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Lester B. Pearson International Airport

Vehicle Monitoring and Control System

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LESTER B. PEARSON INTERNATIONAL AIRPORT VEHICLE MONITORING AND CONTROL SYSTEM

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16. Abstract

This report covers the development of the vehicle-to-roadside communication concept and applications at Lester B. Pearson International Airport. The applications include dispatching and related operations for the commercial vehicle holding areas and terminal curbs, as well as for taxis and limousines, using vehicle-to-roadside communications equipment, driver identification cards, variable message signs and integrated central computer control systems.

The report describes the individual subsystems of the vehicle monitoring and control system, its responsiveness to the landside transportation operation issues of Lester B. Pearson International Airport, and its flexibility for use at other airports.

The system proved successful in many aspects, especially in improving operational control, reducing labour costs and providing management information for both airport use and marketing to commercial fleet operators. With this success, opportunities now exist for functional and geographical expansion of vehicle-to-roadside communication technology applications.

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16. Résumé

Ce rapport rend compte du développement d'un système de communications bilatérales véhicule-route et de sa mise en oeuvre à l'Aéroport international Lester B. Pearson. Ses applications comprennent les fonctions de répartition et d'autres opérations connexes touchant les véhicules commerciaux, taxis et limousines, dans les zones d'attente et aux points d'embarquement de l'aéroport. Il utilise du matériel de communications bilatérales véhicule-route, des cartes d'identification des conducteurs, des panneaux à message variable et des systèmes intégrés de commande programmée.

Le rapport décrit chacun des sous-systèmes qui composent le système de surveillance et de contrôle des véhicules, et analyse son aptitude à répondre aux problèmes de transport côté ville à l'Aéroport international Lester B. Pearson, et son adaptabilité à d'autres aéroports.

Le système s'est révélé une réussite à plusieurs égards : meilleur contrôle des opérations, diminution des coûts de main-d'oeuvre et production de données de gestion utiles autant à l'aéroport et à ses services de commercialisation qu'aux exploitants de parcs de véhicules. Ce succès ouvre la voie à une expansion fonctionnelle et géographique des applications de la technologie des communications bilatérales véhicule-route.

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Lester B. Pearson International Airport Vehicle Monitoring and Control System

EXECUTIVE SUMMARY

Canada's first airport ground transportation Vehicle Monitoring and Control System (VMCS) has automated taxi and limousine dispatching and other related operations at Lester B. Pearson International Airport. The system provides a showcase for the application of Intelligent Transportation Systems (ITS) technologies in the airport environment. The VMCS also highlights the necessary coordination and cooperation efforts between the public and private sectors. Since airport ground transportation issues are not unique to Lester B. Pearson International Airport, the success of this project may prompt similar applications in Canada and the United States. With the VMCS at Lester B. Pearson International Airport in-place, Transport Canada (TC) has not only moved one step further in moving ITS from research, prototyping and pilot projects into routine usage, but also enabled an essential part of our transportation network to become more advanced and efficient.

The project's goal was to undertake the deployment of an innovative information management system to enhance passenger pick-up operations for commercial vehicles, using Dedicated Short Range Communication (DSRC) technologies, developed in Canada, to track and communicate with vehicles. To go beyond what most other airports had previously implemented in terms of DSRC applications, the project aimed to:

- Build and maximize compatibility with current landside commercial vehicle operations for taxis and limousines, as well as pre-arranged pick-up vehicles;
- Demonstrate real-time, two-way communication capabilities between vehicles and roadside infrastructure;
- Demonstrate interface capabilities between in-vehicle units and an infrastructure-based, real-time control system; and
- Establish a foundation for future expansion to create a comprehensive system for interface with the full range of vehicles using the airport.

The VMCS implementation at Lester B. Pearson International Airport originally included DSRC/ Automated Driver Identification (ADI) at entrances and exits of the Commercial Vehicle Holding Areas (CVHAs) and at the terminal curbs for identification and tracking of vehicle and driver movements, Blank-Out Signs and Variable Message Signs at the CVHAs for communication with the commercial vehicle operators, ticket printers at the exits of the CVHAs facilitating authentication of the commercial vehicles at the terminal curbs, and communication and computer subsystems. An overview of the VMCS is provided in this report.

The report identifies possibilities for migration of DSRC technologies, both functionally and geographically, from stand-alone applications at single facilities to integrated applications that include facilities operated by multiple institutions.

Lester B. Pearson International Airport Vehicle Monitoring and Control System

Sommaire

Première initiative du genre au Canada, le Système de surveillance et de contrôle des véhicules de transport terrestre aux aéroports (SSCV) réalise l'affectation automatisée des taxis et limousines, et d'autres fonctions connexes à l'Aéroport international Lester B. Pearson. Le système sert de vitrine pour la mise en oeuvre des systèmes de transports intelligents (STI) dans l'environnement aéroportuaire. La mise en service du SSCV a également mis en relief le besoin de coordination et de coopération entre les secteurs public et privé. Comme les problèmes touchant le transport terrestre aux aéroports ne sont pas l'apanage de l'Aéroport international Lester B. Pearson, il se pourrait que le succès de ce projet suscite des applications semblables au Canada et aux États-Unis. En mettant en place le SSCV à l'Aéroport international Lester B. Pearson, Transports Canada (TC) a contribué non seulement au passage des STI du domaine de la recherche, du prototypage et des projets pilotes aux applications concrètes, mais aussi à l'avancement et à l'efficacité d'un secteur essentiel du réseau de transport canadien.

Le projet avait pour but la mise en service d'un système novateur de gestion de l'information devant améliorer les opérations de prise en charge des passagers par les véhicules commerciaux. Fondé sur les technologies de communications dédiées à courte distance (CDCD) mises au point au Canada, il peut déterminer la position des véhicules et communiquer avec eux. Allant au-delà des applications CDCD mises en oeuvre dans la plupart des autres aéroports, le projet visait à :

- maximiser la compatibilité du SSCV avec les opérations courantes de gestion des véhicules commerciaux côté ville, soit les taxis, les limousines et les bus-navettes effectuant le ramassage de clients;
- faire la démonstration des capacités de communication bidirectionnelles en temps réel entre les véhicules et le bord de la route;
- faire la démonstration des capacités d'interfaçage entre les dispositifs embarqués et un système de contrôle en bordure de chaussée;
- jeter les bases d'une expansion future du système qui devrait déboucher sur un système global assurant l'interfaçage de toute la gamme des véhicules utilisant l'aéroport.

Le SSCV mis en oeuvre à l'Aéroport international Lester B. Pearson comportait à l'origine des systèmes CDCD/d'identification automatique des conducteurs (IAC) aux entrées et aux sorties des zones d'attente de véhicules commerciaux (ZAVC) et aux points d'embarquement de l'aéroport, pour l'identification et le suivi des véhicules, des panneaux de signalisation escamotables et des panneaux à message variable dans les ZAVC assurant la communication avec les conducteurs de véhicules commerciaux, des imprimantes de tickets aux sorties des ZAVC, facilitant l'authentification des véhicules commerciaux aux points d'embarquement à l'aéroport, et un sous-système de communication et un sous-système informatique. Ce rapport donne en aperçu du SSCV.

Le rapport cerne des possibilités de migration tant fonctionnelle que géographique des technologies CDCD, des applications autonomes et uniques à des applications intégrées comportant des systèmes exploités par plusieurs établissements.

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LIST OF EXHIBITS

List of Acronyms

APTS	Advanced Public Transportation System
ATIS	Advanced Traveller Information System
ATMS	Advanced Traffic Management System
AVCS	Advanced Vehicle Control System
AVI	Automatic Vehicle Identification
AVION	Advantage I-75/AVI-Ontario
BOS	Blank-Out Sign
CCTV	Closed Circuit Television
CES	CVHA Entrance Confirmation Subsystem or Curb Entrance Confirmation Subsystem
COTS	Commercially-off-the-shelf
CRCS	Close-Range Communication System
CVHA	Commercial Vehicle Holding Area
CVO	Commercial Vehicle Operations
DBC	Database Computer
DCC	Device Communications Computer
DSRC	Dedicated Short Range Communication
EDT	Electronic Data Transfer
ETTM	Electronic Toll and Traffic Management
FOT	Field Operational Test
GTAA	Greater Toronto Airport Authority
GTMS	Ground Transportation Management System
GUI	Graphical User Interface
HELP	Heavy vehicle Electronic License Plate
IEN	Information Exchange Network
ITI	Intelligent Transportation Infrastructure
ITS	Intelligent Transportation System
LAN	Local Area Network
Massport	Massachusetts Port Authority
MCC	Master Control Computer
PAP	Pay-at-Point
PC	Personal Computer
RF	Radio Frequencies
SMC	System Maintenance Computer
SVS	Summoning Variable Signs
TC	Transport Canada
TCC	Terminal Curb Computer
TDC	Transportation Development Centre (of Transport Canada)
VIN	Vehicle Identification number
VMCS	Vehicle Monitoring and Control System
VMS	Variable Message Sign
VRC	Vehicle-to-Roadside Communication
WAA	Winnipeg Airports Administration
WAAI	Winnipeg Airports Administration Inc.

List of Acronyms (Cont'd)

WAN	Wide Area Network
WIM	Weigh-in-Motion

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Lester B. Pearson International Airport Vehicle Monitoring and Control System

1.0 INTRODUCTION

1.1 OVERVIEW OF ITS

Smart transportation system solutions are developing as the creative convergence of advances in communications, computing and electronics continues. Applications and system concepts can be classified and defined in several ways. Since the transformation of the term Intelligent Vehicle Highway Systems (IVHS) into Intelligent Transportation Systems (ITS), the following classification become prominent:

- Advanced Traveller Information System (ATIS)
- Advanced Public Transportation Systems (APTS)
- Advanced Traffic Management Systems (ATMS)
- Advanced Vehicle Control Systems (AVCS)
- Commercial Vehicle Operations (CVO)

1.2 THE CASE FOR INTEGRATION OF ITS ELEMENTS AT AIRPORTS

The promise of ITS is to improve the operations of transportation facilities and services while making both more user-friendly. Over the past five years, the application of ITS technologies to landside transportation operations at airports has been gaining support from both airport managers and planners, as well as commercial vehicle operators. Overall, these “new” technologies have often been found as low-cost alternatives to more traditional measures of solving landside transportation operation problems and management information needs at airports. In many cases, traditional measures, such as further construction, are not viable, not only because of scarce capital improvement program resources but because of existing developments or environmental protection regulations.

Air travel is expected to more than double over the next twenty years worldwide, with an annual growth rate of 5.7 percent [1]. Predicted growth rates for air travel in North America, considering both domestic and international enplanements, are of the same order of magnitude. These significant growth figures increase the pressure for effective and efficient movement of passengers to and from airport grounds and local destinations. Fewer opportunities for facilitating additional capacity due to limited airport terminal roadway space and limited highway capacity further exacerbate the pressure. Many airports, not only in Canada, have recently been restructured. This has in part changed the way in which the airports are managed and operated, especially in terms of financing. With this move towards self-financing organizations, the issue of revenue collection from users of airport facilities is becoming increasingly important. With these apparent trends it is not surprising that landside transportation operation and management is becoming a focus of many international airports.

