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DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
WASHINGTON, D.C. 20590

MORGANTOWN PERSONAL RAPID TRANSIT DESCRIPTION

September 1975

SYSTEM ABSTRACT

The Morgantown Project is an Urban Mass Transportation Administration (UMTA) demonstration, to provide personal rapid transit (PRT) service between the central business district and the separated campuses of West Virginia University.

The Morgantown PRT system is an automated, two mode (scheduled and demand) transit system. 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. A high level of availability and reliability is afforded in terms of passenger service. The system features year-round operation, as well as direct origin-to-destination service.

The objectives of the Morgantown PRT system are to:

- Demonstrate the technological, operational and economic feasibility of a fully automatic urban transportation system.
- Determine, through system evaluation and operational experience, the potential applicability of personal rapid transit to national needs.
- Qualify the system as a candidate for use in other locations under the UMTA capital grants program.

PROGRAM MILESTONES

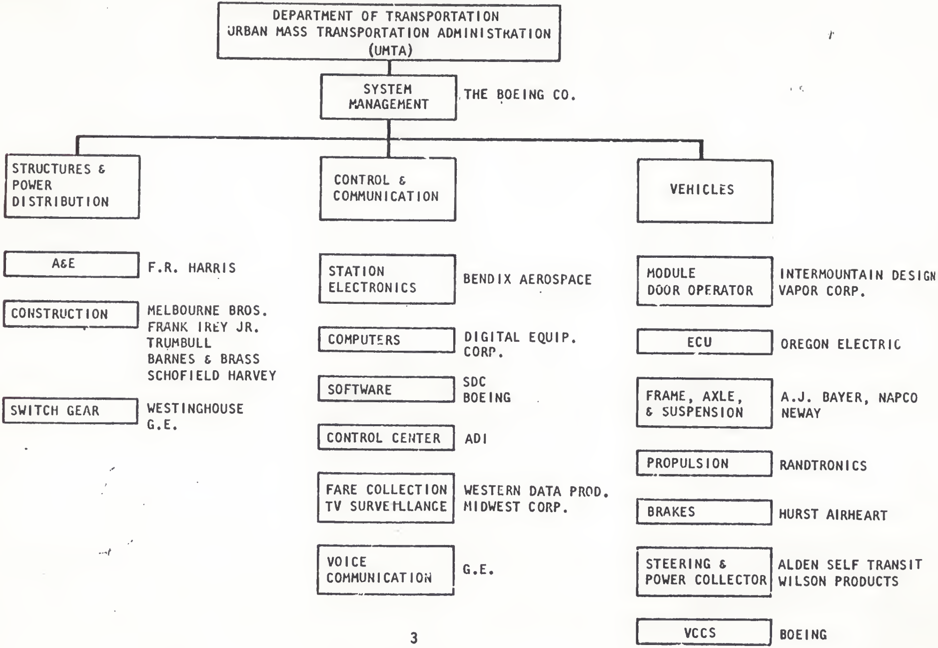
The Morgantown Program began in 1969 when West Virginia University applied for a research grant from the Department of Transportation Urban Mass Transportation Administration (UMTA) to solve its severe transportation problem in the Morgantown area. UMTA, at the same time, was seeking a realistic test site—one that had varied climatic and topographical constraints as well as periods of peak and off-hour traffic demands—to evaluate a new "personal rapid transit" system. This mutual interest led to the birth of the Morgantown project.

The following summarize the major program milestones:

- September 1970 — University grant approved.
- May 1971 — Contract for vehicle design, fabrication and test.
- August 1971 — Contract for overall system integration manager.
- October 1971 — Ground breaking ceremonies at Morgantown.
- April 1972 — First test vehicle roll-out and test runs at Boeing Seattle test facility.
- October 1972 — Dedication ceremonies at Morgantown..
- November 1972 – September 1973 — Extensive system testing at Morgantown.
- June 1973 – April 1974 — Additional testing of vehicles at Seattle

  (17,332 miles accumulated during first phase of testing in Seattle and Morgantown)
- April 1974 — Contract awarded for first production phase of project.
- June 1974 — First production vehicle roll-out.
- June 1974 – June 1975 — Extensive testing at Seattle and Morgantown (45 vehicles).
- Summer 1975 — System available for passenger service at Morgantown.

MORGANTOWN PROGRAM MAJOR CONTRIBUTORS



SYSTEM OPERATIONAL DESCRIPTION

The Morgantown PRT system is operated to meet the traffic demand measured by the service requests at the Destination Selection Units. During off-peak traffic periods the system operates in a demand mode where the passenger summons a vehicle, much like an elevator. The passenger is provided non-stop origin-to-destination service with a maximum station wait time of two minutes. During peak traffic demands, the system is operated in a scheduled mode where the passenger simply proceeds to the loading area and waits (less than five minutes) for a vehicle serving his destination.

Operation of the PRT system as summarized from the passenger's viewpoint: He arrives at the origin station on the concourse level and reads the Platform Assignment Display to determine which platform is servicing his desired destination. He proceeds up the stairs or ramp to the platform level. He inserts a coded card in the Fare Collection/Destination Selection Unit and presses a button selecting his destination. A graphic display illuminates informing him 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, he may telephone the central operator. He is kept informed of changes in the system operating status via the station public address system.

He boards when his vehicle arrives at the loading gate and the door opens. The door closes and the vehicle automatically proceeds non-stop to his destination. At the destination station the vehicle stops at an unloading gate, the door opens and he leaves the station through the exit gate.

The operation of the system elements required to provide the passenger "Personal Rapid Transit" service, as described above, is provided in the following discussion.

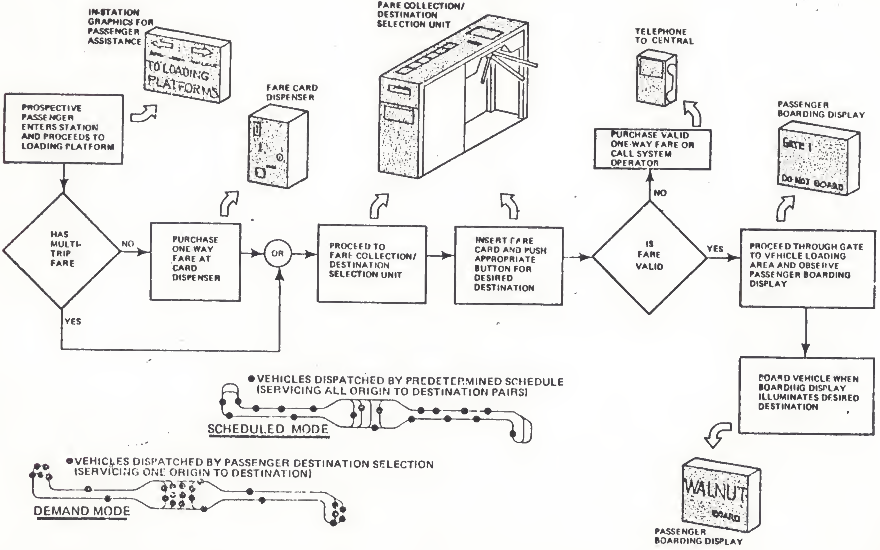
PASSENGER DESTINATION REQUEST

At single platform stations—Walnut Street and Engineering—the passenger enters the station at the street level and proceeds to the platform level. At Beechurst Station, which has two platforms, the passenger reads the Platform Assignment Display at the entry to the concourse to determine 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 at the Fare Collection Unit is required for passage through the entrance gate. A one-way fare card dispenser is available if needed. 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 in the Fare Collection Unit, he pushes the button for his desired destination. A legend then lights to acknowledge the selection. The passenger proceeds through the gate to the vehicle loading area. The Fare Collection and the Destination Selection Unit is reset when the passenger proceeds through the entrance gate.

PASSENGER DESTINATION REQUEST



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. First, the computer looks for an empty vehicle currently in the station loading position. Second, 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.

