Towards advanced transport for the urban environment

Outline Description of the Heathrow PRT Pilot Scheme

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Executive Summary

The CityMobil project includes three demonstrations of advanced transport systems. The first of these is a pilot installation of Personal Rapid Transport (PRT) at the new Terminal 5 of London’s Heathrow Airport. The system used is ULTra, developed and produced by Advanced Transport Systems Ltd of Thornbury, UK. Four-seater battery-electric vehicles navigate automatically and autonomously along 2-metre wide guideways, carrying passengers at 35kph directly from a Business Car Park to Terminal 5. Passengers rarely have to wait for a vehicle since empty vehicles are normally already waiting at stations, and empty vehicles will be called up automatically to a station as they are required. Passengers travel individually or in the same groups they arrived in by car, and there are no intermediate stops on the journey, since stations are off-line. There are 3.8 kms of guideway, mostly elevated, and 18 vehicles.

BAA, the owners of Heathrow, intends the pilot to demonstrate and evaluate the concept of PRT. Once it is shown to work successfully, the intention is to expand the pilot system into a wide network serving the whole north side of the airport, and into a redevelopment of Terminals 1, 2 and 3 of the Central Terminal Area.

This Report describes the Heathrow Pilot PRT system, its route and guideways, stations, vehicles and control systems. Construction began in January 2007 and was completed in May 2009, including some interruptions to the work. The system will be commissioned during summer 2009, and opened to public use before the end of the year.

A preliminary description of the design of the system was provided in Deliverable 1.2.2.1 in May 2007. Since then, a few details of the system have changed. Consequently this Deliverable reiterates much of the earlier account, but it provides a detailed description of the entire project at outturn in May 2009. The main changes are to:

i) the layout of the guideway within the Business Car Park, since the design had not been finalized at the time of the earlier report;

ii) some details of the design of the interior of the vehicles, where the positioning of the seats, push buttons and information screen have changed;

iii) the frequency of the communications system was changed from 2.4GHz to 5.1GHz because the lower frequency is also used for Terminal 5’s Automated Baggage Handling system, and any possibility of interference had to be avoided.

At the time of the preliminary description some foundations for the guideway had been installed but major construction had not begun. Ownership of Heathrow Airport had changed, and understandably the new owners wished to review and re-justify all commitments. Altogether the continuing reviews postponed the construction schedule by approximately a year, and the work did not resume at full scale until spring 2008. Since then, construction has proceeded to the revised schedule with few technical or engineering problems. Even the change of communications frequency was accomplished within this planned timescale. In view of its wholly novel and innovative nature, installation of the ULTra system has been achieved remarkably smoothly.
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Outline Description of the Heathrow PRT Pilot Scheme

1. Introduction

1.1 Background

The CityMobil Project aims to achieve a more effective organisation of urban transport by developing advanced concepts for autonomous and automated road-based vehicles for passengers and goods. European cities need better transport and integrated traffic solutions that provide quicker mobility in an efficient, non-polluting, safe and economic manner.

The CityMobil project will validate and demonstrate the capabilities of new mobility solutions in different European cities. In five horizontal sub-projects the issues that still prevent full-scale implementation of innovative automated transport systems will be investigated and solutions will be developed. At three sites, Heathrow, Castellón and Rome, the project will examine and evaluate large-scale demonstrators set up to supply proof of concept of innovative transport systems integrated into the urban environment.

The first of the large-scale demonstrators is a pilot installation of Personal Rapid Transport (PRT) at Terminal 5 of London's Heathrow Airport. The owners of Heathrow, BAA, installed the system to demonstrate passenger acceptance and evaluate the concept of PRT. Once it is shown to work successfully it is BAA's intention to expand the pilot system into a wide network serving the whole north side of the airport, and running through the entrance tunnel under the main runway into the redeveloped Terminals 1, 2 and 3 of the Central Terminal Area. Thus it is not intended that the Pilot Scheme will of itself be economically justified, but it is intended to be a fully-operational PRT system and, after the Pilot phase, the system will continue to serve passengers travelling between the Terminal 5 Business Car Park and the Terminal building. The design of the Pilot system must, therefore, be as detailed and functional as the larger network. In a larger scheme PRT would operate as a network, enabling passengers to travel directly from any station of the network to any other. In this first Pilot application the system is limited to three stations, and operates essentially as a shuttle between the car park and the Terminal, though passengers will select which of the two car park stations they wish to go to. Only the expanded system will demonstrate the full flexibility of PRT. Nevertheless, this is the first full-scale and public implementation of PRT in the world.