1.3 AIRPORT LANDSIDE TRANSPORTATION SYSTEM

Essential Landside Transportation Subsystems

An airport landside transportation system must accommodate both personal passenger and commercial passenger trips. The following key landside transportation systems need to be considered in order to better accomplish this objective:

- **Commercial Vehicle Control and Management System** – allowing for real-time automated dispatching of commercial vehicles from centralized holding areas to terminal curbsides;
- **Terminal Shuttle Dispatch and Headway Management System –** allowing for real-time adjustments of shuttle bus schedules and interaction with roadway elements to increase schedule adherence and enhance system performance;
- **Parking Management and Information System** – allowing for dissemination of real-time information on parking availability and usage optimization of parking facilities, as well as increased opportunities for coordination with Park-and-Fly facilities outside airport grounds;
- **Travel and Traffic Information System** – allowing for dissemination of real-time information on existing and potentially expected travelling, traffic and roadway conditions on major highways and arterials feeding the airport; and
- **Traffic Data and Count System** – allowing for better day-to-day ground transportation management and planning through the use of the accumulated information contained in extensive databases.

Commercial Vehicle Monitoring and Control System

Canada's first commercial airport ground transportation Vehicle Monitoring and Control System (VMCS) is currently enabling the automation of taxi and limousine dispatching and other related operations at Lester B. Pearson International Airport through the use of a Dedicated Short Range Communication (DSRC) system. The VMCS acts an excellent showcase of what the future of ITS holds, and in particular what can be accomplished through the use of DSRC technologies. The VMCS also highlights the necessary coordination and cooperation efforts needed between the public and private sectors, especially in the efforts made to bring a proof of concept technology to the market. Since the airport ground transportation issues are not unique to Lester B. Pearson International Airport it is important to notice that the success of this project may prompt similar applications in Canada and the United States. With the VMCS at Lester B. Pearson International Airport in place, Transport Canada has not only come one step further in moving ITS from research, prototyping and pilot projects into routine usage, but also enabled a good idea to be realized.

Future steps call for increased functionality to build a comprehensive Commercial Vehicle Control and Management System at the airport and integration with other landside transportation systems and other ITS.

1.4 Key Enabling Technologies for Airport Landside Transportation Systems

ITS applications of today and tomorrow will depend largely on wireless technologies. Today, the following types of wireless communication technologies have extraordinary potential for integration into existing transportation systems:

- Dedicated Short Range Communication (DSRC)
- Cellular Digital Packet Data (CDPD)
- Global Positioning System (GPS)

These communication and location technologies can work alone or in combination for a wide variety of ITS applications. As ITS evolves, it is envisioned that they will be part of a common architecture that is truly cross-functional and based on the needs of the end user. With only a few exceptions, the ITS infrastructure is expected to be based on the use of existing communication protocols[2].

Dedicated Short Range Communication (DSRC) Systems

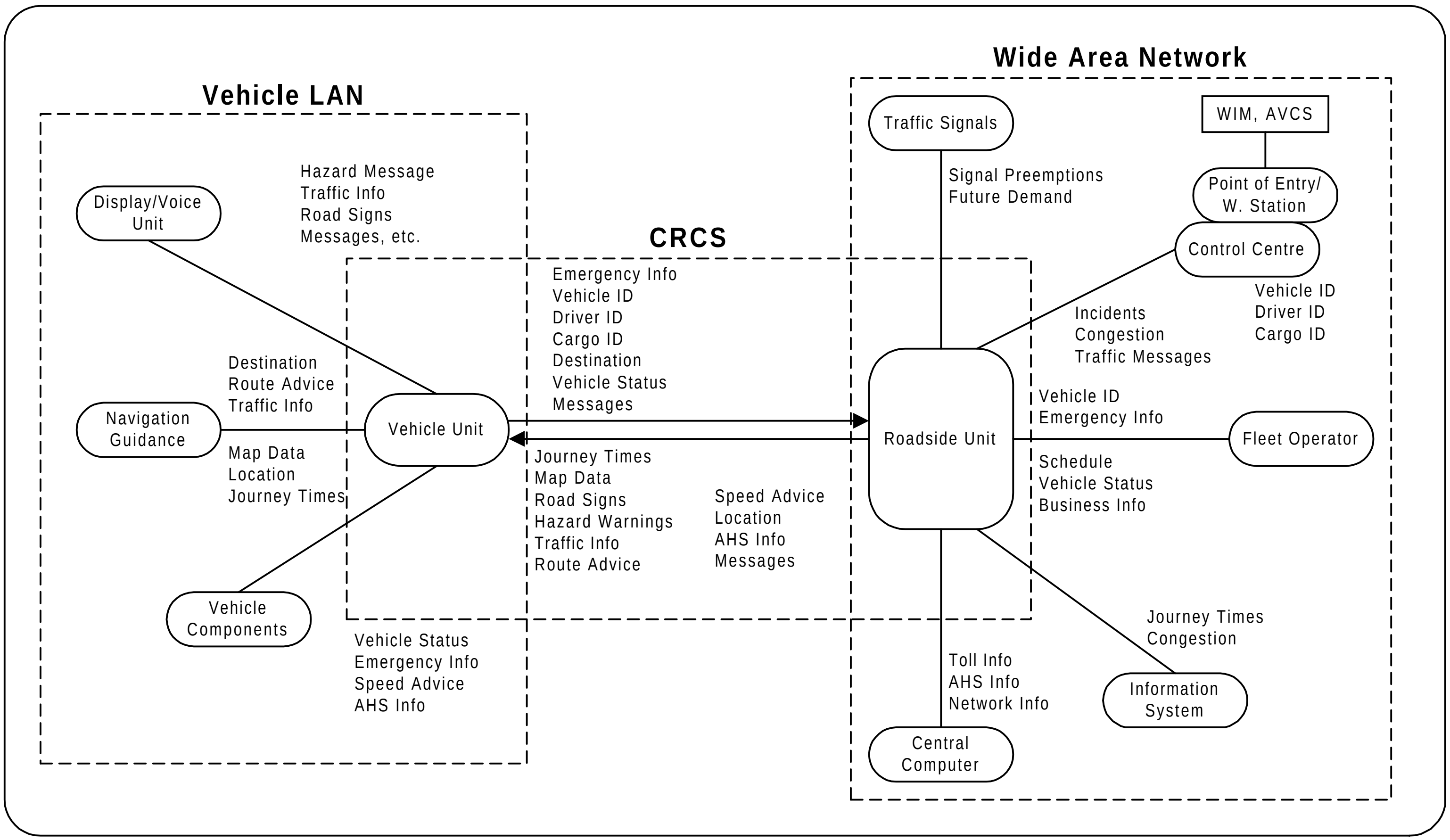
Radio Frequency (RF) communications between moving vehicles and stationary roadside units have been available for about two decades. The technology has, however, managed to follow an evolutionary path as manufacturers have continued to develop new applications and expanded their product lines. The technical approach behind the VMCS at Lester B. Pearson International Airport is based on the fundamentals of a typical DSRC system, i.e. the functionalities generated through the integration of readers, tags and associated software. Today's DSRC applications have evolved from the essentials of Automatic Vehicle Identification (AVI) and Electronic Toll and Traffic Management (ETTM) to technologies where mobile equipment would communicate with roadside equipment through two-way data channels.

The concept behind DSRC applications can best be described as a two-step communication process:

1. Roadside antennae transmitting RF signals to be received by in-vehicle transponders;
2. In-vehicle transponders transmitting a unique identification back to the roadside transceivers in response to the initial RF signals.

With advancements in computer software and hardware, future in-vehicle transponders are expected to be connected via a serial port to a vehicle's on-board local area network (LAN), while the roadside antennae and transceivers will be connected to a national wide area network (WAN) through wired or non-wired transmission. The logical architecture of this concept, originally referred to as the close-range communication system (CRCS) concept [3], is depicted in Exhibit 1. The Exhibit illustrates the logical architecture of the CRCS concept, i.e. the potential data and information flows for several transportation applications.

Exhibit 1: Universal CRCS Concept



Source: Intelligent Vehicle Highway System - The Universal CRCS Concept, R.L. Saboughi, 1991

Physical elements in the Exhibit are separated by the vehicle LAN and the WAN and are presented only to introduce the idea of the "physical place holders" that are expected to facilitate the exchange of voice, data, image or video in a near future. CRCS applications ultimately build on data and information exchange and sharing using different kinds of traffic message encoding and decoding techniques.

The CRCS concept envisioned back in 1991, classified in accordance with the vehicle LAN and WAN concept, included a wide variety of DSRC system applications. Exhibit 2a through Exhibit 2h map these applications to the functional areas of ATIS, APTS, ATMS, AVCS and CVO. This mapping is essential in order to better understand the technology's potential fit in any future transportation system.

Exhibit 2: DSRC System Applications

Display/Voice Unit Applications	**ATIS**	**APTS**	**ATMS**	**AVCS**	**CVO**
hazardous warnings	x		x		
traffic and traveller information	x	x	x		
road signs	x		x	X	
messages	x				x

Exhibit 2a: Display/voice unit applications in relation to general ITS sub-categories

Navigation Guidance Unit Applications	**ATIS**	**APTS**	**ATMS**	**AVCS**	**CVO**
Destination route advice	x	x	x		x
traffic and traveller information	x	x	x		
map and location data	x		x	x	
Estimated/expected journey and travel time data	x	x			x

Exhibit 2b: Navigation guidance unit applications in relation to general ITS sub-categories

Vehicle Component Applications	**ATIS**	**APTS**	**ATMS**	**AVCS**	**CVO**
vehicle status		x		x	x
Emergency status		x	x	x	x
speed advice		x	x	x	x
AHS information				x	

Exhibit 2c: Vehicle component applications in relation to general ITS sub-categories

Traffic Signals Applications	**ATIS**	**APTS**	**ATMS**	**AVCS**	**CVO**
signal pre-emption		x	x	x	x
future demand estimations		x	x		

Exhibit 2d: Traffic signals applications in relation to general ITS sub-categories

Point of Control (Point of Entry/Exit or Transparent)/Control Centre Applications	**ATIS**	**APTS**	**ATMS**	**AVCS**	**CVO**
vehicle ID		x	x		x
driver ID		x			x
cargo ID			x		x
weigh-in-motion			x		x

Exhibit 2e: Point of control (point of entry/exit or transparent)/control centre Applications in relation to general ITS sub-categories

Fleet Operator Applications	**ATIS**	**APTS**	**ATMS**	**AVCS**	**CVO**
Vehicle ID		x	x		x
Emergency information		x	x		x
Schedule adherence		x	x		x
Vehicle status		x	x		x
Business information					x

Exhibit 2f: Fleet operator applications in relation to general ITS sub-categories

Fleet Operator Applications	**ATIS**	**APTS**	**ATMS**	**AVCS**	**CVO**
vehicle ID		x	x		x
Emergency information		x	x		x
Schedule adherence		x	x		x
vehicle status		x	x		x
Business information					x

Exhibit 2g: Fleet operator applications in relation to general ITS sub-categories

Central Computer Applications	ATIS	APTS	ATMS	AVCS	CVO
toll information					x
AHS information	x	x	x	x	x
Network information			x		

Exhibit 2h: Central computer applications in relation to general ITS sub-categories

The CRCS concept is very flexible and could be beneficially used in several types of transportation management information systems, including enhanced airport ground transportation management systems. Several large-scale demonstration and implementation projects have proven the DSRC technologies successful. These projects range from heavy vehicle management systems, such as Heavy vehicle Electronic License Plate (HELP) and Advantage I-75/AVI-Ontario (AVION), to various electronic toll collection systems such as EZ-Pass. The earlier systems, or first generation systems, have focused primarily on the *read-only* (one-way communication) functionality. The planned near future demonstration and implementation projects are focusing on the second generation systems, which feature *read-and-write* (two-way communication) functionality. Some of the key initiatives of such projects are to investigate the interfacing capabilities with emerging in-vehicle technologies and the issues relating to interoperability of systems.