VEHICLE DISPATCH

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. The station informs central of the vehicle destination, requests a dispatch time in the demand mode, or determines if the scheduled dispatch time can be met in the scheduled mode. If a scheduled dispatch time cannot be met, a new time allocation is requested 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 clocks are synchronized with the central clock 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 eight feet per second velocity. Steering switching commands direct the vehicle from the platform channel to the acceleration ramp. On the acceleration ramp the vehicle accelerates 2 ft/sec^2 until main guideway speed is reached (22 or 33 feet per second).

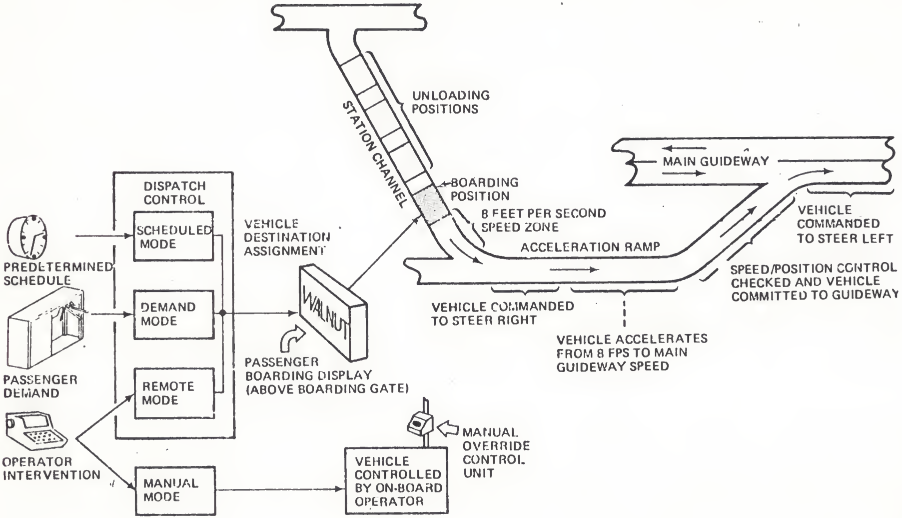
Station control monitors the dispatched vehicles presence detector data on the acceleration ramp to assure that guideway speed is reached and that the assigned slot position is followed. If the speed and position (time of presence detector actuation) are within tolerance the vehicle is permitted to proceed to the main guideway. The vehicle steers right on the acceleration ramp past the merge point on the main guideway and then is 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.

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.

VEHICLE DISPATCH



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, it is interrogated for its identification. At the destination station the ID is recognized as appropriate. 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.

IN-STATION VEHICLE MANAGEMENT

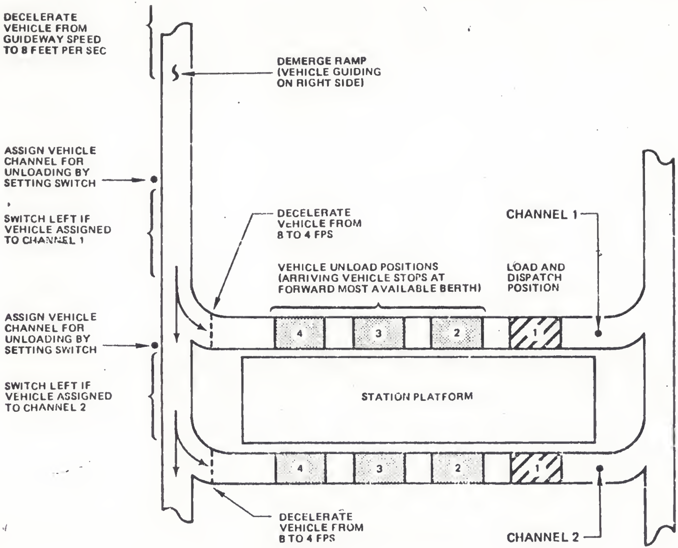
The station computer system controls in-station vehicle movements with overall direction from the control center. Routing of an incoming vehicle to an unloading berth is based on: (1) channel assignment and station fill policy, (2) the availability of an open berth.

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 energization 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.

IN-STATION VEHICLE MANAGEMENT



PRT SYSTEM ELEMENTS

The Morgantown PRT System consists of three major system elements.

These are:

- A Structures and Power Distribution System

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

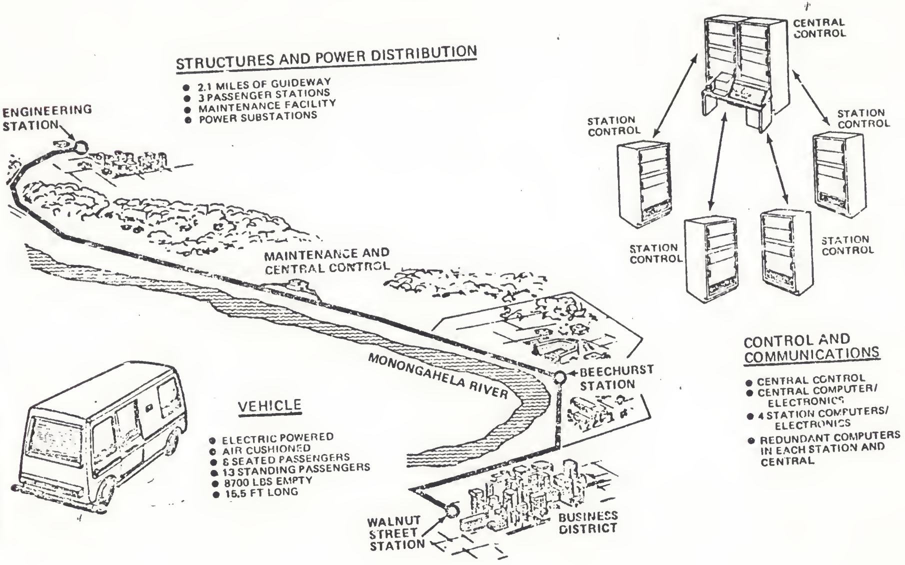
- A Control and Communications System

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

- A Vehicle System

  Includes all the vehicles in the system

PRT SYSTEM ELEMENTS



GUIDEWAY

The guideway structure is a limited access route connecting the PRT stations and the maintenance facility. Approximately 65% of the guideway is elevated, the remainder being 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 27,776 linear feet of guideway network is installed with grades up to 10%. Curves that are superelevated 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 6.5 minutes later at the Evansdale Campus (Engineering Station), a distance of 2.1 miles, any time of day or night. An average speed of 18 miles per hour is achieved and a time savings up to 15 minutes compared to conventional traffic.

PASSENGER STATIONS

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

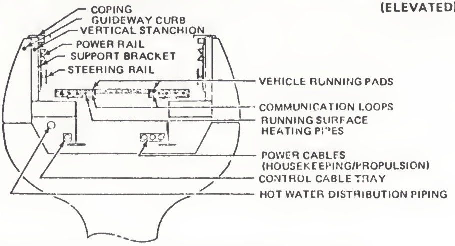
Two types of passenger stations are utilized, end-of-line and off-line. As the name indicates, end-of-line stations are located at the extremities of the system (Walnut and Engineering). The off-line station (Beechurst) allows vehicles to either by-pass or stop, providing passenger non-stop service. 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 has one loading position and two or three unloading positions.

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 PRT system. The stations are designed to provide full passenger service without a station attendant.