This Deliverable describes the scheme in terms of the system concept, the route and guideway, the stations, the vehicles and the various control systems.

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1 The automated transport system which operates on the campus of the University of West Virginia at Morgantown is sometimes described as PRT. It was originally intended to operate as PRT, with small vehicles, but in the event it was provided with large vehicles and operated as an automated people mover, collecting passengers to travel together and stopping at intermediate stations in a similar way to conventional public transport. Nevertheless, it was a substantial technical achievement in its time, and has operated automatically and reliably for more than three decades without accident or any substantial injury to passengers.
1.2 Personal Rapid Transport

PRT is a fully-automated transport system using small driverless vehicles. The vehicles navigate automatically along a network of dedicated guideways with merges and demerges where guideways intersect and stations are constructed “off-line” on sections of guideway parallel to the main through route so that vehicles can stop to load or unload passengers without obstructing other vehicles. Conventional public transport involves waiting, multiple intermediate stops to allow other passengers to board and alight, a predetermined route, and interchange between vehicles operating on different service routes. By contrast, PRT offers in effect a driverless taxi, providing on-demand, non-stop transport from the origin station to any other destination station selected by the passenger on the whole dedicated guideway network. PRT has been described as a horizontal lift or elevator, since it operates on demand and travels directly to the required stop, though unlike PRT lifts frequently stop at intermediate floors. All PRT systems under current development are electric and thus (locally) emissions free. PRT systems aim to have empty vehicles waiting at stations for arriving passengers, so that there is little or no waiting. Because the electric vehicles are quiet and emit no exhaust pollutants, they can be routed through buildings where appropriate.

The system to be installed at Heathrow is “ULTra”, developed by Advanced Transport Systems of Thornbury, UK. The four-seater vehicles are the size of a small car, powered by electric motors running from lead-acid batteries, with four rubber-tyred wheels running on a 2 metre-wide concrete or metal track. Batteries are recharged in the stations. Maximum running speed is 40kph, and vehicles can climb a 10% gradient and negotiate 5m radii. They can reverse and steer backwards, offering great flexibility in manoeuvring.

The ULTra system provided the base operating parameters used in the evaluations of PRT made in the Fifth Framework European EDICT project (www.cardiff.gov.uk/edict), where desk studies were made of PRT applied at four different sites. EDICT showed that a strong case, both financial and socio-economic, could be made for PRT as an urban transport system. It is obviously easier, however, to install the first public example of PRT in the relatively sheltered environment of an airport than in a town. Even so, there is still an obvious risk in installing a completely new type of transport system. Heathrow Airport’s owners, BAA, accepted the risk of becoming the first owner of such a system because of the advantages it can offer over conventional public transport. The full strength of PRT can only be shown in a more complicated network than the relatively limited and simple Pilot system at Terminal 5, which operates essentially as a shuttle between a car park and the Terminal. In a more elaborate network, as would be developed if the system is expanded into the rest of Heathrow, PRT is able to take passengers directly and non-stop from any station on the network to any other. In the Pilot the choice of destinations is obviously very limited, though passengers will choose between the two stations in the car park.

Construction of the system began in January 2007, when foundations for support pillars were installed adjacent to the Terminal building. However, the new owners of BAA naturally wished to review all BAA’s existing commitments before accepting them. The subsequent re-examination of the PRT project led to an overall delay of about a year in the project, but the commitment and details of the plan were confirmed. Construction was completed in May 2009, and the infrastructure handed over to BAA and ATS. Meanwhile the production vehicles were being delivered and tested at ATS’s Cardiff Test Track and, on occasion, at Heathrow. The central control system was also set up at Cardiff and tested in operating several vehicles at once. This equipment was moved to Heathrow in mid-June 2009, and a six-month period of testing and commissioning began. Normal passenger operations will begin in towards the end of 2009.
1.3 This Report

This Report describes the Heathrow Pilot in each of the following aspects:

1. The route
2. The guideway
3. The stations
4. The vehicles
5. The control systems
6. Operation

2. The route

Figure 1 shows the PRT network, coloured according to whether the guideway is at grade (green), elevated (black), or inclined between the two (red), since the various sections require different design solutions. As noted above, the Pilot is limited to providing what is essentially a shuttle between the Business Car Park and the new Terminal 5, but once the concept is proven in operation it is intended to expand the guideway from the yellow section along the northern perimeter of the airport, serving several business and long-term car parks, staff car parks, car hire depots, staff offices and several hotels, with links through a 1km tunnel under the main runway and taxiways into the Central Terminal Area, which presently contains Terminals 1, 2 and 3. These Terminals will be rebuilt. The Pilot system contains 3.8km of guideway, but it is projected that by 2013 the expanded system would contain 48km of track.

