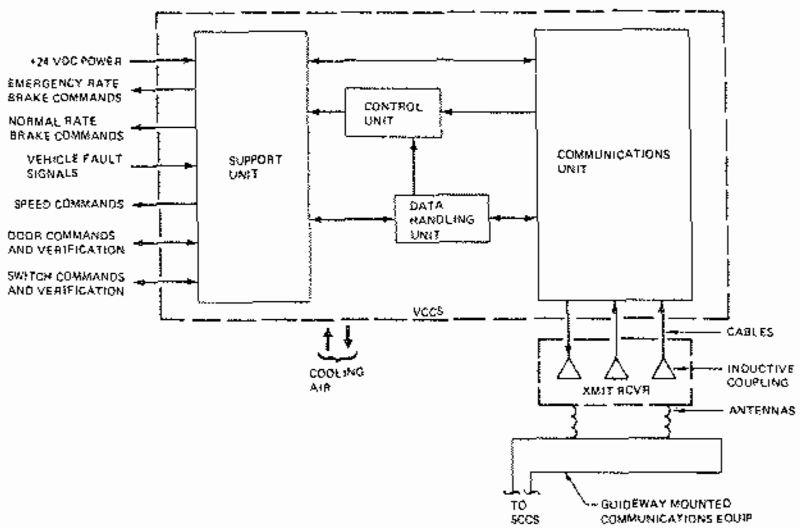
VEHICLE CONTROL AND COMMUNICATIONS SYSTEM (VCCS)

The VCCS consists of 21 printed circuit assemblies (PCA) that respond to guideway-inductive communications to regulate vehicle position (e.g., apply brakes or motor commands) and generate control functions for the vehicle. To provide this function safely, redundancy and fail-safe design principles were used; seven of the PCAs are redundant. Two separate, independent channels are provided for all safety-critical functions: the vehicle motion, switching, and door commands. Both channels are fed from separate antennas, and both must agree before the VCCS will command vehicle action.

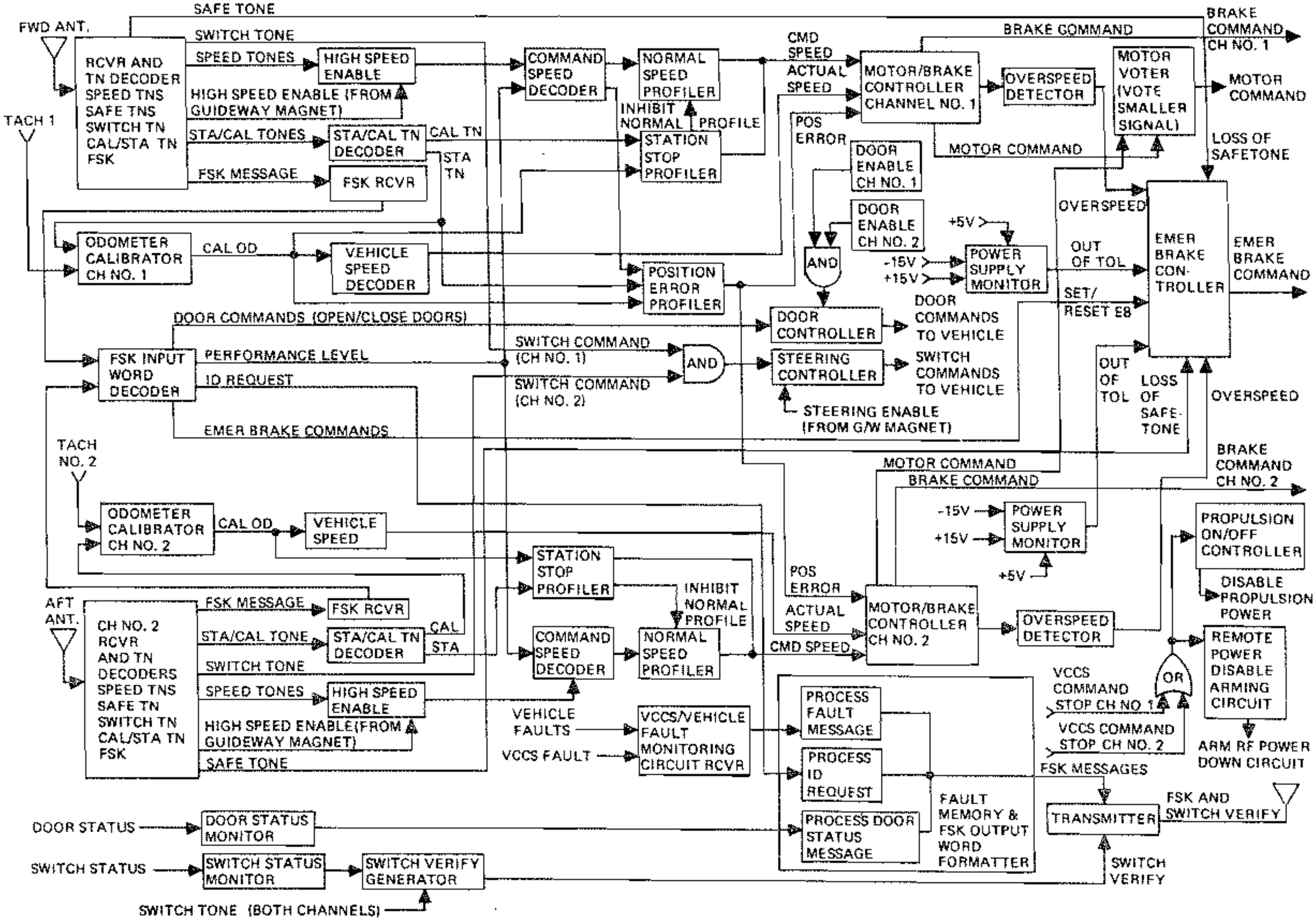
The redundant motor command outputs are compared and the smaller of the two is selected to command the propulsion system. The brake commands from each of the VCCS channels are brought directly to the respective brake amplifiers. Normal brakes will be automatically applied if the vehicle reports a loss of prime power propulsion zero performance, brake overtemperature, hydraulic accumulator low, exit not closed, or loss of both odometers. A power supply out of tolerance, an overspeed, or loss of the guideway safe tone will cause the emergency brakes to be applied. Either channel can set the emergency brakes, but once set, they cannot be reset until the fault is cleared and a reset command is issued. Switching commands are issued to the vehicle only when both channels detect a guideway switch signal and a guideway mounted magnet enables the steering controller. The VCCS will send a switch verify message downlink when physical switching has been accomplished.