MORGANTOWN PRT GUIDEWAY

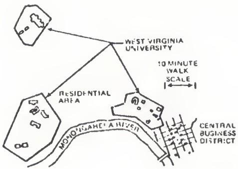
SINGLE GUIDEWAY CROSS SECTION (ELEVATED)

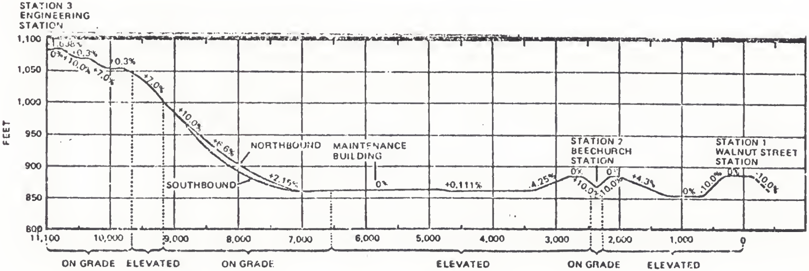
DOUBLE GUIDEWAY (ELEVATED)



NOTE:
THE CROSS SECTION SHOWN IS AT A TRANSITION POINT WHERE DUPLICATE POWER AND STEERING RAILS ARE PROVIDED (MERGE AND DEMERGE POINTS)

SCOPE OF WEST VIRGINIA UNIVERSITY TRANSPORTATION NEED

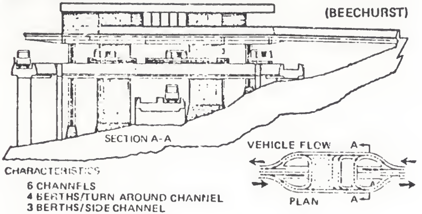




MORGANTOWN PRT PASSENGER STATIONS

GUIDEWAY FLOW RATE: 240 VEHICLES/HOUR
STATION CAPACITY: 22 VEHICLES
PASSENGER FLOW RATE: 8400 PASSENGERS/HOUR

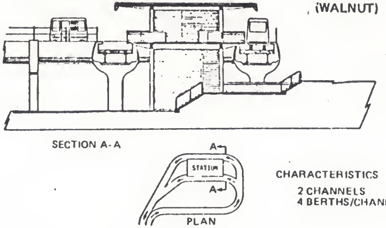
OFF-LINE STATION (BEECHURST)



CHARACTERISTICS
- 6 CHANNELS
- 4 BERTHS/TURN AROUND CHANNEL
- 3 BERTHS/SIDE CHANNEL

STATION CAPACITY: 8 VEHICLES
PASSENGER FLOW RATE: 3360/HOUR

END-OF-LINE STATION (WALNUT)



CHARACTERISTICS
- 2 CHANNELS
- 4 BERTHS/CHANNEL

MAINTENANCE FACILITY

The maintenance facility provides for operation, maintenance, test, cleaning and storage of the vehicles in the Morgantown PRT system. The facility is comprised of a maintenance building and associated guideway. The building houses a maintenance control room, 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 and a vehicle wash area.

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.

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 guideway 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 plant 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 the fluid level in the expansion tanks to an acceptable level.

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. If a boiler doesn't fire when required, the water/glycol level is low, or a fire exists in the boiler plant an audible alarm will be sounded at Central Control and the system operator must then take appropriate action.

POWER DISTRIBUTION DETAILS

The propulsion substations receive power from the 23-kV distribution cables and deliver 575-volt, 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).

A 1000-kVA, three-phase transformer provides the power for the rails. The switch gear is electrically operated to permit remote control.

The housekeeping substations are located with the passenger stations and maintenance center, and provide power for lighting, heating, cooling, and operation of noncritical displays and the uninterruptable power supplies (UPS). Heavy electrical loads, such as for cooling and ventilation, are supplied from three-phase 480-volt power. Lighting is supplied from 230/115-volt circuits. The housekeeping substations also provide for operation of pumps and boiler controls for the guideway heating system.

A 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.

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 allow thermal expansion of the rails. Electrical continuity is maintained across the expansion joints to avoid arcing of the collector brushes.

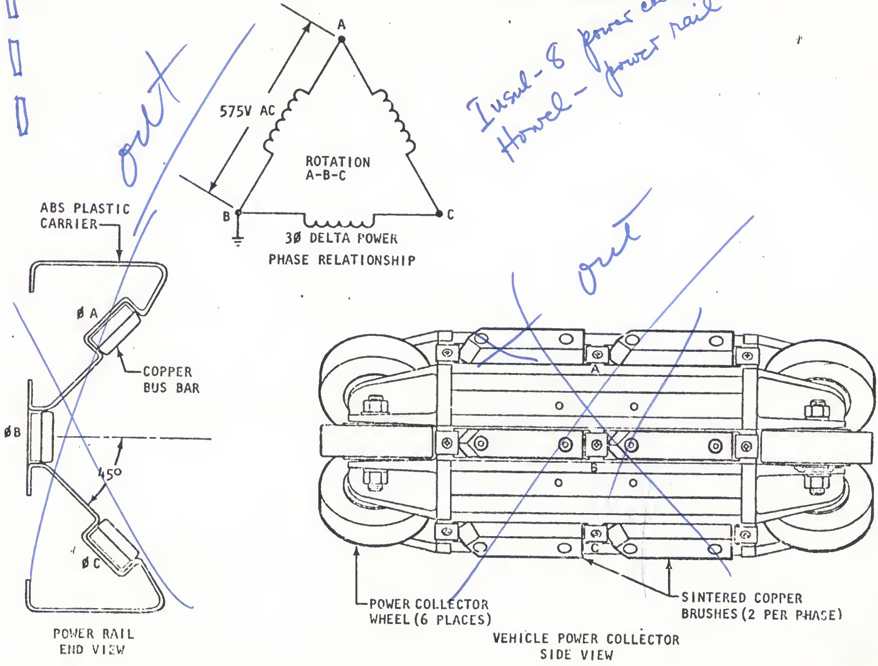
The guideway power rails are connected to the propulsion power substation transformer secondaries through remotely controlled circuit breakers operated from the control center. Independent circuit breakers are provided so that the main guideway on either side of a passenger station can be operated independently, 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-volt 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 to protect the propulsion power system from internal transformer faults fed from the other propulsion power substation transformers via the guideway power rails.

There are seven guideway segments that 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 only be accomplished manually, and only when the software senses that there are no doors open.

The 575-VAC power is distributed by copper bus bars inset in and attached to the plastic carrier. A smooth copper surface is provided to reduce brush wear and arcing by attaching the copper bus bars by means of welded on studs everywhere on the guideway except at the leading edge of curves. Here through bolts are added for an extra margin of safety for protection against stud breakage.

Vehicle power is picked up from the power rail by the power collector that rides on the power rail as the vehicle travels along the guideway. The power collector is shaped to fit the angle of the power rails and power is transferred by sintered copper brushes, two for each phase, that contact against the bus bars. The brushes are compliant so that they may contour to the rails and maintain a constant force against the rails. The load of the collector assembly against the rails is mainly taken up by the six wheels that ride on the individual bus bars.

POWER RAIL/COLLECTOR ARRANGEMENT



Insul-8 power collector
Howel - power rail

out

out

ELECTRICAL POWER DISTRIBUTION SYSTEM

The electrical power distribution system provides the prime power necessary to operate the Morgantown PRT system. The power system is comprised 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 as well as its adaptation to the automatic control system.

The system receives 23 KV, 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 23 KV 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 23 KV input power to 575 volt, 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 volt, 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 to obtain the required regulation and continuity of operation. Standby power generation is provided for critical control and communications, 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 facility. All communications, commands, station signals, and the management thereof are the responsibility of the C&CS. The C&CS provides dynamic graphics and other communications for passenger assistance.

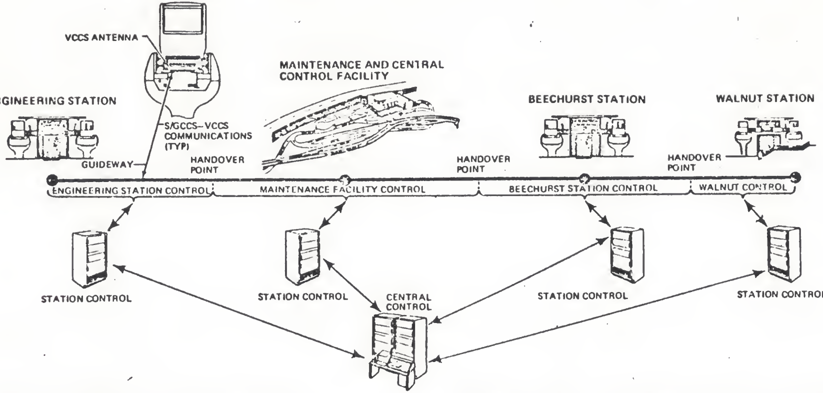
The C&CS consists of dual central supervisory computers, dual station control computers, and the communication links between central control and each station. The C&CS also includes guideway and onboard vehicle control and communications equipment. The C&CS is divided into the following functional areas:

- CCCS—Central Control and Communications Subsystem
- SCCS—Station Control and Communications Subsystem
- 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 to a primary computer.