DSRC Proof of Concept

The overall strength of DSRC as a communications technology lies not only in the straightforward application of the technology itself, but also in the relative low cost of equipment and usage. Tag prices vary widely within a range from $20 to $ 150 depending on the level of sophistication. The infrastructure costs are typically absorbed by the agencies that own the system facilities or are passed on to the end-users through transaction fees.

The VMCS at Lester B. Pearson International Airport relies on an information foundation based on the unique identification codes of the commercial vehicles operating in and out of the airport. Those codes are contained on the vehicle tags, or the transponders, which are attached to the vehicles. It is the reader, or the roadside beacon, that acts as the intelligent agent capturing all the information contained in the tag and downloading it to a host computer through wire or wireless communication backbone infrastructure. Traditionally, DSRC applications were only used in very select situations where other identification methods were considered too unreliable. Today, DSRC has matured as a strategic technology providing a variety of delivery mechanisms enhancing almost any transportation system. With continued mass commercialization of DSRC technologies, these systems are gradually becoming a reality both in Canada and worldwide.

The following types of transponders exist to date:

- **Type-I Transponder**

  Type-I transponders are considered part of older DSRC systems. They are fixed-code one-way (vehicle-to-road) communication devices. Reprogramming can only be done at the manufacturer.

- **Type-II Transponder**

  Type-II transponders came about as DSRC systems were penetrating emerging markets, especially as applications for parking management were identified. They have become commonplace in the tag industry and many alterations have been made to the original Type-II transponder (see below). Type-II transponders are part fixed-code, part variable-code two-way (vehicle-to-road-to-vehicle) communication devices. Reprogramming can be done during passage across reader antennae.

  * **Flat Pack Transponder (Type II FPT)**

    Type II FPT is the most common Type II transponders on the market. It is an interior mounted transponder with no display or feed-back to the driver. It affixes directly behind the rearview mirror on a vehicle's windshield. The transponder can be readily moved between vehicles as desired.

  * **Roof Mounted Transponder (Type II RMT)**

    Type II RMT is a special class of Type II transponders on the market. It is an exterior mounted transponder with no display or feedback to the driver. It mounts directly onto the roof of a vehicle that has characteristics making it unsuitable for the standard Type-II transponder.

  * **License Plate Transponder (Type II LPT)**

    Type II LPT is a special class of Type II transponders on the market. It is an exterior mounted transponder with no display or feedback to the driver. It mounts directly onto the license plate of a vehicle that has characteristics making it unsuitable for the standard Type-II transponder.

- **Type II+ Transponder**

  Type II+ transponders are part fixed-code, part variable-code two-way communication devices. Reprogramming can be done during passage across reader antennae. They represent an update of the typical interior Type-II transponders and carry liquid crystal displays for relevant value-added messages such as travel time, fee/toll amount and account balance feedback. In spite of possibilities for decentralized accounting (through re-programming of the memory chip) the account balance tracking is still conducted in a centralized computer system. Type II+ transponders often allows for audio signals through an internal buzzer device in the transponder. These signals are expected to alleviate the driver from unnecessary or unwanted driving distractions.

- **Type-III Transponder**

  Type-III transponders are part fixed-code, part variable-code, two-way communication devices. While reprogramming is still done during passage across reader antennae it is done in a conceptually different way in comparison with the Type II+ transponder. A Type II+ transponder allows for re-programming to be done internally, i.e. in the transponder unit itself. A Type-III transponder is designed so that it can be integrated with external units or other in-car units. It is therefore expected that account balance tracking will be automated through the integration of smart card usage and other applications. It is also expected that the Type-III transponder will generate additional benefits and potentially bring life to some of the CRCS applications outlined in the conceptual discussion of DSRC systems (see Exhibit 1).

While comprehensive systems are likely to migrate both functionally and geographically, history shows that successful technologies must provide cost-effective solutions to a large number of users.

Outlook for Migration of Dedicated Short Range Communication Systems

What once started as an electronic tag for simple identification purposes is today a system offering two-way communication capability, programmability and intelligence. With these mature capabilities and an overall increase in the interest for ITS, DSRC should be considered a key technology in any transportation system of the future. The remainder of the report focuses on applications of DSRC Type-II and Type-III technologies to commercial vehicle management at Lester B. Pearson International Airport. However, significant potential exists in other areas as well. As implied by the CRCS concept DSRC technologies are allowed to migrate, both functionally and geographically, from stand-alone CVO applications at single facilities to integrated CVO applications at multiple facilities across institutional responsibilities to applications in areas of ATIS, APTS, ATMS and AVCS. Standards supporting a smooth migration are under way.

1.5 Lester B. Pearson International Airport's Landside Operations Management Needs

Landside Commercial Vehicle Operations Prior to the Project

At the project's inception, the need for improved landside operations management at Lester B. Pearson International Airport had been clearly identified as critical for the airport's competitiveness and economical sustainability in the future. Before the project was initiated, the landside commercial vehicle operations environment was characterized by the following elements:

- A diverse range of commercial, municipal, emergency response, delivery and general public traffic;
- Permit requirements for the regulation of commercial traffic;
- Central holding areas for commercial traffic due to terminal curb capacity limitations;
- Pick-up areas for general public traffic due to terminal curb capacity limitations; and
- High operating costs due to excessive staffing needs to supervise the holding and pick-up areas.

The vehicles operating in and out of the airport included:

- Taxis and limousines with permits;
- Other commercial vehicles, including Pre-ARranged Dispatched (PARD) vehicles, courtesy vehicles, out-of-town vans, Airport Express and municipal transit buses; and

- General public vehicular traffic.

Since the volume of taxis and limousines awaiting passengers exceeded the available space at terminal curb pick-up areas, CVHAs had been established at two central locations on airport grounds. One CVHA was associated with Terminals 1 and 2 and the other with Terminal 3. Taxis and limousines that desired to pick-up a fare-paying passenger had to proceed to one of the CVHAs first, either when entering the airport grounds empty or after dropping off their passengers at one of the three terminals.

A Transport Canada permit (decal/sticker) was required to be eligible to pick up fare-paying passengers at any terminal curb. Permits were not required for dropping a fare-paying passenger off at the terminal curbs; they were either issued for single-use or on annual basis. A Transport Canada permit was also required for courtesy vehicles operated by commercial enterprises for transport to and from the airport (even though fares were not charged to passengers) and other for-hire vehicles. The general public vehicular traffic could pick up or drop off at the terminal curbs as long as their vehicles were not stopped longer than required for their passengers to board or embark.

All permitted vehicles, including PARD vehicles, had designated parking areas at each terminal curb. Distinct pick-up areas were maintained for each of the different categories of permit holding vehicles, including the Airport Express and municipal transit buses.

Commissionaires responsible for assigning passengers at the terminal curbs to the taxis and limousines holding annual permits made periodic calls to dispatchers at the associated CVHA requesting that a stated number of additional vehicles proceed to a specific terminal curb. The vehicles entered into one of several queues, some for taxis and others for limousines, and vehicle requests were serviced from the heads of these queues. Summoning instructions were provided by the dispatcher over a public address system. Vehicles returning to the CVHA within a defined threshold time after picking up a fare-paying passenger could become eligible for “short trip” status and thereby bypass the existing dispatch queues at the CVHAs and receive priority for summoning to terminal curbsides.

Commissionaires responsible for assigning passengers at the terminal curbs to the taxis and limousines holding single-use permits, such as PARD vehicles, obtained the relevant information from passengers and then contacted the dispatchers at the associated CVHA to notify about particular passengers awaiting pick-up. If a vehicle was waiting in the CVHA for that particular passenger, the dispatcher summoned the vehicle over the public address system, using the transaction number on the single-use permit, to the terminal curbside.

Intended Landside Commercial Vehicle Operations Improvements

Joint planning between the Lester B. Pearson International Airport administration and Transport Canada’s Transportation Development Centre (TDC) indicated that the existing systems could benefit from the implementation of an automated dispatching system for taxis and limousines. The following objectives were determined as achievable through the implementation of a VMCS:

- Improved passenger service;
- Improved curb access management and enforcement;

- Reduced labour costs;
- Increased and protected revenue; and
- Increased management information for airport use and for marketing to commercial fleet operators.

These objectives were to be addressed by several ITS technologies including:

- Automatic Vehicle Identification (AVI)/Automatic Driver Identification (ADI);
- Blank-Out Signs (BOS) and Variable Message Signs (VMS);
- Pre-arranged vehicle Ticket Issuing Equipment (PTIE);
- Destination Ticket Issuing Equipment (DTIE);
- Communication subsystems; and
- Computer software and hardware subsystems.

Project Award

With the focus on innovative integration of several commercially available enabling technologies as well as on using modern operating systems and database management software, IBI Group was selected to design, develop and prototype a VMCS for Lester B. Pearson International Airport.

Overall Private-Public and Public-Public Partnership Environment for the Project

At the inception of the project Lester B. Pearson International Airport was controlled by the federal government's transportation department. This facilitated excellent coordination between Transport Canada's Research and Development (R&D) directorate and the Airports Ground Transportation Unit (GTU). Today the project has become a fully operational system which is under the jurisdiction of the recently formed Greater Toronto Airports Authority (GTAA). The transition to a local operating authority with full jurisdiction of airport grounds should not preclude a continued role for Transport Canada as a driving force behind R&D.

2.0 RESEARCH STATEMENT

2.1 GOALS AND OBJECTIVES

Transport Canada's TDC is exploring the possibilities of applying DSRC for exclusive CVO applications, and expressed an interest to test a prototype system on airport grounds aiming for automation of the landside transportation operations.

The objective of the project was to deploy an innovative information management system that enhanced passenger pick-up operations for commercial vehicles using advanced DSRC technologies. In order to extend beyond what most other airports had previously implemented in terms of AVI and other DSRC applications, the project was to deliberately:

- Build upon and maximize compatibility with current landside commercial vehicle operations for taxis and limousines, as well as PARD vehicles;
- Demonstrate real-time, two-way communication capabilities between vehicles and roadside infrastructure;
- Demonstrate interface capabilities between in-vehicle units and an infrastructure based on real-time control system; and
- Establish a foundation for future expansion to create a comprehensive system for interface with the full range of vehicles using the airport.

The deployment of the VMCS involved the following six-step procedure:

1. Establishment of operational concept;
2. Selection of enabling technologies;
3. Development of an operational prototype the system and the system software;
4. Specification of system implementation at the airport;
5. Installation, testing, integration and commissioning; and
6. Upgrade of software.

3.0 PROCESS

3.1 OVERVIEW OF PROJECT WORK PLAN

The following section describes the eleven-step work plan for the project. The Gantt chart presented in Exhibit 3 depicts the flow of tasks in the work plan. The actual flow of tasks of the work plan, as executed, is left out because of the restructuring of the flow of tasks into stages.

The boxes below complement Exhibit 3 and are intended to frame the essential goals and objectives of each identified task.