In the Business Car Park PRT vehicles from Terminal 5 enter the black elevated circular guideway from where they can descend on the red sections to either of the two green station loops. Each station is at grade and has two berths. Loaded vehicles leave the stations and ascend to the elevated circular guideway, travelling anticlockwise on it, and demerge onto the red guideway heading west.

Elevated (black) guideway carries the vehicles over both the car park entrance/exit and the airport perimeter road, at a height of 5.7 metres. This section, right through to the Terminal 5 station, is double track, with vehicles travelling on the right-hand side. This follows from the nature of the Pilot as a shuttle system, but in general application most PRT guideway will consist of interconnected single-track loops. This provides for flexibility of routeing and navigation, but it also reduces the footprint and visibility of the guideway. In the Pilot application the double-width guideway has a heavier appearance, especially with the rather heavy-duty fencing fitted for construction and maintenance, and which will be retained during the proving period of the project. More elegant designs of fencing have been developed and will be used in subsequent applications.

As the guideway runs around the airfield perimeter, it has to descend to ground level again because it runs across the end of the runway, and must obey the height restrictions here. It then rises again to clear roads entering both the service lane of Terminal 5 and the multi-storey short-term car park. The double-guideway enters the multi-storey car park at third floor level, and into the Terminal 5 station on this floor. There the guideway makes an anticlockwise loop within the building, giving access to the four off-line berths, and also to several storage lanes for unused vehicles. Although vehicle batteries are charged whilst the vehicle stands in its station berth, there is also provision for charging where necessary in a separate lane.
Figure 1 Plan of system
Inset right: layout of T5 station
Inset left: layout of station in Business Car Park
The location of the Terminal 5 station is necessarily a compromise in what is essentially a trial system. Passengers arriving at the station will have to take a lift or stairs up to the Departure Level of the Terminal, two floors above, while returning passengers will have taken the lift or stairs up from the Arrivals Level on the ground floor. In later expansions of the PRT network it is likely that the stations will be brought closer to, and possibly inside, the terminal buildings.

3. The guideway

A key advantage is the relatively small size of the ULTra vehicle (see Section 5). The vehicles are battery powered, and there is no motive power cabling along the track. At grade, the track is concrete 1.6m wide between kerbs. Whilst the original concept was for a “footpath” type construction, the requirements of containment and ride quality have resulted in a heavier construction than originally intended. This is subject to further review. Where the track is elevated above roads and open spaces, it is designed to be as light and unobtrusive as possible. Because of the low vehicle loading, the structure need be no heavier than a pedestrian footbridge. Its dimensions are:

- **Overall Steel/Concrete Elevated Guideway Width**: 2.1m
- **Overall Concrete At-Grade Guideway Width**: 1.75m
- **Internal Guideway Width**: 1.6m
- **Internal Guideway Height**: 0.25m
- **Typical Elevated Guideway Headroom for main road crossings**: 5.7m
- **Typical Elevated Guideway Headroom for pedestrian crossings**: 2.5m (min)

At Heathrow the guideway is double lane for the whole distance from car park to terminal, with an external width of 3.95m. Most of it is elevated and supported on single pillars as shown in Figure 2.

The loadings to be considered in the design of the elevated sections are the direct loadings from the vehicles together with wind loadings. Important design considerations are fatigue stresses due to the repeated pattern of loading, and the consideration of dynamics and vibration. Where the elevated sections cross highways, as at the Perimeter Road, it is necessary to design the supporting columns to withstand accidental impact from road vehicles. The level of the elevated sections needs to be at least 5.7m above highways to ensure that collision loads do not need to be applied directly to the elevated superstructure.

The optimised span length is 18m between columns, and the depth of the structure is 450mm. The diameter of the supporting columns is approximately 500mm. The maximum span used for any element of the Heathrow application is 36m. A typical span of the elevated structure where it is straight comprises a pair of rolled steel hollow box section girders (450x250mm) interconnected by a series of transverse cross-beams. These
crossbeams in turn support precast concrete running tracks, with a covered cable tray between the tracks for emergency or maintenance use, as Figure 3 shows. The concrete running planks have levelling adjustments at the joints to ensure a smooth continuity.