CONTROL AND COMMUNICATIONS SYSTEM



STATION/GUIDEWAY CONTROL FUNCTIONS

- VEHICLE IN-STATION CONTROL
- INDEPENDENT COLLISION AVOIDANCE
- PASSENGER DESTINATION SELECTION
- GUIDEWAY DATA COMMUNICATION
- VEHICLE CONTROL/MONITOR

CENTRAL CONTROL AND COMMUNICATION FUNCTIONS

- VEHICLE SCHEDULING
- SYSTEM CONTROL/MONITOR
- DATA COMMUNICATIONS WITH STATIONS
- SYSTEM MAINTENANCE INFORMATION
- SYSTEM SYNCHRONIZATION

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 to handle 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.

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 FSK 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 CCCS, SCCS, and VCCS controls 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 safetone 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 safetone from the block immediately behind. If a trailing vehicle violates the "OFF" block, it stops on emergency brakes. In each leg of a guideway merge area, one safetone is normally off. This safetone 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 safetone is normally off. This safetone 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.

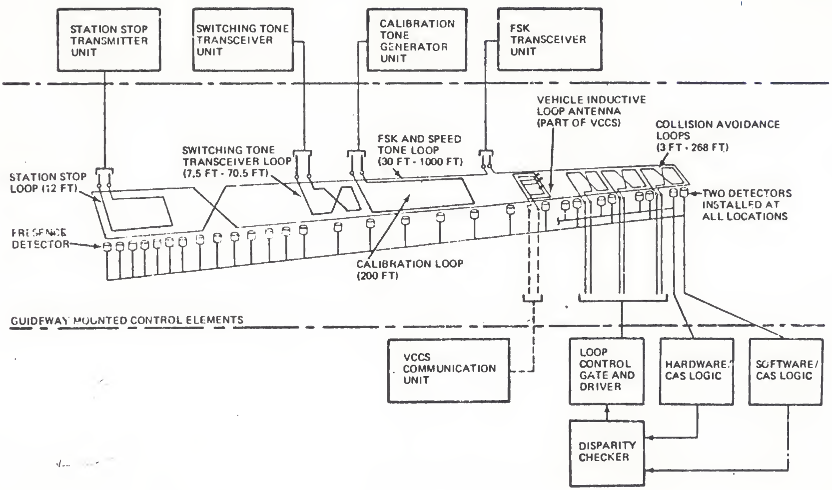
Switching Tone Loops. The switching tone transmitter generates a signal to command the vehicle to "steer left" or "steer right." The vehicle is sent a switch command at every guideway juncture (merge and demerge). The vehicle must verify that switching has been accomplished or it is brought to a stop.

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.

FSK and Speed Tone Loops. The FSK transceiver unit transmits performance level, brake commands, door commands and identification request 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.

Changed 32 fault isolation channels.

GUIDEWAY CONTROL AND COMMUNICATIONS CHARACTERISTICS



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 programs.

The Station/Guideway Control and Communications Subsystem (S/GCCS) controls and monitors local transit system operations at the three passenger stations and the maintenance facility. The S/GCCS equipment is located at each passenger station, at the maintenance facility, and throughout the guideway network. Equipment associated with the S/GCCS 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 programs. 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.

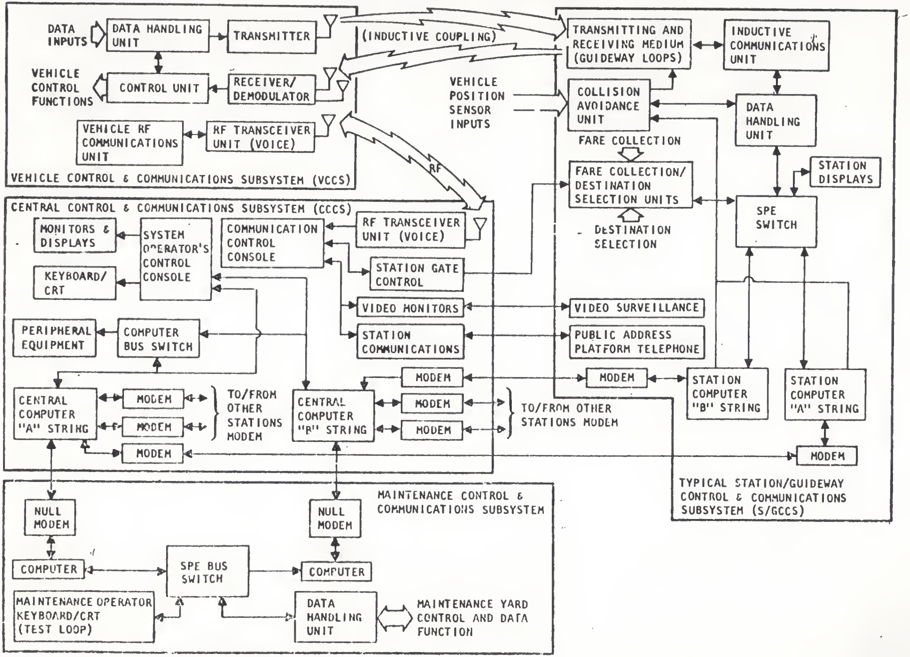
The C&CS software subsystem uses real-time operational programs to manage and control a fleet of vehicles between the three passenger stations and the maintenance facility. The software subsystem is modular and is readily adaptable to an expansion of the system.

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



COMMUNICATIONS 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:

a) Station public address selector panel
b) Control/monitor panel
c) Vehicle radio control unit
d) Public and passenger service phones
e) Maintenance radio unit
f) 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 vehicle radio control unit and the operator can return or initiate passenger communications 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. A sign at Beechurst to close or open the "A" platform is also remotely controlled from this console. This allows efficient flow of passengers at Beechurst to be maintained by Central Control.

VOICE COMMUNICATIONS NETWORK

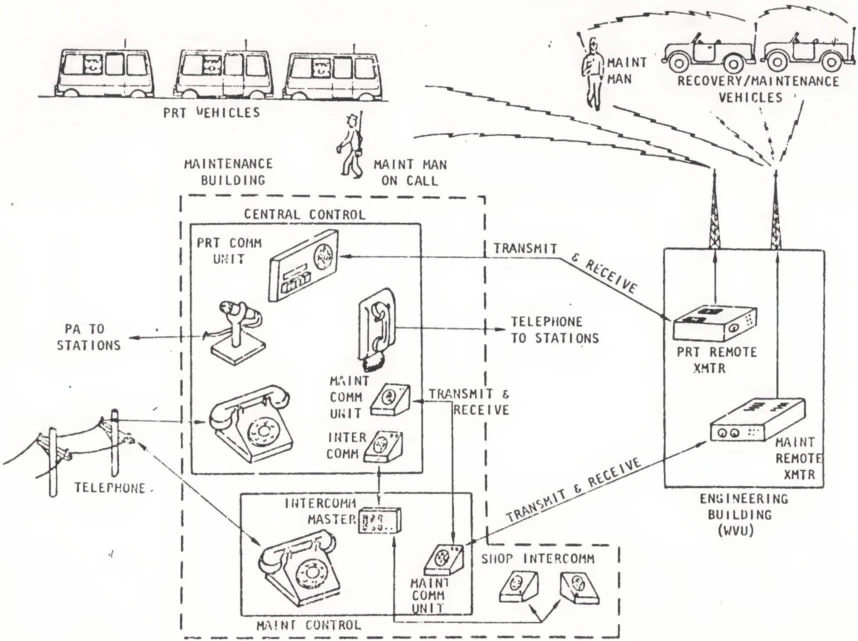
The PRT system uses various methods for communication from central control and maintenance control. Normal telephone communications are provided to each of these areas as well as to the normal office area. The central control area has one unlisted number that has been given to local police, fire, and 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. The recovery and maintenance vehicles are equipped with two-way radios, and hand-held units are provided such that maintenance personnel can be in contact with central from anywhere in the system. Paging ability is also provided so that off-duty personnel can be summoned, if needed, anywhere in the Morgantown area.