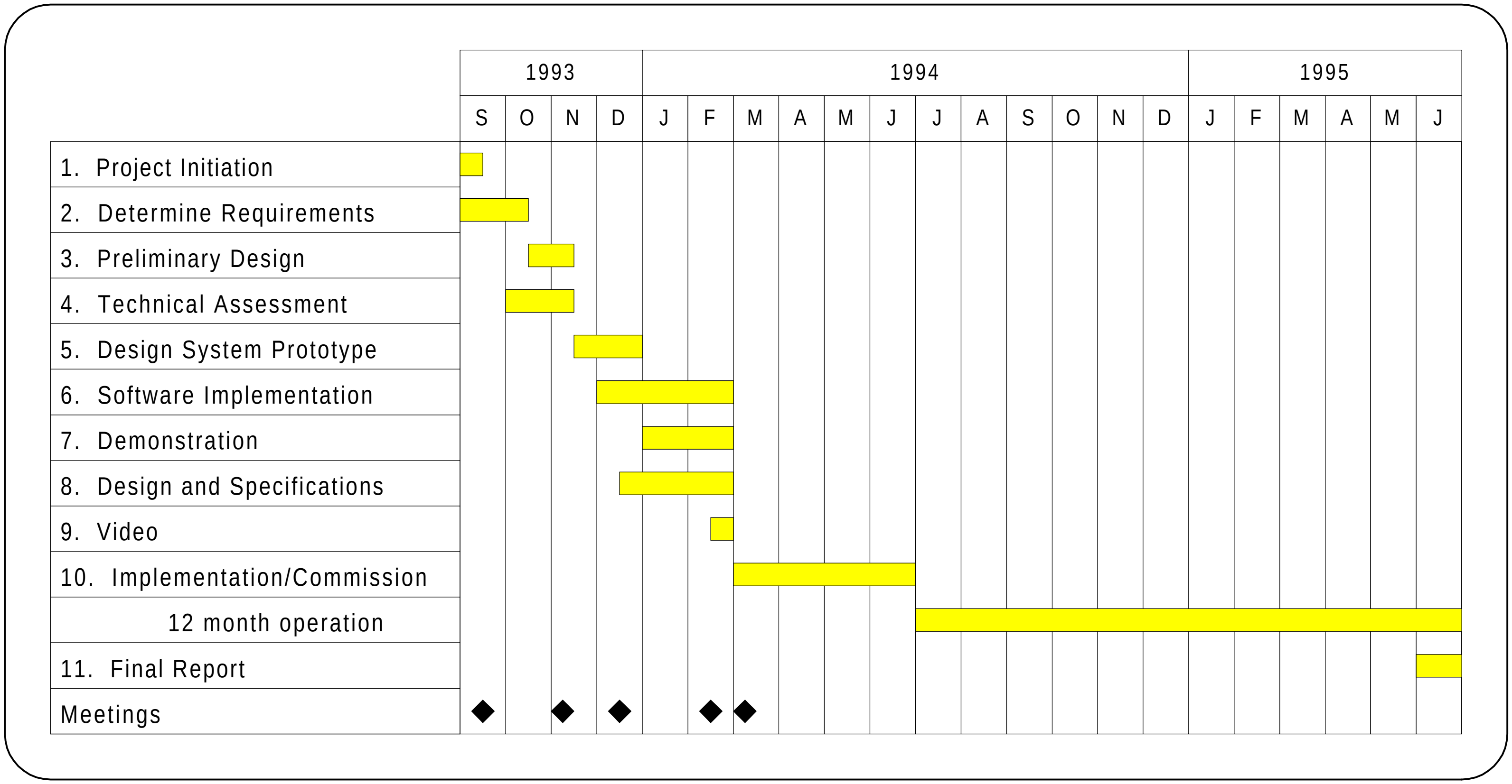
Task 1: Project Implementation
Goals/Objectives
- Establish a clear understanding of work program goals and objectives;
- Gather background information; and
- Establish organizational contacts.

Sample Activities
- Mobilize/orient Project Team;
- Establish working relationships at management level between Steering Committee and IBI Group;
- Establish working relationships at staff level between everybody involved; and
- Facilitate initiation of work program activities.

Task 2: Determine Functional Requirements
Goals/Objectives
- Establish requirements for system design.

Sample Activities
- Develop in-depth understanding of local needs at Pearson;
- Develop in-depth understanding of relevant ITS in the Greater Toronto Area (GTA);
- Define current and future operation concepts/scenarios; and
- Define technological needs for VMCS at Pearson;

Exhibit 3: Revised Preliminary Schedule



<u>Task 3: Preliminary Design</u>

Goals/Objectives

- Review of infrastructure in-place;
- Review technical and physical constraints;
- Review layout plans for equipment installation; and
- Identify integration possibilities.

Sample Activities

- Examine existing drawings;
- Examine layout drawings;
- Inspect site;
- Identify device and field equipment locations; and
- Assess user-friendliness and fit for integration through user focus groups and investigation of strategic master plans.

<u>Task 4: Technical Assessment</u>

Goals/Objectives

- Evaluate functional capabilities of candidate subsystems of VMCS;
- Evaluate fit of subsystems to overall ITS in GTA;
- Identify interface and integration requirements; and
- Recommend suitable subsystem components.

Sample Activities

- Decompose overall VMCS into functional areas such as CVHA devices, terminal curbside devices, management devices, in-vehicle devices;
- Identify options based on existing technology from vendors for all devices and field equipment;
- Sketch on possible configurations; and
- Envisage potential logical designs of the system.

<u>Task 5: Design System Prototype</u>

Goals/Objectives

- Develop a comprehensive system design; and
- Estimate costs.

Sample Activities

- Identify specific devices and field equipment for each functional area;
- Consider opportunities for short- and long-term synergies, both functionally and economically; and
- Develop a detailed overall system cost estimate including capital investment, cost of installment and operations/maintenance costs.

Task 6: Software Implementation

Goals/Objectives

- Create a detailed software design specification;
- Identify suitable computer hardware and operating systems;
- Develop, integrate and test software; and
- Prepare user documentation (manual).

Sample Activities

- Revisit functional requirements of system;
- Review engineering specifications;
- Determine format for documentation;
- Determine availability and functionality of commercial-off-the-shelf (COTS) products and services;
- Obtain computer hardware for development and testing;
- Develop application software based on the design and functional specifications;
- Test application software;
- Demonstrate stand-alone functionality of software;
- Determine integrated functionality of software; and
- Prepare user documentation (manuals) including graphical user interface (GUI) snapshots and descriptions of system operations.

Task 7: Demonstration

Goals/Objectives

- Demonstrate operation of system; and
- Publish interim results to the transportation community.

Sample Activities

- Establish minimum electrical, equipment and space requirements for the demonstration of the system;
- Develop and document test procedures;
- Install software and interconnect devices and field equipment;
- Complete system integration activities necessary to achieve a minimal working prototype and carry out field operational trials; and
- Document and publish results.

Task 8: Design and Specification

Goals/Objectives

- Complete detailed design for installation of system at Lester B. Pearson Airport;
- Prepare comprehensive specifications for all procurements, installation and testing of field equipment; and
- Prepare comprehensive specifications for integration and testing of computer hardware and software as a complete system.

Sample Activities

- Develop installation details for field equipment and its integration; and
- Prepare contract documents including bid item lists, general conditions for bidding, equipment specifications, layout plans to scale, wiring diagrams, communication schematics and separate detail drawings.

Task 9: Prepare Video

Goals/Objectives

- Produce conceptual video highlighting project objectives, design concepts, and the results of demonstration tests.

Sample Activities

- Prepare written script;
- Solicit Steering Committee for feedback and review; and
- Prepare informative video.

Task 10: Monitor Installation/Commissioning and Operation of System

Goals/Objectives

- Achieve contract award at competitive price to qualified contractors;
- Ensure implementation and quality of systems; and
- Ensure integration of software.

Sample Activities

- Assist in bid notice preparation, advertisements, pre-qualification, bidders' meeting, bid evaluation and contract award;
- Monitor contractor performance;
- Provide status reports on progress made;
- Assist contractor in integration of software into the system;
- Provide training and on-call support to airport administration and staff;
- Prepare comprehensive evaluation criteria for system; and
- Complete system evaluation based on established evaluation criteria.

Step 11: Final Report

Goals/Objectives

- Integrate all project documentation into a final report.

Sample Activities

- Solicit comments on old documents;
- Provide conclusions and recommendations on relevant issues; and
- Outline future expansion possibilities and opportunities for interaction/integration with other ITS.

3.2 MODULAR APPROACHES AND COST EFFECTIVENESS FOR FULL-SCALE DEPLOYMENT

Potential benefits of using a modular approach in implementing transportation information management systems, i.e. an approach allowing for gradual and logical growth while minimizing the associated investment risks, called for the project to assess the requirements for a "minimum" and "enhanced" landside commercial vehicle system. By structuring the project along this modular approach concept, Lester B. Pearson International Airport, starting with a "minimum" landside commercial vehicle system, could expand the system over time through several new implementation phases. If new expansion phases would be initiated when the old phases generated sufficient benefits to stand on their own, Lester B. International Airport would soon experience a complete Commercial Vehicle Control and Management System. The theory behind such reasoning is based on proclaimed economies of scale when expanding a basic or lower level of sophistication DSRC system. In practice, the return of an investment would therefore increase as new applications were allowed to piggyback at little additional cost. A full-fledged landside transportation operations system would still, however, require some real-time, person-to-person voice/data communication wide-range systems, such as cellular and satellite, to coexist with the DSRC system.

The prototype system had to be fully operational after the termination of the project and flexible enough to support future enhancements. The assessment of the preferred concept was based on the following criteria:

- Capital investment;
- Operating and maintenance costs;
- Flexibility to maintain (service) system;
- Flexibility to make changes (upgrade) system; and
- Fail-safe operations.

3.3 PHASING OF PROJECT

As can be concluded from the tasks outlined above, much of the work involved to establish VMCS at Lester B. Pearson International Airport included functional and technical assessments of the applicable DSRC technologies. An innovative approach was required to support the operational objectives of the Ground Transportation Unit (GTU) and Transport Canada and to integrate these technologies. Therefore, the natural approach was to divide the system into subsystems and functional areas. Such an approach resulted in an easy and orderly identification of all CVHA, terminal curbside, administration/control area and in-vehicle devices and the essential field equipment. Following identification of system elements a detailed functional and technical review, as well as definition of subsystem and overall system requirements, was undertaken. The interfaces, integration, communications and performance requirements were identified and associated costs for the implementation of the VMCS were projected.

The original system design was completed in 1994. To ensure an efficient process the implementation was divided into three phases where the highest priorities would be added to the system in accordance with the modular approach discussed above. System integration efforts completed to date include:

- Software development;
- Procurement, installation and commissioning of field equipment;
- Modifications to communications, mounting and power infrastructure;
- Proofing and commissioning of concept; and
- Training, documentation and warranty of system.

Issues encountered during the deployment, which was successfully completed during 1996, included:

- Acquisition of Type-III transponders and their supportability;
- Sophistication of overall system functionality; and
- Cost of installing system and prioritization of functionalities within system.

Lester B. Pearson's landside transportation management determined that several enhancements were needed in the near term before bringing the VMCS into use for day-to-day operations. A Phase II effort, completed in mid-1997, included the adding of one additional large VMS at each CVHA and several mid-terminal antennae at the terminals with multiple passenger pick-up areas. These improvements allowed for taxi and limousine queues to be displayed separately at the CVHAs and an optimization of the replacement of taxis and limousines as they left the passenger pick-up areas at the terminal curb sides by keeping a real-time count. A Phase III effort addressing the initial operational goals of billing and revenue management has been identified recently by facilitating curb usage tracking. This enhancement, along with increased integration between terminal curb workstations and the central computer, would allow for fee collection based on entry/exit and dwell times, as well as for increased enforcement possibilities at the terminals.

4.0 APPLICATION

4.1 INITIAL IMPROVEMENTS OF THE LANDSIDE COMMERCIAL VEHICLE OPERATIONS

The VMCS application at Lester B. Pearson International Airport provides an automated control and monitoring system for the dispatching and tracking of both airport-based and private taxis and limousines. The design implemented included DSRC at entrances and exits of the CVHA and at the terminal curbs for identification and tracking, BOS and VMS at the CVHAs for communication with the commercial vehicle operators, ticket printers at the exists of the CVHAs facilitating authentication of the commercial vehicles at the terminal curbs, and communication and computer subsystems. An overview of the CVHAs and the three terminals is provided in Exhibit 4.