Where the structure carries a divergence of tracks or is curved the sizes of the main structural members are increased. In order to construct the guideway from standardised prefabricated lengths and curves, super-elevation of the running tracks has been avoided. This requires some compromise in the curved elements, but simplifies construction, and works satisfactorily. A desirable horizontal radius of 30m is sought to optimise speed and comfort on the system, though smaller radii may be employed with consequent reductions in speed. At 50m radius vehicles can travel at their maximum design speed of 11 m/s. With a 20m radius the speed must be decreased to 7 m/s. Low speed manoeuvring, in stations for example, can be achieved with 5m radii at 2 m/s. Although the vehicles can climb 10% gradients, a maximum gradient of 6.25% (1:16) has been used to ensure passenger comfort.

The elevated structures are designed, as far as possible, to current British and Highways Agency Standards, as listed in Table 1, though there are departures where some of these standards do not directly address the ULTra design situation. ATS and Arup are developing a design code which captures all key issues which are specific to the guideway and infrastructure design for the ULTra system, and which may become part of a design standard for PRT systems,

![Figure 3](image3.png) **Figure 3** Guideway, showing running surfaces and cable tray between

**Figure 4** shows the double-width guideway as it approaches the Terminal 5 building, threading its way over and under the various approach roads. Especially compared to the heavy structures of the elevated roads it is markedly slim and light, even with the rather obtrusive fencing which has been adopted for this early stage of PRT implementation at Heathrow. As noted earlier, later developments will have less obtrusive fencing. **Figure 5** shows the guideway entering the short-term multi-storey car park, where the Terminal station is located.

![Figure 4](image4.png) **Figure 4** Guideway approaching Terminal 5

![Figure 5](image5.png)
Table 1  Engineering Standards applicable to the design of the ULTra system

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ULTra loading is 2.2kN/m², compared with the British Standard for a footbridge of 5kN/m², and office floor loading of 2.5-5 kN/m², a requirement light enough for the vehicles to be run through a Terminal or office building without any need for strengthening beyond the normal floor design load.

Figure 5  Guideway entering the multi-storey car park adjacent to Terminal 5
4. Stations

Figure 6 shows the layout of the guideway at the Business Car Park, with station loops at each end. The guideway descends from the 3.2 metre height of the central oval, which permits cars to pass between the northern and southern sectors of the car park, demerging to east or west depending on which of the two stations they require to access. If a passenger has directed the vehicle to the wrong station, it can be redirected back across the circular guideway to the other station.

Each station has two chevron berths, which vehicles steer into from the main throughway, when doors on both vehicle and station screen will open simultaneously, allowing passengers to alight to the side of the vehicle. While the vehicle is at rest in the station it is recharged by contacts on the underside of the vehicle sliding into contact with studs set in the floor of the berth. When the vehicle is loaded and the passenger has pressed the “start” button, the journey begins with the vehicle reversing out of the berth and then steering forwards back onto the main guideway. If a vehicle arrives when all berths are full, it will wait in the “buffer” space ahead of the station until a berth clears. This arrangement still permits empty vehicles to run past the stations if it is required to send them back to the other end of the network.

The system depot and control centre is located at the western station, where there is provision for running the vehicles off the station loop and into the depot for maintenance. Vehicles can be stored here, though mostly they will be stored in the lanes provided at the T5 station. Figure 7 shows the west station and depot, and Figure 8 shows the station with a vehicle in one berth.

In the Pilot, the network is a simple shuttle between the car park and the Terminal, and the destination is obvious, but when the network is expanded to include many possible destinations passengers will use the touch screen terminal by each berth (Figure 9) to select from a list of destinations. For the Pilot, passengers merely use the terminal to activate the system, which opens both station doors and vehicle doors simultaneously or, if no vehicle is in the station, to call up an empty vehicle. At the T5 station, however, the passenger will have the choice of the two car park stations, and will select the one nearest to where he or she has parked the car.
When the doors are open, the passenger or passengers enter across the level floors and, once seated, press the “start” button by the side of the door, and the vehicle will set off once it receives confirmation from the control system of a clear slot for the journey. If no vehicle is waiting, when the passenger touches the call button on the touch-screen terminal, he or she will be told that a vehicle will arrive within a stated time, which will normally be less than a minute.

