The Ultra Control Systems

Three layers of control

The control system forms the heart of the PRT concept. Once the passenger has confirmed their destination, central control immediately begins the process for carrying out their chosen journey, which is the first of three layers of control:

- **Central Control:** Ensures all vehicles launched on non-conflicting paths.
- **Autonomous Vehicle Control:** Maintains vehicle to prescribed path using laser sensors.
- **Automatic Vehicle Protection System (AVP)**: Fixed block signalling system to ensure vehicle separation.

These systems have been subject to extensive simulation and testing over many years, with their functionality well developed and refined to produce a highly efficient, robust and reliable control system.

Central Control

The Central Control System provides a number of functions:

- Routing and scheduling of vehicles
- Empty vehicle movement management
- Fault detection and response
- Display of system information to Network Controllers

Routing and Scheduling of Vehicles

The central control system responds to the passenger's request by allocating a vehicle for the journey and instructing the vehicle on the required path and timing for that journey. Each path is

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unique ensuring there is no interaction between vehicles. This provides the first level of active safety in the system.

The control system uses a "synchronous" method which allocates vehicles to slots on the guideway in the same way as an aircraft control process. This ensures a congestion-free journey as the entire guideway route is planned out from the start.

To enable efficient station operations, vehicles are initially routed to simply to the destination station as a whole, and only as the vehicle approaches that station are instructions provided as to which berth or wait point to go to. This allows other vehicles to vacate the station as the vehicle is on route, ensuring that whenever possible, incoming vehicles are subsequently routed straight to a berth to allow passengers to alight without waiting.

Empty Vehicle Management

The central control system also provides the empty vehicle management (EVM) process which ensures that vehicles are sent to where they are needed. The EVM function attempts to keep a certain number of vehicles at each station, which is sufficient to meet the anticipated demand, and hence minimize passenger waiting times. The required number of vehicles at each station can be varied to cope with variations in the actual demand by the Network Controller.

Fault Detection and Response

The Central Control continuously receives status and fault information from vehicles, stations and the automatic vehicle protection system. Using this information it determines if there is a fault with the system and the appropriate response. It then either carries out this response automatically or informs the Network Controller of the fault and appropriate response.

This process is designed to maintain safety and operability of the system. For example if a vehicle has a fault on the guideway then the central control can either slow, stop or divert other vehicles to avoid any hazard and continue operations. In most cases reducing vehicle speeds should ensure the faulty vehicle arrives at its destination with minimal service disruption.

Information Display

The Central Control also acts as the interface between the autonomous systems and the Network Controllers. System information is displayed via a Graphical User Interface (GUI), which can show all relevant status information about Vehicles, Stations and other network elements. This interface also allows controllers audio communication with passengers either in vehicles, berths or stations.

The GUI is displayed within a single control room from which all network operations can be directed. The control room also includes CCTV displays, allowing controllers access to all visual information on the system as well as that from the central control.

Autonomous Vehicle Control

The vehicles are controlled autonomously: Once the vehicle has received its instructions from central control it will continue to its destination without any need for further central control input. On arrival at the destination station further instructions are received to specify the berth or wait point for the vehicle to go to.

In order to ensure the vehicles were designed using the most effective control mechanism, extensive tests of different vehicle control technologies were carried out. PRT performed full scale system evaluation tests at a number of sites to examine control methods based on wire guidance, embedded guideway magnets, optical and radar sensing, embedded guideway transponders and local sensors based on Ultrasonics or lasers.

Lasers sensing was found to be significantly the most reliable and robust technology and so was selected for use in the PRT vehicles. This provides both lateral and longitudinal navigation information that the vehicle uses to determine its exact location within the guideway and so follow a specified path and speed profile to complete the desired journey.

Embedded guideway transponders are also used to confirm vehicle locations when required, for example at station berths.