The UHF radios are hardwired to remote transceivers on top the WVU Engineering Building. Separate antennas on top of that building allow vehicle and maintenance communications to be held simultaneously. Central control can both monitor and talk as desired over the maintenance frequency. Intercom units are also provided between central control, maintenance control, and the shop area of the maintenance building.

VOICE COMMUNICATION NETWORK



STATION/GUIDEWAY CONTROL AND COMMUNICATIONS FUNCTIONAL DESCRIPTION

The S/GCCS equipment is located at each station in the system and at maintenance, and consists of dual station computers and modems, a Data Handling Unit (DHU), an inductive Communications Unit, a Collision Avoidance System (CAS), and operational service equipment for passenger interface.

The data link between the S/GCCS and the CCCS is a hardwired, 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 either 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, except for maintenance, 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 link between each SCCS and the vehicles on the guideway is an inductive communications link that transmits vital signals by tones and nonvital signals by FSK digital data message transmissions. Inductive communications are accomplished by guideway-embedded loop antennas that are connected to associated transmitter and receiving units in the station equipment room, and by vehicle-borne receiving and transmitting antennas that couple signals to the vehicle VCCS electronics.

STATION COMPUTER CONFIGURATION

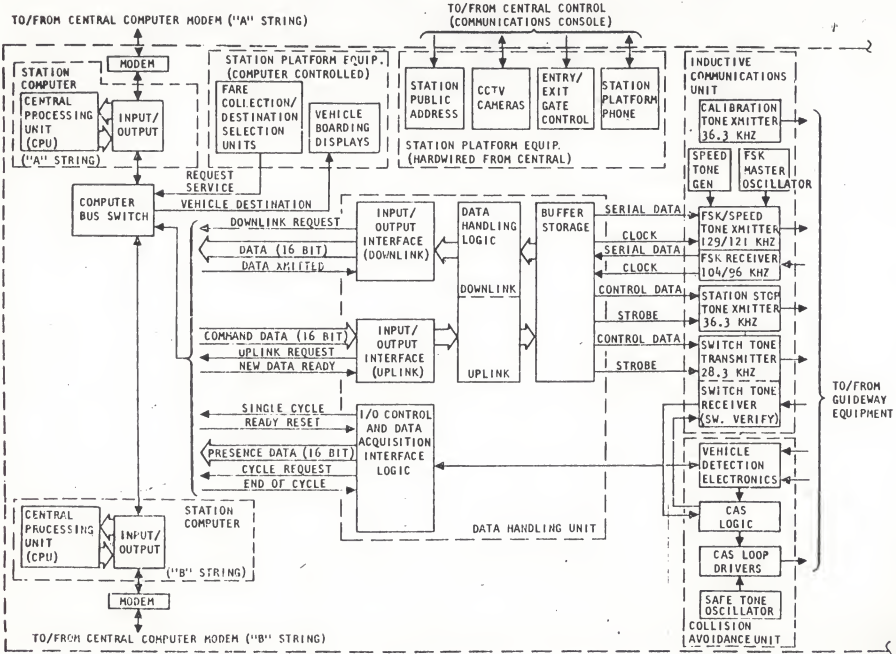
Each station computer consists of PDP 11/20 or 11/40 computers in a dual (two string) configuration, which is the primary control and monitoring element of the S/GCCS. The principal operating elements of each station computer are: a KH11 CPU, the MM11F core memory (20K), the KE11A extended arithmetic unit, and the KW11P programmable real-time clock. All station electronics equipment input/output devices are connected to the special purpose equipment (SPE) kit switch, which switches from the primary computer string to the backup string if a malfunction is detected.

Each computer interfaces with the station DHU by DR11 interface devices. A DR11C provides an input channel for direct parallel transfer of 16-bit presence data words into the core memory under the control of the CPU. The DR11A interface units provide buffer storage for parallel transfer of 16-bit computer generated command (output) messages. A DR11C provides an input channel for FSK status messages under the control of the CPU. Appropriate control signals are also provided between the interface device and the DHU to effect the transfer of data. The control signal sequence and functions are discussed under data handling functions.

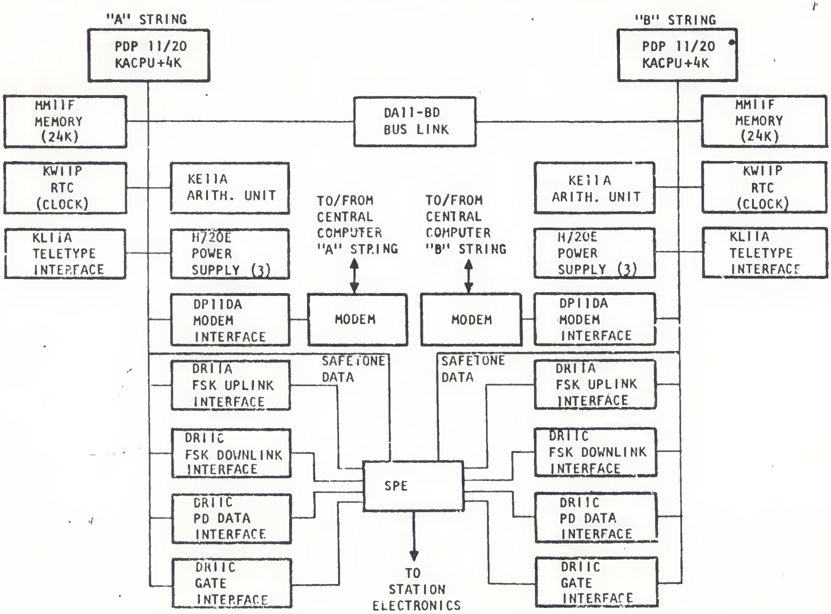
The computer interface with station platform equipment is via Gate and Display SPE. The SPE receives destination request input signals from destination selection terminals in each fare collection/entry gate and provides a data received signal back to the gates as well as vehicle destination signals to the passenger boarding displays.

Finally, the station computer contains a KL11A teletype interface unit that is provided to accommodate an ASR-33 keyboard printer at any of the stations. This interface will be used only when the station is initially being started up or while it is performing station diagnostics during maintenance.

STATION/GUIDEWAY CONTROL AND COMMUNICATIONS FUNCTIONAL DIAGRAM



TYPICAL STATION COMPUTER CONFIGURATION



COLLISION AVOIDANCE SYSTEM CONCEPT

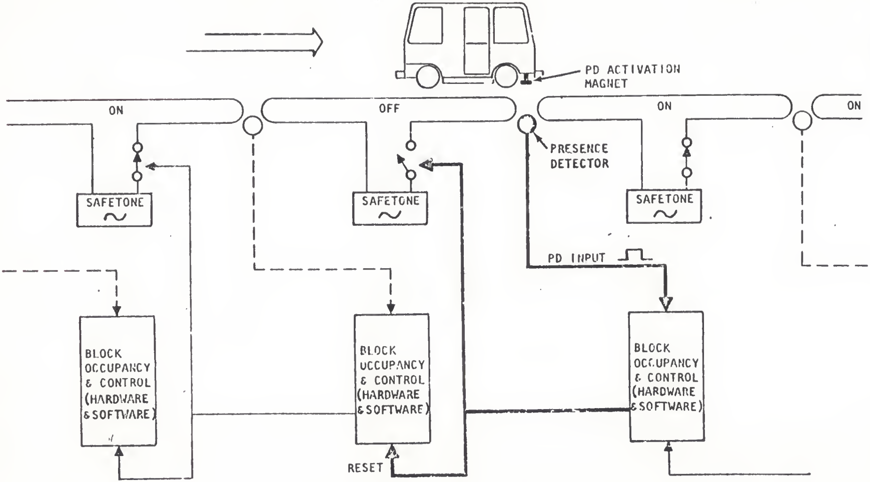
An independent Collision Avoidance System (CAS) is used to prevent collisions in the event of failure of the primary vehicle controls. The CAS is a block control system which transmits a safetone to the vehicle in a block if it is safe to proceed. Protection is provided by turning off safetone in the 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 used in the CAS. "Normally-off" 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 safetone 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 safetone 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 utilizes special purpose logic circuits to accomplish block control. Both logic paths must agree on block occupancy or safetones 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, safetones 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 irrevocably stopped. 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.