The initial VMCS Lester B. International Airport was based on the following five-step procedure:

Step 1: Entering the CVHA

- Identify vehicles via transponder unit;
- Once identified, VMS confirms vehicle registered into system queue;
- Determination of qualification for "short trip" status (which permits queue pre-emption) based on elapsed time since vehicle left terminal curb, relative to a defined time threshold.

Step 2: Information to Queued Vehicles

- Display of the queue lists through VMS for order in which vehicles will be summoned;
- Display of the top-10 vehicle identifiers for each system queue (one for taxis and another for limousines) with a flagging symbol added when vehicles are summoned to exit.

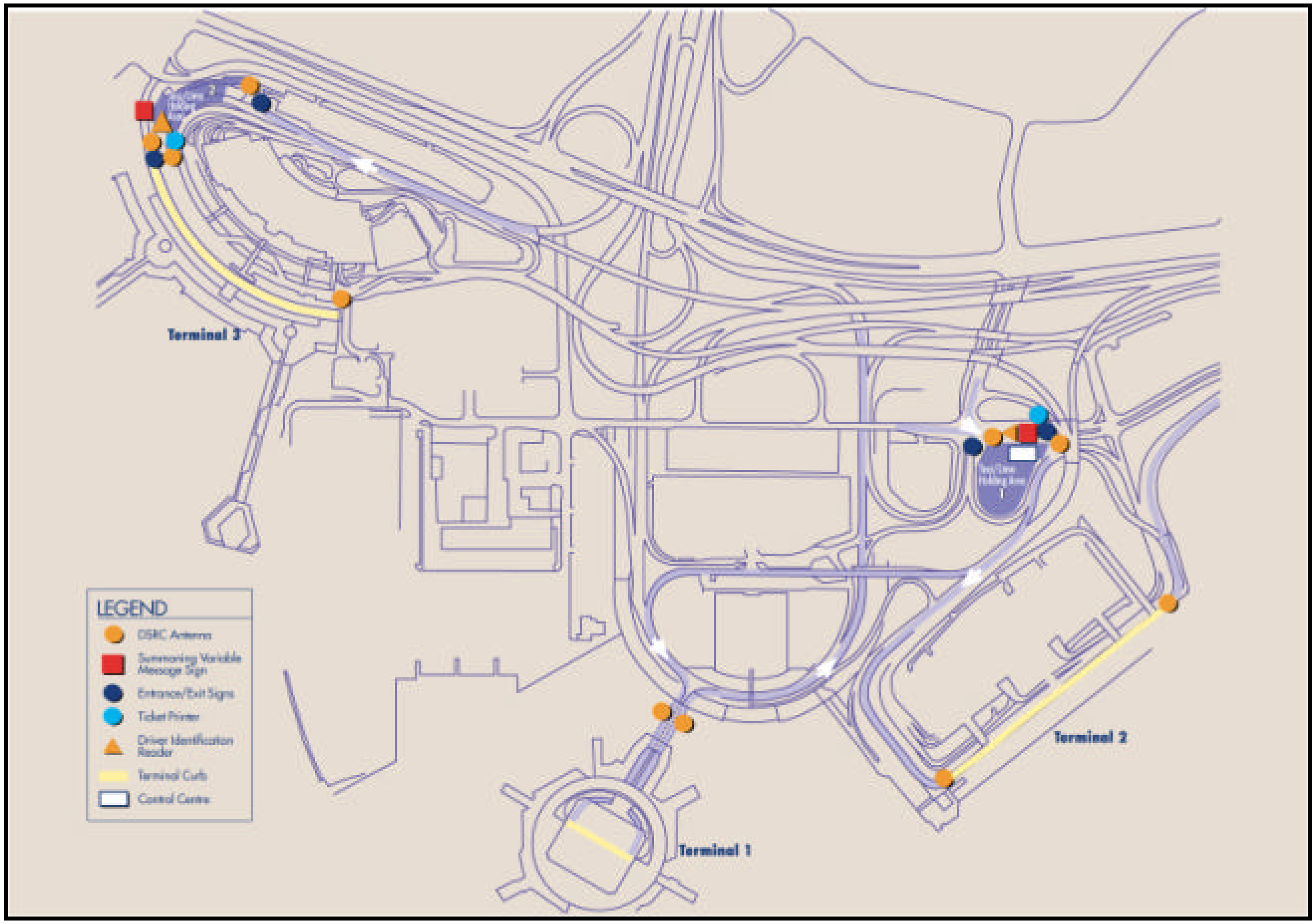
Step 3: Exiting the CVHA

- Provide authentication ticket to vehicles summoned to exit;
- Display request for authentication ticket pick-up and destination information via VMS;
- Register driver identification through card transaction.

Step 4: Summoning to a Terminal Curb

- Identify vehicles via the transponder unit upon arrival and departure to determine whether curb queue has increased or decreased;
- Tracking terminal curb queue lengths against target parameters to facilitate just-in-time dispatching of vehicles as required.

Exhibit 4: Overview of the CVHAs and Terminals



Step 5: Pick-up at Terminal Curb

- Authenticate arriving vehicles by drivers' authentication tickets or authentication list displayed on terminal curb computer.

With this five-step process, the anticipated operational benefits of the VMCS (described earlier) were possible. The VMCS showcased the Type-II transponder capabilities to perform multiple functions in a landside commercial vehicle operation environment at an airport. These functions include tracking, dispatching and future revenue collection. With such functions in a fully operational system, it would be imperative to reach for the additional benefits of the Type-III transponders in any expansion of the VMCS.

As indicated from the initial development phases, the final VMCS would be greatly enhanced by Type-III read-write transponder with its added efficiency and functionality. Actual deployment would not only help optimize the overall system performance, but open up for additional integration opportunities. For example, the card transaction enabling driver registration in Step 3 could be done in a fully automatic and seamless fashion by integration of a Smart Card to the Type-III transponder. Such integration would allow for an extensive array of additional information exchanges between vehicles and roadside infrastructure.

Adjustments to the Originally Planned Vehicle Monitoring and Control System

As the projected costs were isolated for each of the VMCS subsystems, adjustments to the key functionality of the VMCS had to be made. These adjustments, limiting much of the efficiency and some of the functionality, included:

- Consolidation to one VMS per CVHA;
- No use of Type-III transponders;
- Low-cost driver identification;
- No PARD vehicle automation; and
- No machine-readable tickets or terminal curb ticket readers.

Exhibits 5 and 6, illustrating the general field equipment locations for a typical CVHA and terminal curb, respectively, reflect these key adjustments. The original CVHA design also called for intercoms at entrances and exits. The rationale for intercoms was to allow for drivers not so experienced with the system to request advice or help if confused. Intercoms were never installed, however, due to concern of blockage at these points. If there were problems, taxis and limousines would instead have to report through their company dispatcher by radio. The anticipated blockage occurred anyway, especially during peak hours, due to the relative long transaction times for driver identification. The driver identification card readers have been removed and no substitution has been made to date. The operational VMCS is therefore exclusively based on vehicle identification.

Exhibit 5: Layout of Commercial Vehicle Holding Area

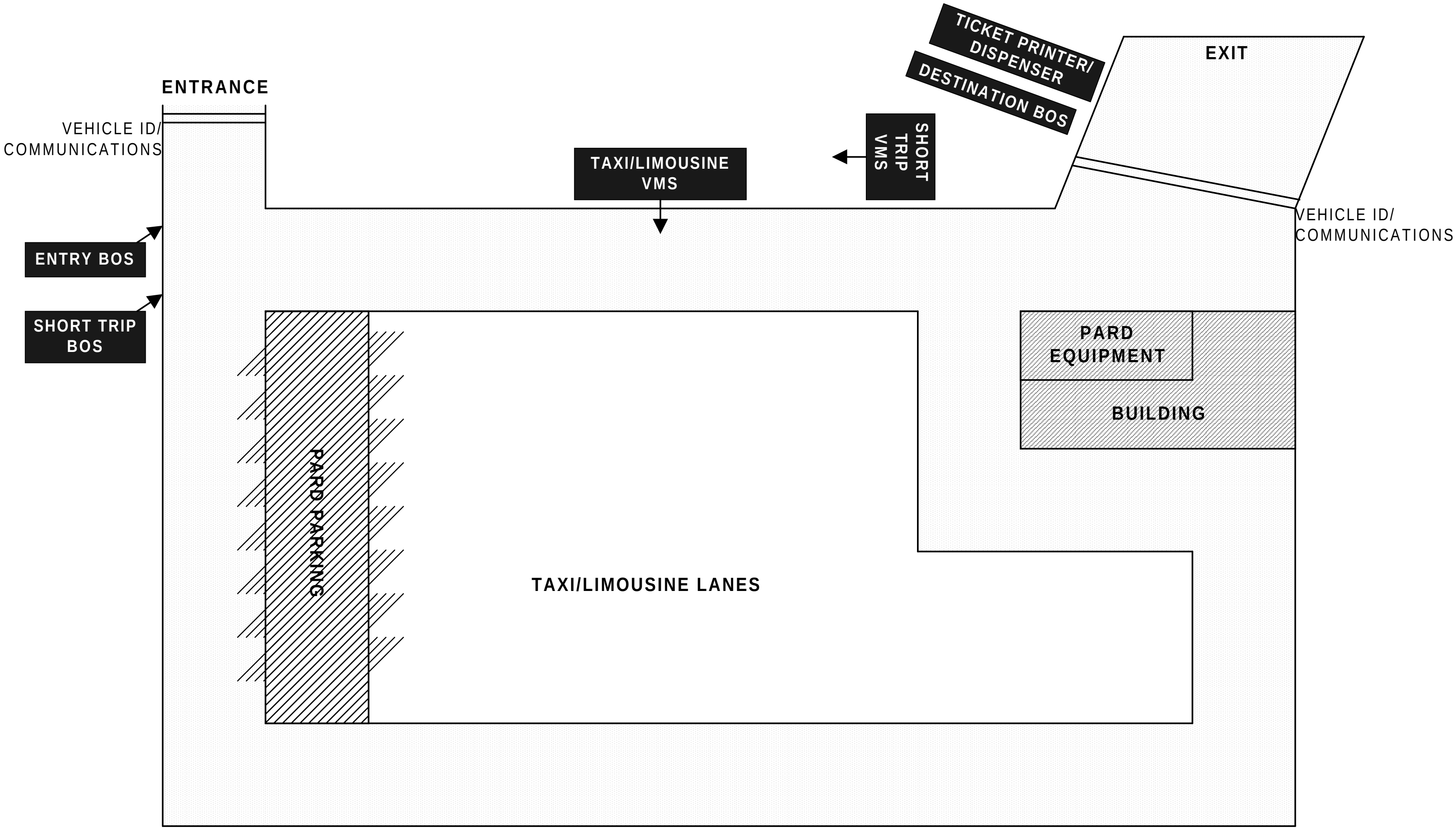
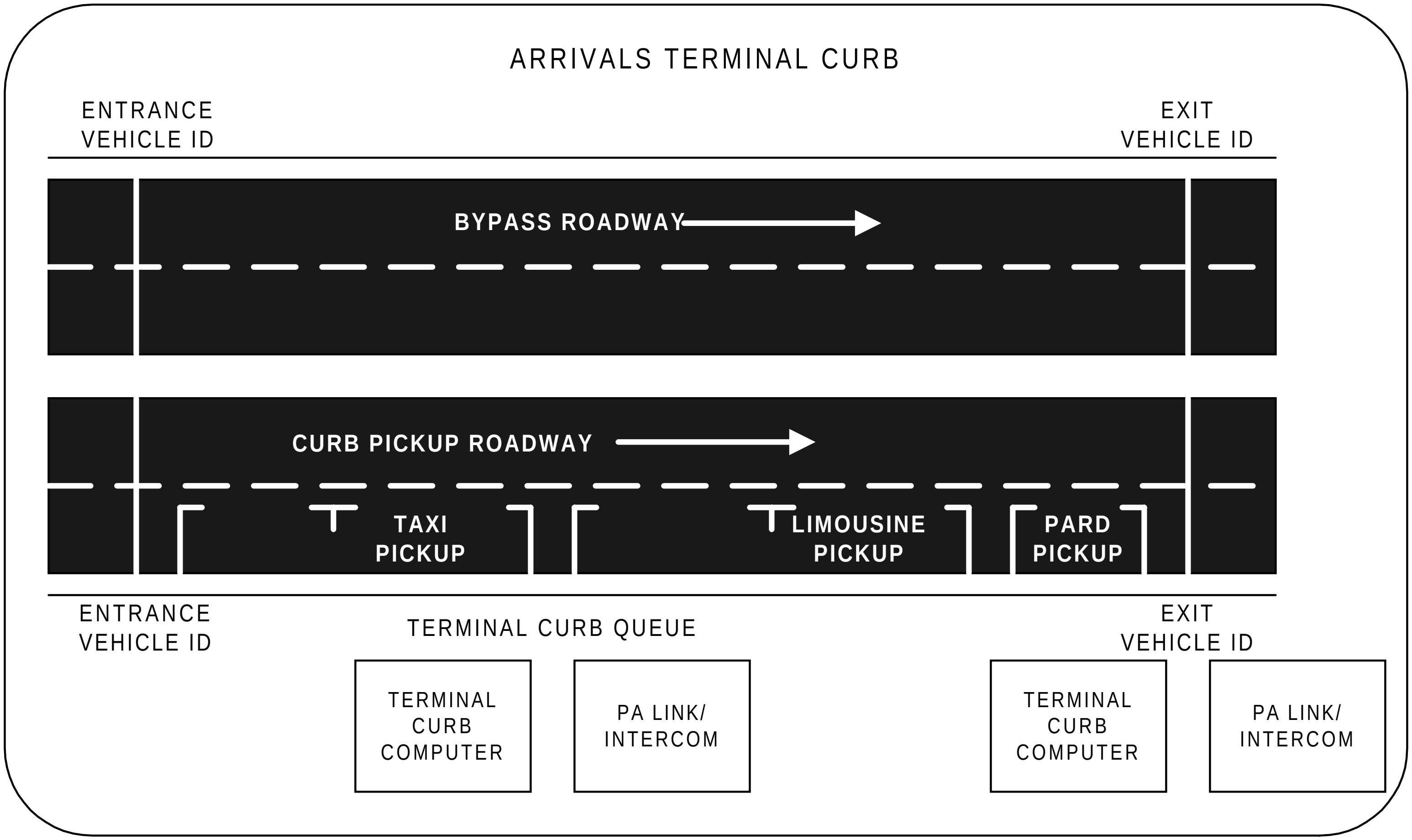