Door commands are issued via the FSK uplink but both VCCS channels must provide door enable signals to the door controller before the doors will open. The door enable signal is interlocked with the zero speed signal from the propulsion system and a station stop tone. When either channel of the VCCS is commanding a full scale normal brake command, the propulsion on/off controller interrupts power to the propulsion system and the main contractor opens, removing power from the motor armature.

VCCS FUNCTIONAL DIAGRAM



VCCS FUNCTIONAL SCHEMATIC



System Maintenance Concept

SYSTEM MAINTENANCE REQUIREMENTS

73 VEHICLES
- 1.56 MILLION MILES ANNUALLY
- AVERAGE VEHICLE SPEED 14 MPH
- AVERAGE UTILIZATION 30%
- 13 HRS/DAY 260 DAYS/YEAR
- 5½ HRS/DAY 105 DAYS/YEAR

GUIDEWAY
- 8.65 MILES

5 PASSENGER STATIONS

1 CENTRAL CONTROL STATION

ANNUAL O & M COSTS

SYSTEM SAFETY REQUIREMENTS

DEVELOP CRITERIA

MANPOWER REQUIREMENTS

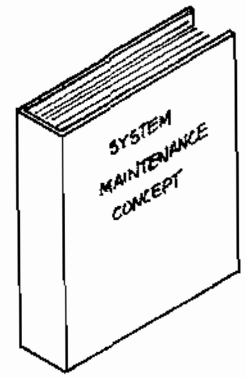
SUPPORT EQUIPMENT

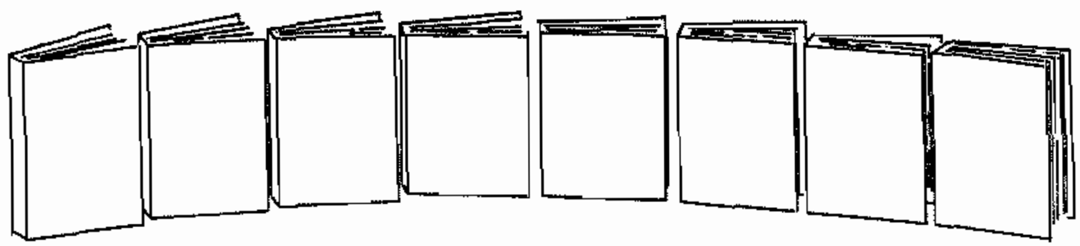
SPARES & EXPENDABLES

MAINTENANCE FACILITIES

VENDOR/CONTRACTOR OVERHAUL SUPPORT

OPERATION AND MAINTENANCE MANUALS





O & M MANUALS