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Specification of a Communication Based Collision Avoidance System (CBCAS)

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1 Executive Summary

Advanced Transport Systems Ltd are developing a new urban personal rapid transit system (PRT) called ULTra (Ultra Light Transport). This is typical of current PRT system state-of-the-art, and utilises small autonomous vehicles for short range low speed passenger transportation on a dedicated guideway network. The vehicles run on rubber tyres and have similar dimensions to a small car.

Vehicle navigation, guidance and control on the guideway is fully autonomous with vehicles following predetermined speed profiles along centrally dictated routes. A Central Control System (CCS) is used to manage the entire network and co-ordinate vehicle movements, so as to avoid conflicts. When operating normally, no collision hazards exist since all vehicle movements are designed to be non-conflicting. However potential collision hazards can arise due to failures within the system (e.g. vehicle breakdown) or intrusions from outside (for example pedestrians trespassing on the guideway network). Existing PRT systems (at Heathrow and Morgantown) use collision avoidance systems based on wire loops set in the track surface which detect the position of vehicles. While these systems are conceptually simple they are costly and are likely to have poor availability, due to the large number of components required. Moreover their simple fixed configuration gives rise to significant performance limitations and they have no capability to prevent collisions with obstacles other than PRT vehicles. Due to these reasons it is considered desirable to eliminate the use of such systems if PRT is to achieve its full potential. Since individual PRT vehicles already posses fully autonomous driving functions, know their speeds, locations and intended paths with high precision, and have radio communications equipment to communicate with the CCS, the function of avoiding collisions between vehicles may be realised (to some extent) at low cost, using pre-existing information and system components to form a Communication Based Collision Avoidance System (CBCAS).

This document sets out the high level requirements for a communication-based collision avoidance system for use with a PRT system. These requirements form the first stage of ATS Ltd's involvement in the CityMobil project (Work Package 1.2.6) and will be used to assess different design proposals for CBCAS.

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COMMUNICATION BASED COLLISION AVOIDANCE SYSTEM REQUIREMENTS SPECIFICATION

1 Introduction

Advanced Transport Systems Ltd are developing a new urban personal rapid transit system (PRT) called ULTra (Ultra Light Transport). This is typical of current PRT system state-of-the-art.

ULTra utilises small autonomous vehicles for short range low speed passenger transportation on a dedicated guideway network. The vehicles run on rubber tyres and have similar dimensions to a small car. They are limited by design to a maximum speed of 40kph with a maximum GVW of 1300kg and an empty weight of around 800kg. The guideway on which the vehicles operate utilises a concrete or asphalt running surface and has inherent safety features; it is one way, it is physically segregated from other traffic and pedestrians and it is bounded on either side by kerbs that constrain the vehicle’s path and are capable of containing it (under guidance failure conditions). Vehicle navigation, guidance and control on the guideway is fully autonomous with vehicles following predetermined speed profiles along centrally dictated routes. A Central Control System (CCS) is used to manage the entire network and co-ordinate vehicle movements, so as to avoid conflicts. The CCS communicates with the vehicles using a full duplex radio system. All vehicles on the network maintain accurate estimates of their own status, speed and location and communicate this to the CCS. When operating normally no collision hazards exist since all vehicle movements are designed to be non-conflicting. However potential collision hazards can arise due to failures within the system (e.g. vehicle breakdown) or intrusions from outside (for example pedestrians trespassing on the guideway network).

For PRT systems that are sited in secure locations (for example airports), there is little likelihood of external intrusion, so collision hazard due to failure is by far the most likely and the principle risk is of collision between PRT vehicles. However for systems located in less secure environments (e.g. urban systems), this may not be the case and there may also be significant risk of collision with pedestrians and other miscellaneous objects.

Existing PRT systems (at Heathrow and Morgantown) use collision avoidance systems based on wire loops set in the track surface which detect the position of vehicles and transmit signals to them to stop their motion when a potential collision hazard exists (i.e. they get closer than planned to another vehicle). While these systems are conceptually simple they are costly and are likely to have poor availability, due to the large number of components required. More over their simple fixed configuration gives rise to significant performance limitations and they have no capability to prevent collisions with obstacles other than PRT vehicles. Due to these reasons it is considered desirable to eliminate the use of such systems if PRT is to achieve its full potential.

A number of different technical approaches to collision avoidance are feasible. These include use of sensors on vehicles to detect obstacles (for example automotive and industrial radar and lidar systems), use of fixed infrastructure sensors (for example CCTV) and use of intelligent obstacle location based systems (in which use is made of potential obstacles' own knowledge of their own location).

Given the different strengths and weaknesses of each of these technologies (and the different synergies that they have with requirements for functions outside of collision avoidance) it is likely that mature systems will utilize a combination of technologies to realize the best performing lowest cost design.