Exhibit 6: Layout of Terminal Curb



Success Indicators of the Vehicle Monitoring and Control System

In general, passengers are enjoying a more pleasant curbside experience with ground transportation through better service and less curbside congestion. The environment for commercial vehicle drivers and operators is perceived as less cluttered and more equitable in terms of revenue and dispatching, hence also limiting the number of confrontations between drivers. The airport landside operations management are continuously improving their information base which helps them make better decisions in both daily management of commercial vehicles operations and in long-term planning efforts.

Given the fact that current draft standards for DSRC technologies in North America support both asynchronous backscatter systems (used primarily by Amtech and Sirit (formerly Texas Instruments)) and synchronous active systems (used primarily by Mark IV and Raytheon (formerly Hughes)), the lack of guaranteed interoperability between systems may proceed, but the end user, as well as the industry, will also have more time to evaluate what various technologies and standards can and cannot do.

Further Improvements to the Landside Commercial Vehicle Operations

GTAA staff is seriously considering implementing system enhancements such as those described above as part of the "enhanced system". Such system enhancements would build on the existing infrastructure and the positive experience and feedback to date. In brief, an "enhanced system" based on such a modular approach would contain features to support the following additional functions and subsystems:

- Taxi and limousine information system
  - In-vehicle staging line information
  - Vehicle assigned terminal destination information
  - Computer-controlled display sign messages
  - Call-out information
- Pre-arranged ride staging and dispatch
- Pay-on-foot trip fee automatic teller machines for pre-arranged trip vehicles
- Registration and maintenance of vehicles
- Registration and maintenance of drivers
- Registration and maintenance of owners
- Accounts receivable billing
  - Trip charges
  - Dwell-time charges

- Violation tracking
- Detailed vehicle activity tracking
- Detailed driver activity tracking

Potential improvements at Lester B. Pearson and integration and migration aspects to other ITS applications are discussed in Section 5.

4.2 System and Subsystem Functionalities

The overall system design for the VMCS constitutes a series of electronic subsystems that are integrated to bring forward an overall system. The VMCS context diagram illustrated in Exhibit 7 presents an overview of the external interfaces of the system. The various VMCS field equipment items, their interconnections and their serial communications interfaces (where the field equipment is integrated with the remainder of the VMCS) are schematically illustrated in Exhibit 8. As depicted in the Exhibit, the devices and field equipment have been categorized by their subsystem functionalities. The subsystems include the identification subsystem, the signage subsystem, the ticket issuing subsystem and the voice communications subsystem. Exhibit 1 complements Exhibits 7, 8, and 9 by summarizing the data exchanges that occur through the communication interfaces between the VMCS and the field equipment.

The following types of information will need to be referenced by the VMCS, and stored in the system as lists and parameters:

- Valid Vehicle Identification Numbers (VIN);
- “Short trip” status threshold time;
- In-vehicle equipment complement for each VIN;
- Valid Driver Identification Numbers (DIN);
- Terminal curb destination identifiers;
- Terminal curb destination identifiers associated with each terminal curb reader;
- License plate numbers associated with VINs for each fleet (PARD vehicle operations only); and
- Registration information from PARD vehicles.

The administration of Lester B. Pearson International Airport is responsible for supplying the initial values for most of these “inputs”, as well as for providing the resources to update this information on an ongoing basis, through interaction with the VMCS software. To facilitate such functions, the software package was developed to run in a Windows NT® environment. The software is also flexible enough to assist the airport administration in archiving of information to and from the Oracle® database, as well as creating the reports and other needed “outputs” for administrative and planning purposes. Any future connections and interfaces of the VMCS to other ITS or information management systems, either at or beyond the airport grounds, are ensured through the modular software and flexible database structure. Exhibit 10 depicts the overall system architecture for all devices, field equipment and central computer control system components.