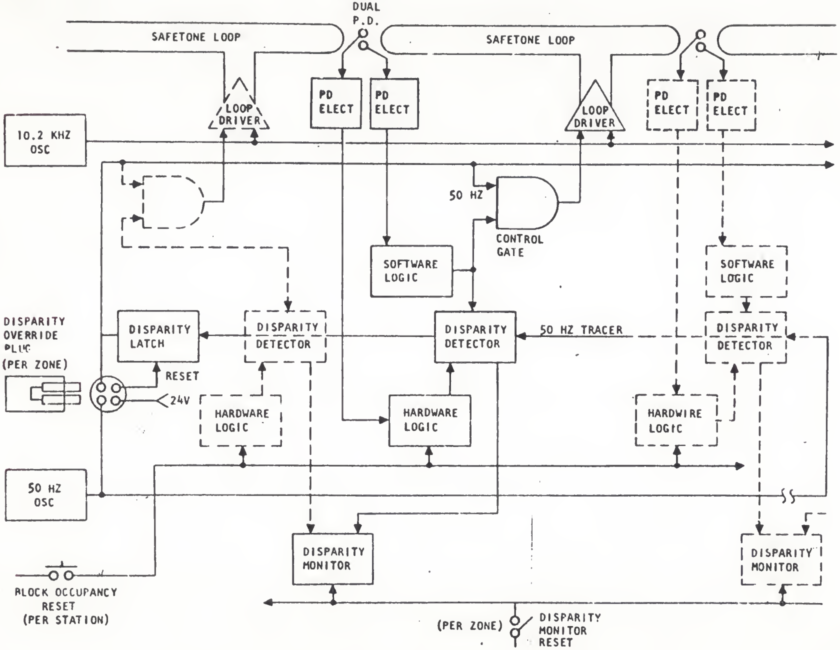
The CAS is redundant for block logic functions up to the interface with the disparity checkers. One CAS logic path enters the station computer where software computes the proper block occupancy, and commands safetones on or off. The other logic path is accomplished in special logic hardware which computes the same occupancy, but provides an output only to the disparity checker. Inputs to the two paths are provided by independent presence detectors located on the guideway at the beginning of each block. Presence detector signals are converted to appropriate logic levels by redundant P.D. electronics circuits. After processing by the station computer, the safetone command is routed to a control gate which passes the 50 Hz modulation signal to the safetone 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 safetone modulation frequency is obtained from a master oscillator in the Maintenance facility. This 50 Hz frequency is first distributed to each station, and 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 disparity occurs, the 50 Hz tracer is interrupted causing the zone disparity latch to latch open, and modulation is removed from the loop drivers in that zone. This causes loss of safetone 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 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" safetone at the switch is turned on allowing the vehicle to pass. The latches are reset when the vehicle triggers the next P.D.'s clearing the switching block.

At merges, a special purpose block control circuit receives P.D. 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" safetone in either leg of the merge is turned on 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 safetone state must be in agreement with the hardware path or zone disparity will occur.

CAS FUNCTIONAL DIAGRAM



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, 575 volt 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, the air conditioner, the hydraulic and pneumatic pumps, the control system, and charges the batteries. The pneumatic system provides an automatic vehicle leveling control and extends the power collector arms to contact 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).

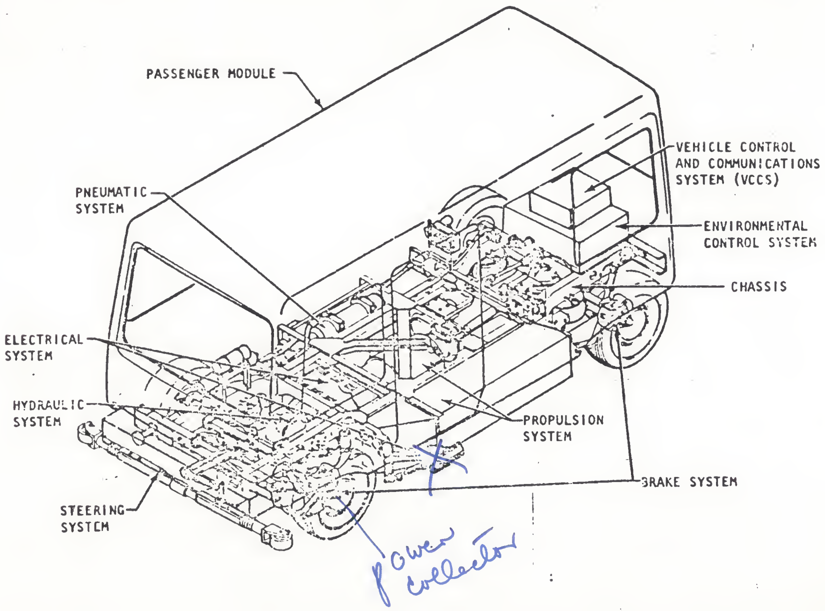
- PHYSICAL CHARACTERISTICS

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

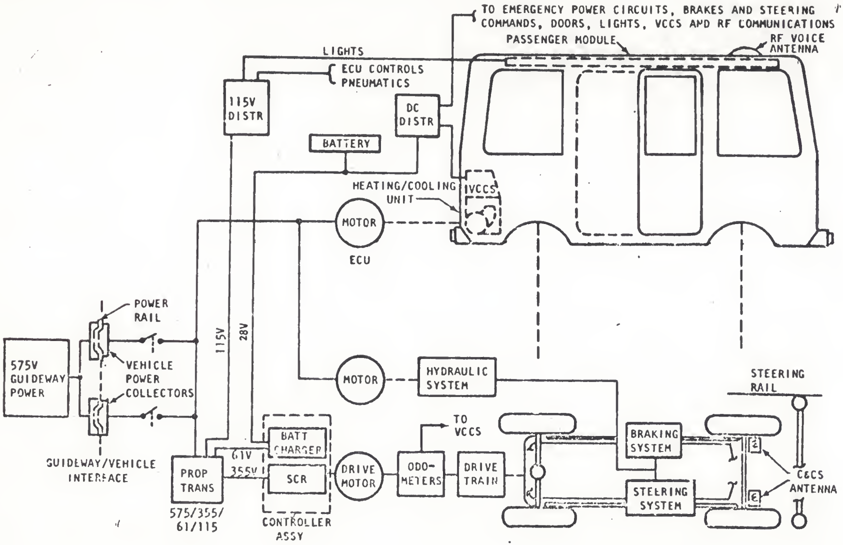
- PERFORMANCE CHARACTERISTICS

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 VEHICLE SUBSYSTEMS



MORGANTOWN PRT VEHICLE FUNCTIONAL SCHEMATIC



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, 24-VDC lights that are powered by on-board batteries automatically come on. The doors are also powered by 24-VDC 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, the vehicle will apply the 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 windows are large for a pleasant view, yet are strong enough to contain passengers within the module in case of an emergency. A UHF radio is also provided for emergency voice communication to and from central control.

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 dips below 65°F. The cooling capacity is approximately equivalent to two tons at 100°F ambient. The heaters are electrical units (575 VAC) with a heating capacity of approximately 4.5kW.

The air in the module is drawn in through the grill in the aft end of the passenger compartment, is conditioned by the ECU, and is fed back into ducts on either side of the vehicle that carry and exhaust the air around the light fixtures in the ceiling of the vehicle. Approximately 20 percent of the air circulated comes in as outside air through a small grill on the outside of the vehicle, near the left rear wheel cutout.