Figure 7 Station A in the Business Car Park, and the Vehicle Depot

Figure 8 Car Park station with vehicle in bay

Figure 9 Touch-screen terminal at station

Figure 10 Layout of the Terminal 5 station

Figure 10 shows the layout of the Terminal 5 station, with four chevron berths. This lies within the covered multi-storey car park, and does not need a separate building. The glass screen between the station access from the Terminal and the berths contains the automatic doors which operate in synchronicity with the vehicle doors. The passenger selects the required car park station from the touch-screen terminal by each door. Vehicles enter the chevron berths forwards, and depart by reversing out, just as in the Business Car Park stations.
5.5. Vehicles

The system will have 16 vehicles in operation, plus another two on standby or in maintenance. ATS has a further three vehicles for development purposes, but if it proves necessary to provide sufficient capacity these may also be made available to the Heathrow system.

ULTra vehicles are four wheeled with rubber pneumatic tyres. The vehicles are front-wheel steered and have conventional damped spring suspension. The vehicles comprise an aluminium ladder rack chassis on which the majority of the vehicle propulsion and guidance equipment is mounted. The vehicles have been built by ARRK Technical Services Ltd, Basildon UK, and the chassis is shown in Figure 11, where the rubber tired wheels and traction motor can be seen.

Sitting on top of the chassis is an aluminium honeycomb floor. The body shell is constructed of a steel frame and an ABS panel body that can be fitted with single side or double side electric doors. The vehicle interior and exterior bodywork design can be made to suit individual client demands. The vehicles are air-conditioned, have internal destination and information screens, CCTV internal surveillance and audio controller contact.

Vehicles are currently lead/acid battery powered to allow for rapid charging (up to 150amps) and to achieve recyclability, but they are designed to be adaptable for future battery developments such as lithium-ion, and for other power sources such as hydrogen fuel cells or ultra-capacitors. Batteries are charged via electrical contacts at station berths, or at waiting points. ULTra vehicles have a very low energy usage of 0.15Kwh/vehicle km at 25mph.

The vehicle has a carrying capacity of 500kg, which is sufficient for five adults plus luggage, though the Heathrow car has two seats at each end. Figure 12 shows two production vehicles at Heathrow. The production vehicle, although based on the original prototype ULTra vehicle chassis and with the same overall dimensions, has more space between the seats, and the ends of the shell are more vertical than in the prototype. This gives more space for baggage, and allows all four seats to be fixed. At one end is an emergency escape hatch. Although emergencies requiring passengers to evacuate the vehicle will be extremely rare, the hatch provides an easy escape route since the central section of the bench seat pushes out to provide a deep escape path. A similar external hatch at the other end allows access to the vehicle’s electrical and electronic equipment, and serviceable items.
Figure 13 shows the vehicle with doors open. Doors are provided on both sides, but in the Pilot layout only those on the right-hand side are used. Figure 14 shows the interior, with the “Doors close”, “Doors open” and “Start” button visible in the panels on either side.

The vehicle contains an information panel, which at present merely says the time to destination (the total journey takes less than 5 minutes) but which could be used for a variety of informational, promotional or advertising tasks, and an emergency button for communication with the control centre. CCTV cameras in the vehicle enable the controller to monitor the vehicle to ensure nothing is amiss.

**In summary**, the main aspects of the vehicle are:

- The vehicle has two forward facing and two rearward facing seats. There is ample room for luggage, wheelchairs, buggies or bicycles.
- The compartment floor is at the same height as the station platform for ease of access for those with limited mobility and those in wheelchairs.
- The vehicle runs on four rubber-tyred wheels and automatically steers itself along a path stored within its on-board software. This autonomous system controls the movement of the vehicle, (i.e. the path and speed) over all sections of the network, from origin station to selected destination, and the door opening/closing.
- The vehicle is electrically powered from 48 volt on-board batteries that are recharged in stations and at off-guideway charging points when necessary.
- The powered doors are also electrically operated and include edge-strip sensors (or equivalent) to prevent the doors closing on objects or passengers’ feet, fingers, etc.
- Vehicle route and schedule instructions are received from the Central Control System. The vehicle then sets off at the allotted time on the selected route, but once in motion its path is determined by its on-board mapping, dead-reckoning and updating from the guideway beacons.
- The vehicle’s critical systems are monitored by the Health and Usage Monitoring System, the aim of which is to identify faults as early as practicable such that the vehicle can be withdrawn from operations before the fault results in a failure of the system.