Exhibit 7: VMCS Context Diagram

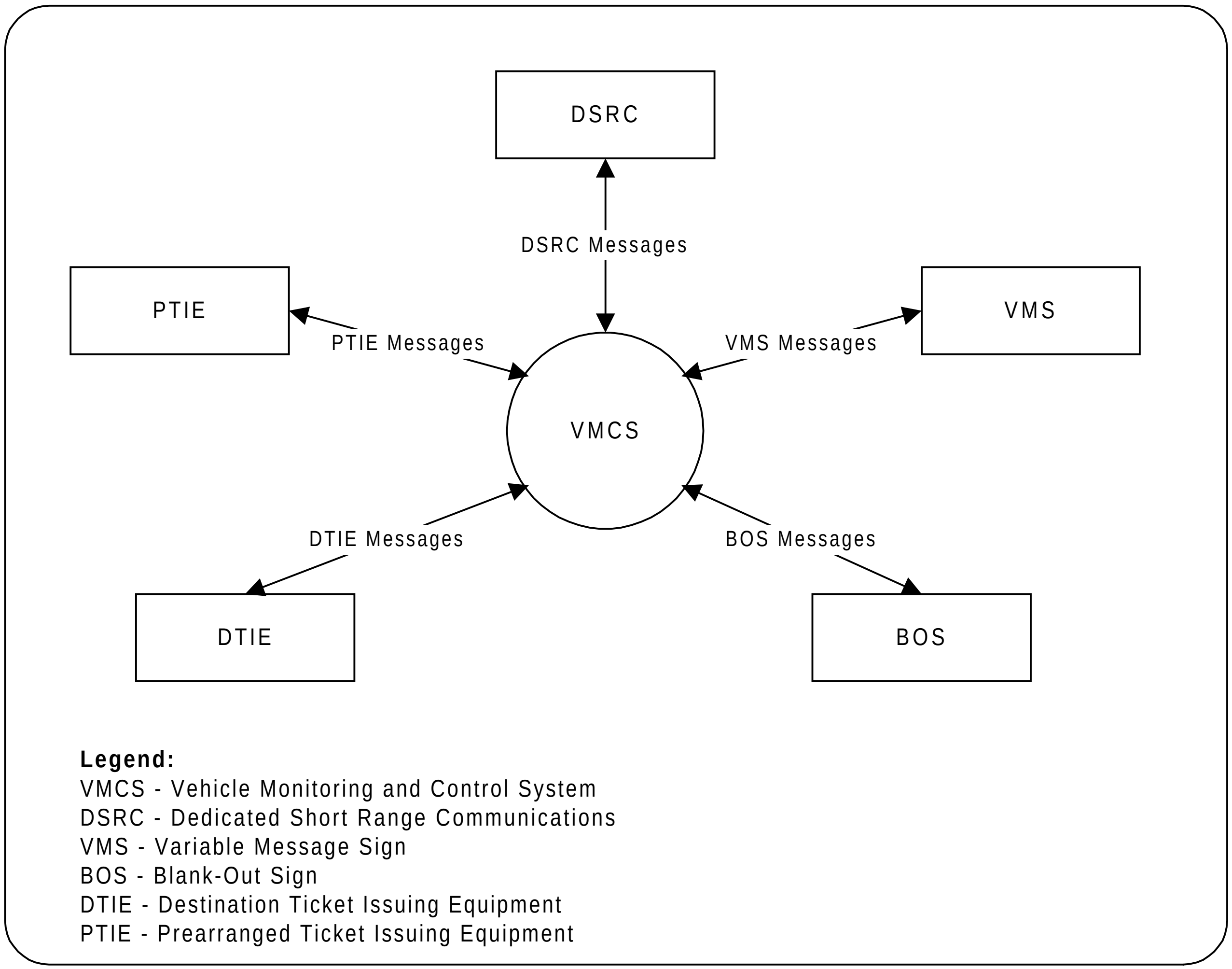


Exhibit 8: VMCS Field Equipment Schematic

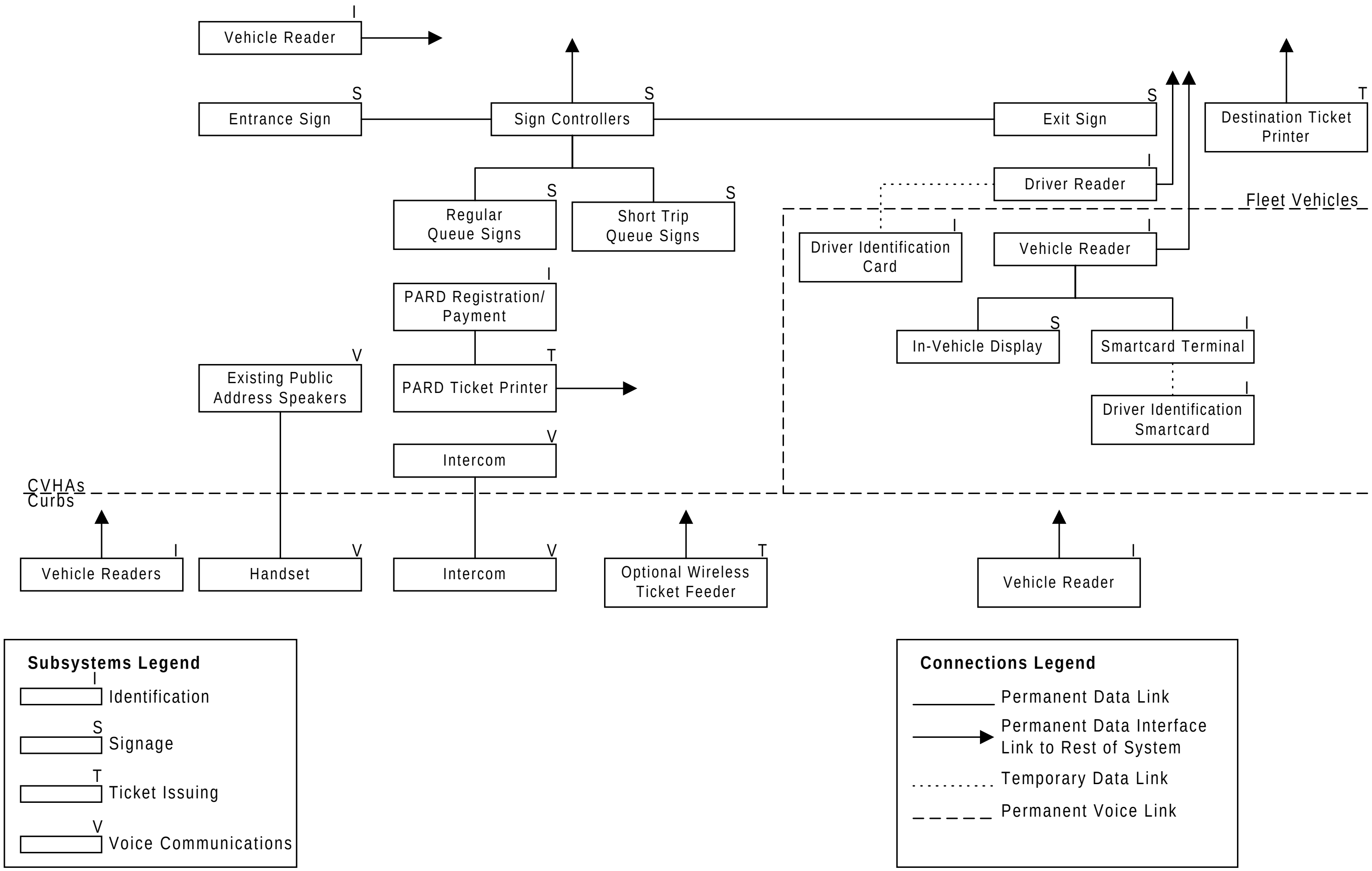
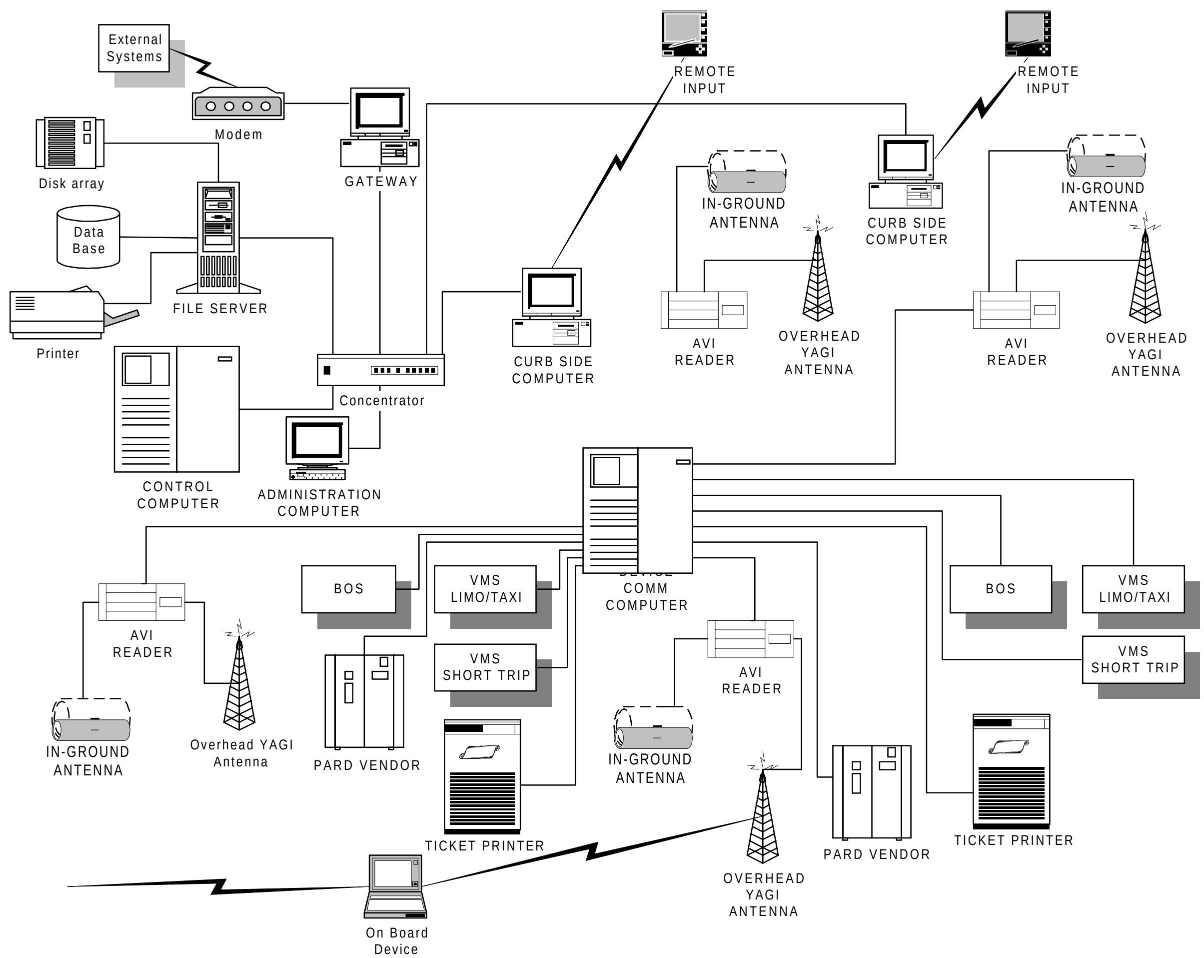


Exhibit 9: In-Vehicle Field Equipment Interfaces

DATA FROM VMCS	FIELD EQUIPMENT	DATA TO VMCS
• Message for display on in-vehicle display	Vehicle reader	• Vehicle identification (if Type-II) • Vehicle identification and driver identification (if Type-III)
	Driver Reader	• Driver identification
• Sign state selection • Sign message	Entrance/Exit Sign (BOS)	
• Sign message contents	Queue Sign (VMS)	
• Ticket information and print authorization	Destination Ticket Issuing Equipment (DTIE)	• Ticket identification
• Central database vehicle information • Payment required	PARD-vehicle registration, payment and receipt Ticket Issuing Equipment (PTIE)	• Vehicle license number • Entered vehicle information • Transaction number • Passenger name • Payment received • Ticket identification
• Ticket authentication	Ticket Reader	

Exhibit 10: System Architecture for the VMCS



Functionality of Installed Roadside Components and Subsystems

The DSRC Subsystem

DSRC equipment is used to track the location of the resident airport commercial vehicles. Each airport vehicle is equipped with a special DSRC transponder identified by a unique VIN. As an airport vehicle passes by an DSRC antenna, its VIN is read by the reader/antenna and data is sent to the VMCS. This continuous process enables the VMCS to sense the overall vehicle movements within the airport through the DSRC subsystem. PARD vehicles, with or without transponders, are not being tracked by the VMCS.

DSRC antennae are strategically placed so that the resident airport commercial vehicles will be tracked entering and exiting the CVHA and the terminal curbside pick-up queues. Each DSRC antenna is connected to a DSRC reader, which constitutes the DSRC Subsystem Controller unit. The DSRC readers send VIN data as they become available while the VMCS communicates with the DSRC subsystem through the DSRC readers by sending data messages to affect a desired change on one or more of the in-vehicle sign displays connected to Type III transponders. Unfortunately, those data exchanges are currently not active because no commercial vehicles were equipped with Type III transponders.

BOS Subsystem

The BOS Subsystem relays discrete fixed information to commercial vehicle drivers entering the different CVHAs. Depending on the physical layout, each VMCS is equipped with multiple BOS. The first BOS indicates “short trip” priority status information and positive acknowledgement to the driver, confirming successful entry into the VMCS. Other BOS area used to inform the driver of the terminal destination. Control of these BOS is through the BOS Subsystem Controller unit, which sends the relevant data messages to affect a desired change on any of the BOS units of the different CVHAs.

VMS Subsystem

The VMS Subsystem relays dynamic vehicle queue information to commercial vehicle drivers. Depending on the physical layout, each CVHA will be equipped with two or more VMS. The VMS is used to display the queue lists for all “normal trip” and “short trip” vehicles. The queue lists comprise one list for taxis and one for limousines, both displaying the current top-10 dispatch queue in a chronological fashion. Control of these is through the VMS Subsystem Controller unit, which sends the relevant data messages to effect a desired change on any of the VMS units of the different CVHAs.

Pre-arranged Vehicle Ticket Issuing Equipment (PTIE) Subsystem

Travellers may pre-arrange for pick-up with external taxi/limousine service agencies or specific airport-based vehicles. External taxis/limousines need to substitute for the DSRC transponders. The purchase of a special PARD vehicle permit/ticket addresses this need and gives them access to the CVHA. Each CVHA is equipped with one PTIE strategically placed at the entrance to allow for controlled access to the CVHA and facilitate a clear flow to the special PARD waiting area. In a conceptual context the PTIE Subsystem could substitute the functional role of the DSRC Subsystem taxis and limousines with transponders. The PTIE Subsystem contains an intelligent controller for interfacing with the VMCS to enable data flow for control and prompting of PARD vehicles. The PTIE Subsystem is, however, not sophisticated enough to sense the overall movement of PARD vehicles within the airport. Specific airport-based vehicles still need a PARD vehicle ticket/permit even though today’s technology (Type III transponders) could respond to the requirements of such system.

Destination Ticket Issuing Equipment (DTIE) Subsystem
Each CVHA is equipped with one DTIE strategically placed at the exit to produce tickets to summoned commercial vehicles, with or without transponders, leaving the CVHA. These tickets record a variety of information for management purposes. Most importantly, the ticket indicates the terminal curb destination for the vehicle. The DTIE Subsystem contains an intelligent controller for interfacing with the VMCS to enable data flow for control and messaging to airport-based vehicles. The PTIE Subsystem does, in a conceptual context, substitute the functional role of the DSRC Subsystem for taxis and limousines without transponders but is not sophisticated enough to sense the overall movement.

Central Computer Control System Components and Subsystems

Each of the above identified roadside components and subsystems is controlled and communicated with through a centralized computer control system. The centralized computer control system is logically divided into two systems. One computer system handles the CVHA for Terminal 1 and Terminal 2, and the other handles the CVHA for Terminal 3. They are linked using a LAN creating a distributed computing environment for the VMCS. The central computer system is comprised of the following three central computers:

- Device Communications Computer (DCC);
- Master Control Computer (MCC); and
- Database Computer (DBC).