However, since individual PRT vehicles already posses fully autonomous driving functions, know their speeds, locations and intended paths with high precision (in order to navigate, maintain schedule and drive safely along the guideway) and have radio communications equipment (in order to communicate with the CCS), it is apparent that the function of avoiding collisions between vehicles may be realised (to some extent) at low cost, using pre-existing information and system components to form a Communication Based Collision Avoidance System.

In such a system, intelligent obstacle location information (the path and location of vehicles and possibly other obstacles) would be exchanged so that potential collisions could be identified and appropriate avoidance action taken by individual vehicles.

Using just vehicle location knowledge might provide effective prevention of collisions between vehicles (and thus meet airport system requirements) but would be unable to prevent collisions with other obstacles. To provide that function, knowledge of the location of such obstacles would be required. Such knowledge might be obtained in many ways, however consideration of these is beyond the scope of this document.

This document sets out the high level requirements for a communication-based collision avoidance system for use with a PRT system.

This report makes the assumption that the guideway on which vehicles operate will be bounded by kerbs (or something similar), so that the potential paths followed by vehicles are tightly constrained and that the vehicles are of similar size and performance to those used in ATS' ULTra PRT system.

These requirements will form the first stage of ATS Ltd's involvement in the CityMobil project (Work package 1.2.6) and will be used to assess different design proposals for CBCAS.

2 Definitions and Abbreviations

The sections of this Requirement Specification titled “Outline Description’ provide useful additional information to aid understanding of the requirements. They do not, in themselves, reflect requirements.

2.1 Definitions

The word ‘shall’ is used to mean that the requirement is mandatory.

The word ‘should’ is used to mean that the requirement is a design objective or aim.

The ‘Guideway’ is defined as the road system on which the vehicle normally operates. This includes the running single lane one way roads and merging and diverging swept junctions. Vehicles on the guideway are limited to a maximum forward speed of 40kph and are not permitted to reverse in normal operation.

‘Stations’ are defined as the areas within which vehicles move at low speed and manoeuvre up to and away from the berths at which they stop (in order to allow passengers access to and from the platform). Vehicles in this area are limited to a maximum forward speed of 8 kph and a maximum reversing speed of 4kph.

‘Vehicle Control System’ is defined as the vehicle system responsible for the vehicles normal autonomous driving and navigation.

The term ‘failure’ shall be interpreted as any fault in the system that prevents a vehicle from completing its planned journey on the guideway or stops a vehicle in the station or depot movement areas.

‘Significant Obstacles’ are defined as those obstacles which are large enough to pose a significant safety hazard to the subject vehicle or its occupants if hit by the subject vehicle travelling at maximum speed.

‘Insignificant Obstacles’ are defined as those obstacles which are small enough to pose no significant safety hazard to the subject vehicle or its occupants if hit by the subject vehicle travelling at maximum speed.

‘Comfortable Reaction Distance’ is defined as the speed dependent distance ahead of the subject vehicle at which it must detect and begin to react to a stationary obstacle in order to bring the subject vehicle to a smooth and comfortable stop without colliding with the obstacle.

‘Safe Reaction Distance’ is defined as the speed dependent distance ahead of the subject vehicle at which it must detect and begin to react to a stationary obstacle in order to bring the subject vehicle to a safe stop without colliding with the obstacle.

'Availability' is defined as ratio of the time the system is fully operational and fault free over that time plus the time the system is out of service for maintenance and repair.

2.2 Abbreviations

ALARP	As low as reasonably practicable
CBCAS	Communication-based collision avoidance system
CRD	Comfortable Reaction Distance
ISO	Insignificant Obstacle
PRT	Personal Rapid Transit
SO	Significant Obstacle
SRD	Safe Reaction Distance

3 Functional Requirements

3.1 Outline Description

The primary function of the CBCAS is to prevent collisions between PRT vehicles on the guideway network. The CBCAS should also, if possible, prevent collisions between PRT vehicles and other significant objects on the guideway (e.g. people or other vehicles). The CBCAS should achieve its collision avoidance functions by providing information to each involved vehicle’s Vehicle Control Systems (VCS), such that it can brake and/or steer the vehicle in such a way as to avoid collision. The CBCAS should not generate “false alarms”. It is desirable that the CBCAS provides timely indication of potential collision hazards such that the severity of avoidance actions can be minimized so that they are safe and comfortable for passengers.

3.2 Safety Requirements

3.2.1 - The overall collision avoidance function should meet SIL2 requirements (Appendix 1 - Technical data, p24)

3.2.2 - The probability of a false negative error (non-detection of potential significant collision when one is present) shall be less than 1.0e-6 per hour (Appendix 1 - Technical data, p24)

3.2.3 - The probability of a false positive error (detection of potential significant collision when none are present) shall be less than 1.0e-5 per hour.