The general intention is to provide the passengers with a level of comfort, ride quality and privacy to rival that of the car they have just left. After selecting their destination on the touch-screen terminal at the station door (which also calls for a vehicle if there is not one waiting), passengers seat themselves in the vehicle and have the familiar control buttons of a
lift: close doors, open doors, start. The visual and audio information panel above tells the passengers how long it will take to reach their destination: it will take less than five minutes between terminal and car park. The vehicle has two CCTVs to ensure passenger security, and direct communication with central control. It also carries an overload sensor to ensure that it will not start if its weight capacity is exceeded.

5.1 Specifications of the Heathrow Pilot ULTra vehicle
The specifications of the vehicle are listed below:

1 General
Configuration: front steered, rear wheel drive, four wheeler running on pneumatic rubber tyres.

2 Physical dimensions
Length 3.7m, Width 1.5m, Height 1.8m
Empty weight 820kg
Door opening >1.5m x 0.9m (h x w)
Flat floor area 1.4m x 1.2m (l x w)

3 Performance
Maximum speed > 11 m/s
Emergency deceleration rate ~3 m/s²
Turning radius 5m
Max climb angle >20%
Max planned climb angle 10%
Max planned descent angle 6.25%
Maximum payload 500kg
Max range on single battery charge 40km

4 Features
Powertrain: 7kW synchronous AC electric motor driving through reduction transmission
13” wheels with tubeless radial tyres
Power source: 48V lead acid battery pack:
`4x45Ah starved-electrolyte lead/acid traction batteries at rear
Braking: regenerative service braking with failsafe emergency/park brakes
Steering: electrically actuated steering system
Control: Autonomous navigation, guidance and control system
Recharging: Automatic battery charging connection
Safety interlocks between brakes, motors and doors

5 Passenger compartment features
Automatic door and level entry
Seating for 4 adults or 2 adults and three children: can accommodate a wheelchair
Forced air ventilation, automatically controlled lighting
Automatic destination display
Smoke and overload detection and warning systems
CCTV monitoring
Passenger address and emergency two-way audio communication system
Vandal resistant journey start, door open and passenger alarm signal controls
Rear emergency exit hatch
Safety interlocks between all doors and brakes
6. The control systems
The operation of the system is controlled by several different systems:

6.1 Vehicle navigation
Each vehicle has its own autonomous navigation system. Once a vehicle is launched from a station by the Central Control system, its own internal software “map”, steering mechanism, and location sensors enable it to navigate around the network to the specified destination station without any further input from Central Control.

In the Heathrow system, two lasers on each side of the vehicle reflect off the kerbs and measure the distance between the vehicle and kerb. ATS performed full-scale system evaluations with various forms of vehicle control, examining control methods based on wire guidance, optical and radar sensing, embedded track magnets and local sensors based on ultrasonics or lasers, and selected laser location as providing most reliable control. The vehicle’s internal map determines where the vehicle should be at that point on the track and steers accordingly. At intervals shape-coded markers on the kerbs identify the vehicle’s location, so that the vehicle knows exactly where it is and any accumulated errors are updated. The navigation is extremely precise, and also provides a smooth and stable motion both longitudinally and laterally. The internal mapping also adjusts the speed of the vehicle according to the curvature of the track, approach to merges or demerges, and approach to a station berth.

In stations the vehicle navigates into its berth according to the laser measurement (on one side only as it approaches the berth), but in addition raised rails on the floor of the berth physically guide the vehicle in and raise it off its suspension so that it provides a totally stable platform whatever load is placed on it as passengers board or alight. This also brings the vehicles battery-charging contacts into touch with the berth-floor contacts.

6.2 Central Control
This system provides overall operational control of the network. It receives positional information from each vehicle, and knows whether a vehicle is:

i. empty and waiting in a station
ii. loading passengers in a station
iii. loaded and waiting for clearance to depart
iv. loaded with passengers and in transit to another station
v. waiting to enter a berth at a station
vi. unloading passengers at a station
vii. empty and in transit to a station (or to a depot, charging or standing area)

When a passenger arrives at a station and requests transport to another station on the touch-screen terminal, if there is already an empty vehicle waiting at a berth the Central Control opens both berth and vehicle doors and invites the passenger(s) to board. If no vehicle is waiting, the system identifies a nearby empty vehicle and directs it to the station.