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 units 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 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 by 6.75, 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 SYSTEM

The hydraulic system provides the energy to steer and brake the vehicle. There are two hydraulic systems that share common returns and reservoir: the bias switching and brakes share one system powered by a variable-volume pump; and the power steering is served by the other system through a fixed-volume pump. Both hydraulic pumps are driven from a common 575-VAC, 3-phase motor. Operating pressure is approximately 1000 psig for the braking and switch system and up to 750 psig for the power steering system. Nominally the power steering requires between 50 and 400 psig.

There are three accumulators in the system: two 1/2-gallon accumulators are reserves for the redundant braking system, and a one-gallon accumulator provides the reserve necessary to operate the bias switch. There is an oil cooler in the system that automatically switches on if the hydraulic fluid temperature begins to rise above 150 degrees F. If the temperature continues to rise, a switch activates and the pumps are shut down. Pressure switches are also included to apply brakes if the hydraulic pressure drops below an acceptable value. Any disparity in the brake system pressure is monitored and displayed to the operator.

The parking brakes are spring-loaded and held off with hydraulic pressure. Thus, a loss of hydraulic pressure will automatically apply the parking brakes and stop the vehicle providing added safety to the system. Two filters continuously trap contaminants in the fluid to keep it clean and to protect the numerous small ports in the system.

PNEUMATIC SYSTEM

Modified

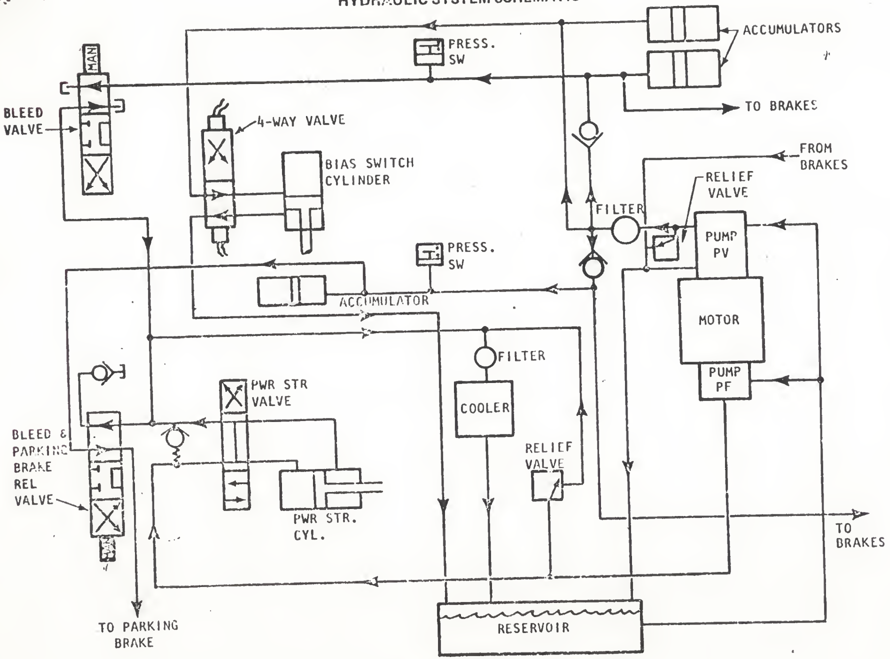
The 90 to 100 psig pneumatic system levels the vehicle and extends the power collector.

The vehicle is leveled by four air springs, one at each wheel; and three height control valves, two on the rear axle and one on the front axle. As passengers board or leave the vehicle, their weight changes would product a change in the relationship between the vehicle floor and the platform that would be undesirable. However, the height control valves recognize this change in height and through a mechanical linkage open an air valve that either allows air to flow into or out of the air springs to maintain a constant vehicle floor height.

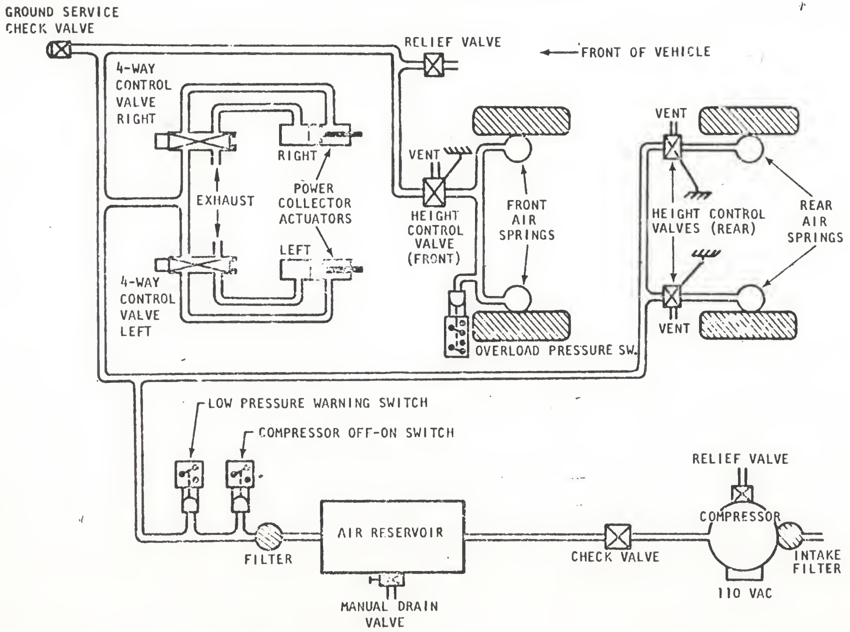
The vehicle power collectors must be held against the power rail with a relatively constant force and yet must be compliant as the vehicle sways into and out of curves on the guideway. This is accomplished by the air-type actuators, which act as translational devices and air springs. Their rate of extension and retraction is controlled by needle value orifices in the four-way control valves.

The compressor operates long enough to pressurize the reservoir and then shuts off. A low pressure warning switch warns the system operator if the pressure decays to approximately 25 psig. An overload warning pressure switch signals if the passenger load exceeds 3150 pounds, and the vehicle cannot be dispatched until some passengers exit.

HYDRAULIC SYSTEM SCHEMATIC



PNEUMATIC SYSTEM FUNCTIONAL DIAGRAM



BRAKE SYSTEM

The vehicle brake system is a dual system, either one of which can stop the vehicle safely. Every component of the dual systems is redundant and independent up to the brake pads. The brakes are discs on all four wheels, 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 900 psig) to the calipers. There are two braking modes: normal and emergency. In the normal mode, the VCCS provides an analog voltage of 0 ± 10 VDC to the brake amplifier and the servo responds with 25 to 800 psig. The emergency mode is created by an absence of a 28-VDC signal to the brake amplifier, which causes the servo valve to release up to 900 psig to the calipers. Normal rate braking provides up to .0625g deceleration and emergency rate braking is limited to .3g 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 by two solenoid valves in the system, which would open because of absence of DC voltage, by-pass the servo valves, and dump all the energy in the accumulators 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. In the event that hydraulic pressure should decay to an unsafe pressure the parking brakes would automatically come on. The pressure can be dumped, and thus the parking brakes can be applied manually from the maintenance panel on the front of the vehicle.

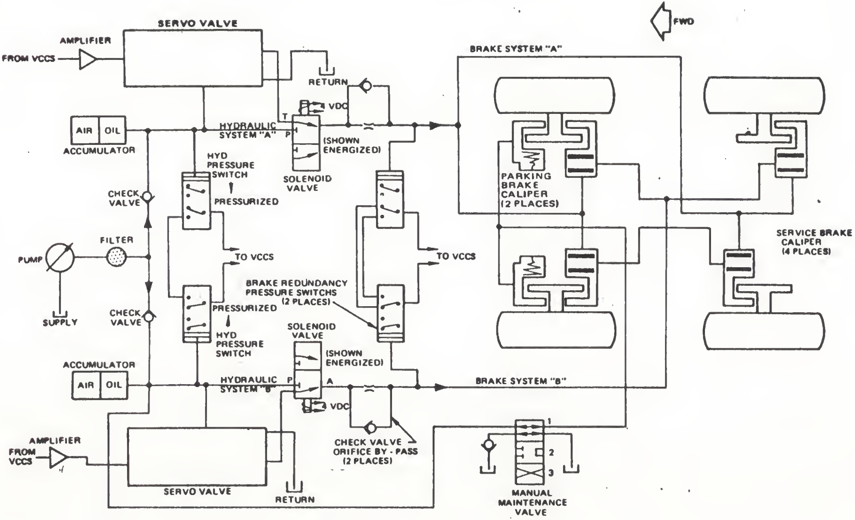
STEERING SYSTEM

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.