The vehicle control system is also fed a variety of inputs from sensors that allows it to constantly monitor the vehicle status. A HUMS (Health and Usage Monitoring System) processes these inputs to confirm that all vehicle systems are operating within normal limits. If any of these parameters fall outside the expected range this is flagged, and the vehicle can perform any appropriate response. This allows many vehicle problems to be captured early, before they become critical and have any effect on the vehicle, so minimising impact on network operations. Even in the event of a fault affecting the vehicle there are a number of different modes of operation it can adopt to complete its scheduled journey, thereby reducing the impact on other vehicles.

The vehicle has two separate hardware controllers which between them perform all aspects of the vehicle control functions. These controllers independently perform the safety critical functions required of the vehicle control system, providing diverse redundancy to give a robust safety architecture.

Automatic Vehicle Protection (AVP) System

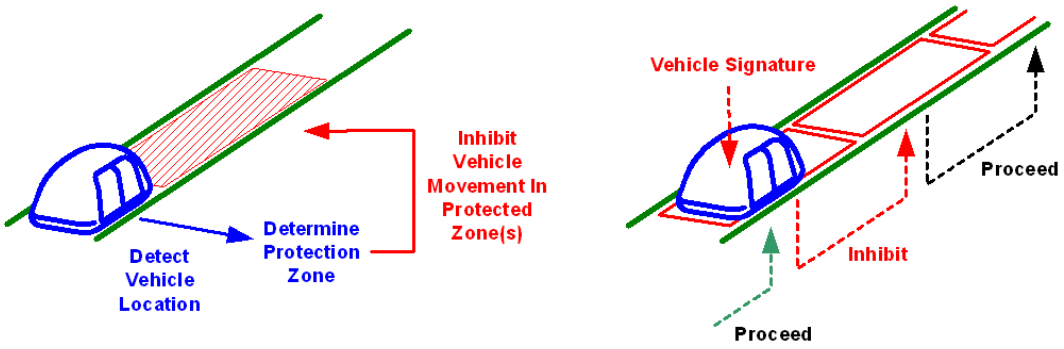
Finally, the ultimate protection for passengers on the PRT system is provided by an independent high integrity Automatic Vehicle Protection (AVP) system. The system installed at London Heathrow is based on a fixed block signalling system parallel to that used on railways, which uses inductive coupling between sensors on the guideway and in vehicles for reliable communication.

In order for a vehicle to be in motion, it must be receiving the "Proceed" signal which is continuously transmitted from the guideway equipment. Lack of the “Proceed” signal forces a vehicle to perform and emergency stop.

The guideway equipment also detects the locations of all vehicles on the network and inhibits the transmission of the “Proceed” signal in the area directly behind every vehicle, thus creating a protected zone behind each vehicle, where a following vehicle would be automatically stopped. The size of the protected zone is calculated to avoid any vehicle collisions and so is location specific dependant on the local speed profile of the vehicle.

Therefore, if in an emergency situation a vehicle was forced to stop suddenly on the guideway, any vehicle following directly behind would automatically be halted once it approached within a certain distance. The following diagrams illustrate the basic principles of the AVP system.

Vehicles far enough behind the stopped vehicle would either be pulled into a nearby station or be rerouted onto a different branch of the network before reaching the incident, in order that they could avoid the blocked link.



The AVP System employs redundant architecture so that single failures within any section of guideway do not result in any impact on operations or require that the safety system be completely switched off to allow continuing operations.

The system is continuously monitored by Central Control in order to capture any failures as soon as they occur, so that the appropriate action can be taken by the Network Controllers to maintain the safety and availability of the network. This monitoring minimizes the likelihood of the AVP system either inadvertently stopping a vehicle, resulting in a service interruption, or failing to stop a vehicle when required, potentially resulting in a vehicle collision.

The AVP system is powered from power supply units (PSUs) located in the Guideway Equipment Enclosures located periodically along the guideway. These PSUs have battery backups to ensure that this safety critical system will continue to operate even in the event of a total power failure to the network.