Once the vehicle is loaded, the system identifies a clear slot through the network to the required destination. The simulation uses a “synchronous” control system which allocates vehicles to slots in the same way as an aircraft control process, ensuring that at no time will the vehicle enter a guideway sector which has already been booked for another vehicle at the same (future) time. Each sector corresponds to the length of a required headway between vehicles. The vehicle will not be given clearance to start its journey until this clear
route has been identified. Each path is unique, ensuring there is no interaction between vehicles. This provides the first level of active safety in the system. The whole trajectory of the vehicle, in terms of time of occupation of each sector, is then blocked from use by any other vehicle.

Central Control also operates the **Empty Vehicle Management** system (EVM). When a vehicle unloads at a station it will normally be left there until passengers arrive to use it. However, if a loaded vehicle arrives and needs to occupy the berth, for example because all other berths at the station are occupied, the EVM will instruct the empty vehicle to drive to another station, or possibly to circulate around a loop and return to the station if another berth is about to become vacant and it is likely that more passengers will arrive. The EVM will also identify and direct an empty vehicle to call at a station where passengers are currently waiting at an empty berth. Generally the system will call in empty vehicles from as close to the station of the arrived passengers as possible in order to minimise waiting time, but the algorithms need to be as forward looking as possible in order not to circulate empty vehicles more often than necessary. Even if no passengers are calling for a vehicle, the EVM may bring up an empty vehicle to anticipate demand, or to rebalance the supply of vehicles around the stations, for example to ensure that there is always one empty vehicle waiting at each station, or more if a large influx of passengers regularly occurs at that time of day. A good EVM system is crucial to the efficient working of the PRT system.

Each station has its own **Station Management System**, and once a vehicle leaves the main through-guideway it is managed by this system in terms of approaching the berth, docking, and departing.

The Central Control system also manages vehicles in the case that the **Vehicle Monitoring System** decides that a vehicle needs to be charged at a higher rate than can be achieved when it calls at stations, or some other form of maintenance or repair is needed, in which case the vehicle will be taken out of operation. In case of any emergency, the Central Control will flag the event up to a human operator, who will then intervene and take appropriate action.

### 6.3 Automatic Vehicle Protection (AVP)

The ultimate protection on the ULTra system is provided by an independent Automatic Vehicle Protection system, a second level of safety beyond that provided by Central Control. This is based on a fixed block signalling system similar to that used on railways. The fixed blocks are defined by inductive loops set into the track which interact with sensing circuits on the vehicle. A vehicle is not allowed to enter a block if there is a vehicle in the block ahead of it, thus maintaining at least the required minimum headway. If for some reason this is not the case, the vehicle will apply its brakes in emergency mode. The system has been tested by abruptly stopping one vehicle on the Cardiff Test Track, with another vehicle running at minimum headway behind. AVP brings the second vehicle to a halt with a good separation from the first. In normal operation the Central Control system will ensure that the AVP is never brought into play, but in the event of an unexpected event such as a blockage on the track the AVP will operate to avoid a collision.

### 6.4 Vehicle Monitoring System (VMS)

The philosophy of ULTra is that reliability of the whole system should be maintained by close monitoring, so that Central Control is aware of any evolving problem, and can take appropriate action, before it causes disruption of the service. The VMS checks the state of charge of the battery, the operation of vehicle doors and navigation systems, temperature of the motors and electrical system, and of the interior of the vehicle, and for the existence of
any smoke. With routine problems such as a low battery or malfunctioning door the system automatically directs the vehicle to an appropriate maintenance area as soon as it unloads, but in the case of more serious emergencies it hands control over to manual operation.

6.5 Manual and special control

The whole operation is monitored and controlled by the Network Controller(s) using the Display and Control System. In addition to the above systems the Network Controller will have a CCTV system which covers the entire system (guideways and stations) and allows monitoring of the complete network, and a communication system which allows the Network Controller to communicate with passengers in the vehicles, the public on the stations and, when required, with the emergency services and the police. The Heathrow system operates in a secure area, and it is very unlikely that vandals could place obstacles on the track, but if this were to happen it would be picked up by the controller monitoring CCTV images around the track. Ultimately, image analysis of the CCTV images will be used to detect automatically the blockage and alert the controller. The vehicles have been tested for their ability to push smaller obstacles off the track safely, and have performed well.

In the case of a vehicle stopping on a guideway, the Network Controller takes over control of all vehicles, stopping movement on all or part of the network, bringing the stricken vehicle under emergency power to the nearest station, or calling out a special vehicle to push the vehicle slowly to a suitable point on the network, or in extreme circumstances directing passengers to evacuate the vehicle. With good vehicle monitoring, these would be extremely rare or non-existent events.