3.3 Detailed Functional Requirements

The CBCAS system:

3.3.1 - Shall prevent collisions between vehicles operating on the network

3.3.2 - Should prevent collisions between vehicles operating on the network and people and other significant obstacles

3.3.3 - Shall enable the network to operate safely with minimum headway between vehicles of 2.5 seconds ('brick wall' stopping assumption).

3.3.4 - Should enable the network to operate safely with minimum headway between vehicles of typically 1 sec or less.

3.3.5 - Shall not interfere with the operation or movement of vehicles when the network is operating normally and without fault.

3.3.6- Should take account of infrastructure constraints on vehicle paths when determining collision risk and avoidance action.

3.3.7 - Shall provide a graduated response to potential collision hazard such that where possible, changes in vehicle velocity are made at rates which are both safe and comfortable to passengers but also enabling the full use of the highest possible deceleration rates when required to prevent collision (even though the rates may be high enough to potentially cause passenger unseating and consequent injury).

3.3.8 - Start Up

3.3.8.1 - Once properly configured, the system shall be fully operational within 10 seconds of vehicle power up.

3.3.8.2 - When provided with no external power for 30 days, the system should not suffer any loss of configuration requiring external intervention to restore proper operation (Requirement to cope with maintenance and storage of vehicles).

3.3.8.3 - When provided with no external power for 30 minutes, the system shall not suffer any loss of configuration or data degrading subsequent operation (Requirement to cope with 30 minute system power outages).

4 DESIGN requirements

4.1 Outline Description

CBCAS may consist of externally sited communication controllers and/or vehicle mounted sensors.

4.2 Safety Requirements

4.2.1 Health and Safety

4.2.1.1 The system shall impose no greater health and safety risks than the lowest levels accepted in other contemporary ground transport systems.

4.2.1.2 The system health and safety risks shall be minimised according to ALARP principles.

4.3 Detailed Design Requirements

4.3.1 The system unit lifetime cost shall be minimised.

4.3.2 The system shall comply with EC end of life directives.

4.3.3 The appearance of any vehicle mounted components should be designed to be coherent with the vehicles external styling.

4.3.4 The system shall be secure to unauthorised interference

4.3.5 The system shall be unaffected functionally by likely sources of interference

4.3.6 No special measures shall be required to protect the system from damage during normal maintenance and repair of the vehicle electrical systems.

4.3.7 The system shall not be damaged by electrical fault conditions that may reasonably be expected to occur in a battery powered electric vehicle.

4.3.8 The system should be designed to permit economical adaptation and upgrade as vehicle performance is increased.

4.3.9 The system shall achieve a minimum operational life of eight years or 600,000km, whichever occurs soonest.

4.3.10 The system shall contribute no more than 10% to the vehicle capital and maintenance costs.

4.3.11 The system shall be supplied with all documentation necessary to support normal installation, operation, maintenance, diagnostics and economic repair.

4.3.12 The system should facilitate rapid fault finding and economical repair in the event of failure.

5 Environmental Requirements

5.1 Normal Environmental Conditions

5.1.1 The system shall fulfil all the performance requirements under conditions where the vehicle is operated normally and external environment parameters are all within the following ranges:

a) Ambient temperature: -25 to +55 degrees Celsius

b) Precipitation: none to heavy rain, hail and snow.

c) Visibility: greater than 5 meters in normal daylight, clear to dense fog.

d) Ambient light levels: bright sunshine to total darkness.

e) Wind Speed: 0 to 30 knots steady continuous and 0 to 45 knots gusting, from any direction.

f) Road surface: clean, minimum skid resistance = 60

g) Surface condition: wet or dry, 0 to 5mm standing water or snow covered up to 10mm of loose snow on any surfaces.

5.2 Public Acceptability

5.2.1 The system shall not irritate or annoy those exposed to it through sound, light or radio emissions or interference.

5.3 EMC Compliance

5.3.1 The system shall comply with relevant EU and US standards.

5.4 Radio Environment

5.4.1 The system shall operate in urban and airport radio environments without causing adverse disturbance to existing systems.

6 Interface Definitions

6.1 Infrastructure Interactions

6.1.1 The system shall be designed to minimise infrastructure implications.

6.1.2 It shall not require the addition of high cost, high maintenance or vulnerable features to the infrastructure.

6.1.3 It should as far as possible not cause additional restrictions on guideway geometry (beyond those set out in Appendix 1 - Technical data, p20)

6.1.4 It should not depend upon guideway features that will be difficult or expensive to maintain.

6.1.5 It should not impose restrictions upon the guideway construction method.

6.2 Vehicle Interactions

6.2.1 The system should not cause additional restrictions on vehicle performance (beyond those set out in the Appendix 1 - Technical data, p14)

6.2.2 The system shall comply with vehicle packaging constraints

6.2.3 Power consumption of any vehicle components shall not exceed 100W

6.2.4 Any vehicle components shall not exceed 2 kg.

6.2.5 Vehicle aesthetics should not be adversely affected by any vehicle components