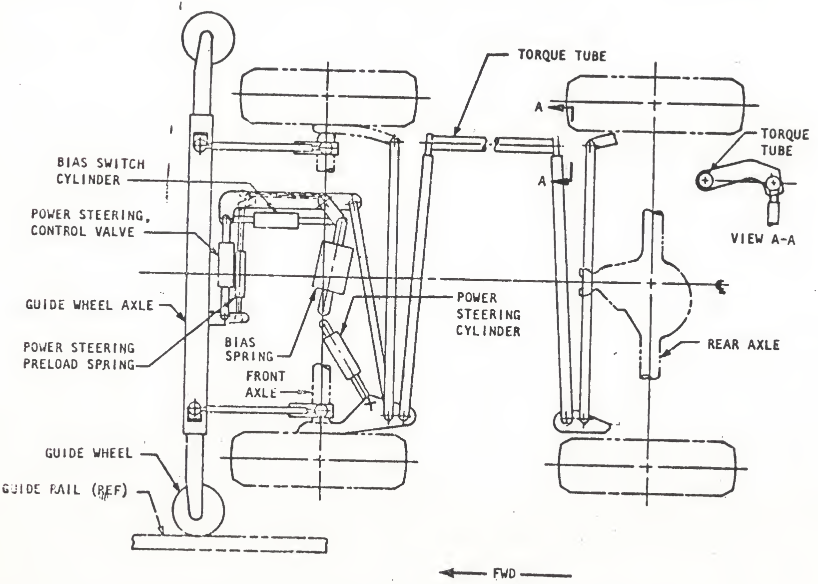
Steering forces are transmitted from the guide axle to the power steering control valve, which opens to allow hydraulic pressure to be applied to the power steering cylinder. The power steering cylinder is constantly countering the steering force being applied by a mechanical bias spring so that a force of up to 180 pounds is applied to the guide rail. The bias spring would exert a 400 to 500 pound force against the guide rail if the power steering cylinder were disconnected. If the power steering were to fail, the vehicle would continue to steer, but the tire wear would increase from the increased side load.

The vehicle will follow a guide rail or steering rail on one side of the vehicle or the other depending on whether the bias switch cylinder is positioned to the left or the right. Vehicle switching is accomplished on the vehicle as opposed to guideway-mounted mechanical switches. Switching from left to right is done by the bias switch cylinder, which moves the bias linkage over center and applies a rotational moment in the opposite direction. The power steering cylinder now receives its input from the other side of the four-way power steering control valve. A preload spring around this valve returns the directional valve dependent on whether the bias switch is in the left or right position.

BRAKE SYSTEM SCHEMATIC



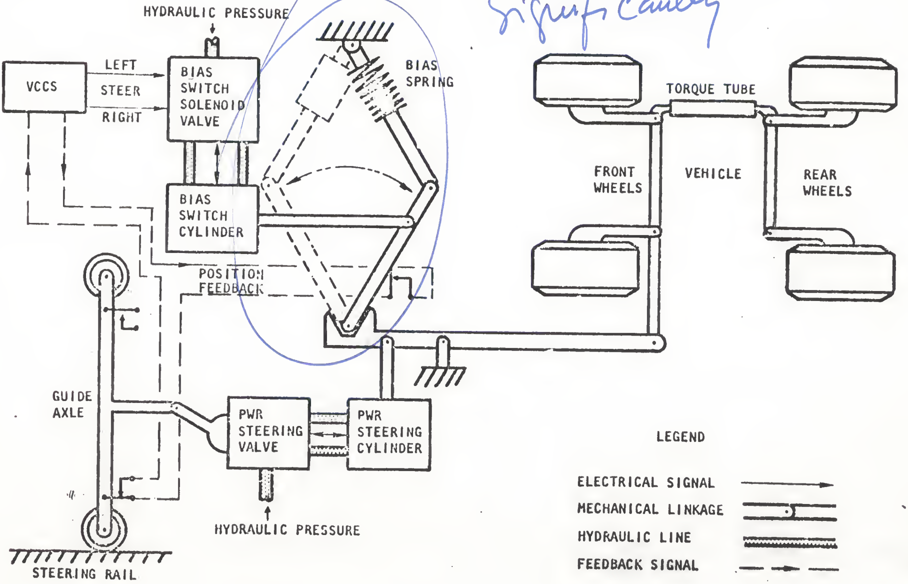
STEERING SYSTEM FUNCTIONAL DIAGRAM



changed

STEERING FUNCTIONAL SCHEMATIC

Significantly



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 575-VAC, 3-phase power to 355 VAC, 61 VAC, and 120 VAC. Temperature sensors are buried in the transformer windings, the Silicon Control Rectifier (SCR) heat sinks, and the motor to warn the system operator if the temperature begins to rise beyond a safe limit and to shut the system down if the temperature becomes critical.

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 10 VDC) provided by the VCCS, and 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.

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

The propulsion motor is a compound-wound DC motor rated at 70 hp at 2730 rpm with 420 volts on the armature and 24 VDC on the shunt field. The motor is suitable for upside-down mounting. The motor has an internal fan opposite the commutator and a duct that accepts air from the controller cabinet blowers at the commutator end. Cooling air first cools the motor controller 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 then are fed to the VCCS and the motor controller. The motor shaft is spline-mounted to the drive shaft to drive the rear wheels.

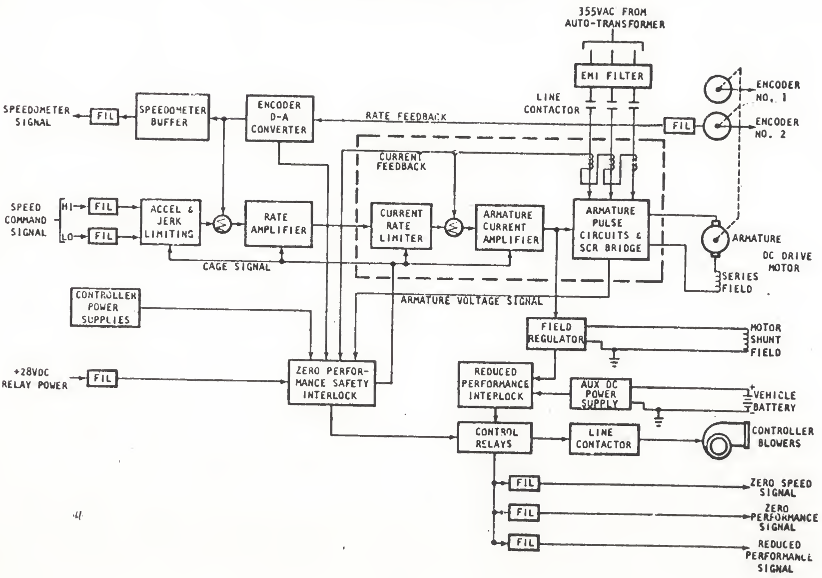
ELECTRICAL SYSTEM

The electrical system receives the guideway 575-VAC power through either the left or right power collector and distributes it in several different voltages throughout the vehicle. The vehicle requires 575 VAC, 3 phase; 120 VAC, single phase, and 26-28 VDC. The main autotransformer also outputs 355 VAC, 3 phase and 61 VAC, 3 phase for the propulsion drive and control circuits respectively.

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

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

PROPULSION SYSTEM SCHEMATIC



VCCS has been modified (simplified)

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 link between the VCCS and the station (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:

a) Brakes
b) Steering
c) Doors
d) 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 SYSTEM (VCCS)

The VCCS consists of 18 printed circuit boards (PCB) 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; six of the PCBs 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 output 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, 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 have to 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 contactor opens, which removes power from the motor armature.

VCCS FUNCTIONAL SCHEMATIC