The Special Vehicle Management System controls the automatic movement of Special Vehicles, which are designed for guideway inspection and maintenance, or ‘first operation’ checking, or for recovery of immobilised vehicles. Special Vehicles may be operated automatically or manually, depending on their function.

6.6 The Control Centre

The control centre is situated adjacent to the Vehicle Depot at the western station in the Business Car Park. This provides accommodation for up to three controllers facing a schematic plan of the system showing the location of all vehicles, plus a bank of monitors displaying CCTV views of the guideway, stations and, on call, the interiors of selected vehicles when communication is required. Controllers can initiate voice and video contact with vehicle occupants when they see something amiss, or when the occupant has pressed the emergency call button in the vehicle. Controllers can also make voice contact with the stations. Because the PRT system is novel and entirely different from conventional transport, it will be important that controllers reassure passengers who are uncertain about how the system works.

6.7 Regulatory Approvals

The overall approach to automatic vehicle control has been approved by the UK’s HM Rail Inspectorate, who has provided their consent to the carriage of passengers on the prototype system. This followed a full hazard analysis and failure modes and effect analysis undertaken in conjunction with industry safety specialists. The documentation resulting from these analyses provided the basis for the HMRI evaluation and consent. HMRI have also provided consent in principle to the approaches to be used in the Pilot Heathrow scheme, and to
operation in tunnels which will be relevant in future for the intended extension of the network into the Central Terminal Area.

7. Operation

The Pilot scheme will be commissioned through the summer and autumn of 2009 to ensure complete reliability, and will open to public operation before the end of the year.

Passengers arriving at the Business Car Park will take a ticket on entry which will determine the charge to be paid on exit. The cost of PRT travel to Terminal 5 will be included in the car parking fee. In this case, no payment is required on entry to the PRT system, and the touch-screen terminal at the station will accept a request from any arrival. For travel to Terminal 5 selection of the station is not necessary from the car park, but passengers need to note the identifier (A or B) of the car park station for their return. If however passengers mistake their station, they have the opportunity on arrival at the car park to request the PRT to take them on to the correct station.

If a vehicle is already waiting at the berth, which will be the normal situation except during sudden short-lived peaks in demand, the doors will open and the passenger(s) will seat themselves and press the “Start” button. The vehicle will reverse out of its berth as soon as it receives permission from Central Control to launch, and then continue forwards on its way. The information panel will show the time to destination, and a voice will announce both time and destination. Travel times will be less than five minutes. The vehicle will speed up to maximum speed, 11 m/s, along the straight dual guideway stretch, but will slow on bends to ensure a comfortable ride. On arriving at Terminal 5 it will drive into one of the four berths, or if they are all full may have to wait for a short period for a berth to clear. Given the demand levels on the Pilot scheme, such enforced waiting will be unusual, but will occur occasionally due to random variations in demand.

Once unloaded, the vehicle will generally remain at the berth until passengers want to travel from Terminal 5 to the Business Car Park, but if the berth is required by an incoming vehicle, or if the EVM decides it is needed to carry arriving passengers at the car park, it will be moved back to one of the car park stations.

Except where a large number of passengers arrive at the same time, they will usually find a vehicle waiting. If not, one can be called up within a minute or two. Micro-simulations of the ULTRA system show that average passenger waiting times are of the order of 30 seconds even in systems with much greater demand than the Pilot, and that it is rare for a passenger to have to wait more than a minute.
8. Summary

Construction of the Heathrow Pilot project is now complete, and full passenger operation will begin before the end of 2009. The guideway runs between two two-berth stations in the Business Car Park to a four-berth station on level three of the multi-storey short-term car park alongside Terminal 5. There are 3.8 kms of guideway, mostly elevated. 18 four-seater battery-electric vehicles will operate the system, though two of these may be undergoing maintenance at any given time. Passengers select their destination station via a touch-screen terminal at the station, which provides access to a waiting vehicle or, on the rare occasions when all berths are empty, calls up a vehicle. Passengers board and seat themselves, then press the “Start” button. Vehicles reverse from the berth and then travel to the required station, which takes less than 5 minutes. Vehicles remain in the berth waiting for a passenger in the return direction unless the berth needs to be cleared for an incoming vehicle. Vehicles are recharged during the stay in the berth. Empty vehicles are directed automatically to fill empty berths or to respond to a passenger call, or to return to a storage lane or to a battery-charging point, or to maintenance, as required.

9. Source of additional material

The ATS website at www.atsltd.co.uk contains a library of documents, pictures and videos for further information.