The functional role of the DCC
The DCC is responsible for all communications to external system devices. In brief, the DCC provides commercial vehicle operators with logical and necessary protocols to communicate with each external device. In general, the devices are interfaced through industry standard RS232 serial data interfaces. However, the DCC does accommodate other industry standards as well, as required by some system devices. The DCC is a PC-based platform running Windows NT® operating system for cooperative real-time multi-tasking capabilities.

The functional role of the MCC
The MCC is responsible for monitoring and control of vehicle movements within the system. The main task is to maintain the vehicle queues at terminal curb sides and CVHAs. The MCC is a PC-based platform running Windows NT® operating system for cooperative real-time multi-tasking capabilities.

The functional role of the BDC
The BDC contains the central database of the VMCS. The database is a client/server architecture and is accessible by all computers on the network. The DBC is a PC-based platform running Windows NT® operating system for cooperative real-time multi-tasking capabilities.

The following computers are also found in the VMCS:

- System Maintenance Computer (SMC); and
- Terminal Curb Computer (TCC).

The functional role of the SMC
The SMC provides a central facility to configure or re-configure applications of the VMCS. From the SMC users may add/remove driver and vehicle information, add/remove external field devices, and obtain statistics on system performance and reliability. The SMC is a PC-based platform running Windows NT® operating system for cooperative real-time multi-tasking capabilities.

The functional role of the TCC
The TCCs are located at each terminal curb and provide the terminal curb operators means to interact with the system through a GUI. From a TCC, users may summon vehicles, review vehicle queue information, and enter certain parameters and vehicle information data. The TCC is a PC-based platform running Windows NT® operating system for cooperative real-time multi-tasking capabilities.

Design and Technology Selection Issues

Important aspects in making the VMCS highly functional included the selection of technology to support the above described subsystems. For example, the LAN network employed is an industry standard 10-Base-T system capable of supporting TCP/IP, Ethernet and Novell Netware® traffic. In brief, this selection recognizes the importance of communication and exchange of data between any computer on the VMCS network.

Additional considerations included an assessment of the different on-board vehicle units, i.e. Type I, Type II and Type III (with smart card capabilities) transponders, applicable COTS software and specially developed (tailored/user-friendly) software and hardware, and the selection of the most appropriate communications media for interconnection of the central control computer system and the various devices and field equipment. The selection of the specific central computer control system architecture reflects the performance requirements of the VMCS. The use of a PC (versus mainframe computer) allowed for the design of generic applications and user-friendliness at all levels. The Oracle® relational database management system facilitated easy integration with desirable GUI, while the Windows NT® operational system enabled real-time traffic and some level of redundancy without reducing system performance in terms of required processing loads. In terms of selecting an appropriate communications backbone, issues included both financial aspects, i.e. leased or owned, and technical aspects, i.e. twisted pair, coaxial cable, fibre optic cable, radio frequency, packet radio, cellular telephone, microwave or infrared.

Future enhancements need to recognize that the communication with on-board equipment of taxis and limousines is in many cases, at least thus far, only possible if in-ground or embedded antennae are deployed. With appropriate visualizations of how Type III transponders may continue to operate under different standards, system integrators and deployers alike need to further address the need for open protocols and long-term system interoperability.

5.0 NEXT STEPS/FUTURE

Future Improvements of the Landside Commercial Vehicle Operations at Lester B. Pearson International Airport

The VMCS software design and the flexible database structure provide an adaptable, expandable and modular product that allows for future enhancements and integration with other inside and outside systems. As stipulated in Section 1, a comprehensive landside transportation system incorporates the following systems:

- Commercial Vehicle Control and Management System;
- Terminal Shuttle Dispatch and Headway Management System;
- Traffic Information and Count System; and
- Parking Control and Information System.

While such a comprehensive system may take decades to realize, near future expansions could easily attain a more full-fledged commercial vehicle control and management system now when the basic VMCS is in place.

With the VMCS at Lester B. Pearson International Airport fully operational, research and development efforts should further advance the understanding of the VRC concept. With this new insight, the outlook for functional and geographical migration is positive. For example, near future applications, through host-to-host computer integration, would allow for the VMCS at the airport to disseminate current commercial vehicle operations to the COMPASS Freeway Traffic Management System. The following recap of the universal concept of VRC in ITS, provides additional support for such ventures.

Short-term Expansions and Upgrades

New Card Technology/Type-III Transponders

The incorporation of proximity card technology for ADI *in lieu* of magnetic stripe cards (later taken out of the VMCS) would allow commercial vehicle operators to present identification without lowering the driver's side window. This would facilitate a more seamless system since there is no need to come to a complete stop. As recognized in the different stages of the project, *read-write* Type III in-vehicle transponders still offer an alternative approach to ADI and communications with drivers.

Automated Ticket Vending Machines

The incorporation of Automated Ticket Vending Machines (ATVM) for commercial vehicle operators seeking single-use tickets is still desirable in the VMCS. The ATVM would allow the driver to register with the VMCS for a particular passenger pick-up as well as to pay for the corresponding permit. The permit would be printed out along with a receipt at the ATVM upon payment.

Hand-held/Portable Computer Devices

The incorporation of hand-held/portable computer devices would bring about more efficient operations at the terminal curbs. For example, printed bar codes on the authentication tickets could be scanned by a special pen connected to the hand-held/portable computer devices (which would communicate with the terminal curb computer) would decrease staffing requirements. With increased automation of the terminal curb processes, such as authentication checks of vehicles and queue length tracking, additional functions could be achieved through integration with the CVHAs.

Long-Term Expansions and Upgrades

With these and other elements put into the VMCS, Lester B. Pearson International Airport could benefit from additional functionalities such as:

- Dwell time charges;
- Monitoring of departure terminal curb and terminal bypass roadways;
- Shared ride coordination;
- Pre-paid fares;
- Airline systems interface for peak load anticipation;
- Support for transponders on the full-range of commercial vehicle traffic; and
- Support for more extensive deployment of DSRC/ADI readers on airport roadways.

With the first VMCS in place at Lester B. Pearson International Airport, opportunities to be considered are not limited to modular expansion within, but also through integration with other ITS in the Greater Toronto Area (GTA). Immediate opportunities exist for roadside DSRC-readers in Toronto's COMPASS Freeway Traffic Management System and along Highway 401, in conjunction with the Advantage I-75/AVION corridor project to estimate travel times from fleet vehicles identified at successive locations. By virtue of the fixed and mobile elements of a VRC system, there are several potential applications for location and positioning. Interesting opportunities also exist to extend these applications to run in concert with other related information technologies, such as Global Positioning Systems (GPS).

Benefits from Coordinated Planning and Standards Development

These other opportunities should be carefully considered and identified, since great potential exists for an overall system approach, where redundancies could be eliminated and, consequently economies of scale generated. While ITS shows great promise in addressing landside operation management problems at airports and overall problems of accidents, congestion and environment, the danger of having competing systems is apparent. This danger is especially pronounced for the individual end-users if they are forced to install a high number of ITS devices in their vehicles in order to benefit from or comply with the systems. In some cases, competing systems have been known to interfere with one another resulting in reduced performance and loss of benefits. Note that DSRC offers a high-impact alternative by being an exclusively CRCS, with all the fundamental data transfer characteristics, but without a limited range of applications due to the wide range of emerging two-way communication functions.

Current/Potential Migration of DSRC to ATIS and APTS Applications

ATIS applications to date have failed to dramatically bring "intelligence" to users. In many cases, they merely disseminate information to increase driver confidence and reduce uncertainty when incidents occur in the transportation system. With the addition of DSRC technologies, the ATIS elements can be immensely improved. DSRC allows for information to be very compressed by using so-called traffic message code. This allows for effective dissemination of relevant real-time information with sufficient detail. DSRC applications that are likely to gain momentum in a near future are focused on the evident probe functions that will come about when vehicles equipped with transponders can start communicating with infrastructure elements along the street and roadway network. Several probe functions are possible and are expected to be pinned down as market forces and regulatory agencies develop a framework in which they can evolve.

ATIS and APTS applications based on DSRC technology will generate data allowing for estimations on average travel times on certain important highway segments. In brief, journey times between monitoring sites for vehicles equipped with transponders are recorded on an individual basis and then analyzed and processed for traveller information purposes. Such systems already exist to a limited extent and scope using only taxis and municipal buses for collecting travel time data. Future developments are likely to include more advice and warning elements to the individual users through paging and messaging as private vehicles become equipped with in-vehicle systems.

With incorporation of other technologies such as GPS, information dissemination will become more efficient through added capabilities of filtering out unnecessary information. DSRC technologies allowing for coding/decoding of messages, dead reckoning and other map matching techniques will help enhance advanced guidance, navigation and Mayday functions based on GPS by correcting for errors or supporting such systems in dense or rural areas where satellite signals may be too weak.

Current/Potential Migration of DSRC to APTS and ATMS Applications

DSRC applications for control and monitoring functions could be prominent in a near future based on the need for traffic signal pre-emption and interactive signal control systems. This is especially true in congested urban areas where no more capacity can be added through traditional transportation planning measures, but also in rural areas where public transit would have a potential to blossom only if service could be improved. DSRC technology, with its vehicle identification capabilities, could assist in the implementation of preferential vehicle systems. Emergency and public transit vehicles with transponders and unique VINs could provide all-red status or priority passage through intersections, thus improving safety for all users of the relevant transportation system facilities and ensuring enhanced transit adherence for public transit services.

DSRC technologies are currently penetrating highly commercial facilities such as parking structures, where they have been found particularly viable due to the reduced operating costs and potential for marketing and program incentives to their customers along with restricted access possibilities. Long-term applications based on DSRC technology call for an interactive signal control system where real-time data collected on traffic and roadway conditions from probe vehicles and other sources would interact with collected data on vehicle destinations and expected travel patterns. When fully coordinated and integrated, such a system would allow for optimized signal control and autonomous route guidance.

Automatic toll collection systems based on DSRC technologies already exist worldwide. However, many automated toll collection systems are not using the full capabilities of DSRC. This is in part due to the lack of advanced transponders, not allowing for advanced *read-write* two-way communication, at the time of implementation. With upgrades of in-vehicle units and efforts to integrate different toll collection systems to create a more seamless travelling, today's DSRC equipment allows for cost effective system operations and customer convenience. Accounting can be performed "centrally" or "on-vehicle".

The technological features of DSRC also hold great promise in assisting policy makers to reach congestion management goals as High Occupancy Vehicle (HOV) concepts are being considered in concert with High Occupancy Tolling (HOT) concepts. Vehicles equipped with modern two-way communication transponders can seamlessly be assigned space in the transportation network and get charged according to existing congestion levels and requested service levels.

Current/Potential Migration of DSRC to AVCS/AHS Applications

With these systems in place and as Intelligent Vehicle Initiatives (IVI) continue, DSRC applications cannot only be used for automatic speed control functions but for real-time adoptive speed control. With roadside units in place and information on the transportation system performance on hand, *read-write* two-way communication capabilities could assign calculated speeds to the necessary in-vehicle units (acceleration/brakes and cruise control) which would easily be disseminated to the vehicles, thus improving safety while dramatically increasing highway capacity.

6.0 REFERENCES

[1] Hinson, David R., FAA Administration at Federal Aviation Administration Annual Forecast Conference, Washington, D.C., March 5, 1996.

[2] Westerbrook, Mary N., **ITS 101: Wireless Technologies**, ITS World On-line Magazine.

[3] Sabounghi, Lewis R., **The Numerous Applications of the Enhanced AVI**, Transportation Association of Canada Annual Meeting, Winnipeg, 1991.

[4] Parker, Doug, Sabounghi, Lewis R., et al., **The Lester B. Pearson International Airport in Toronto**, ITE 94 Canadian District Conference, Windsor, Ontario, 1994.