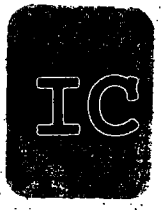

INDUSTRY CANADA
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ASSESSMENT OF SENSOR TECHNOLOGIES FOR ITS

FINAL REPORT

MARCH 1996

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16. Abstract

The report defines the various infrastructure and on-board sensing applications required to support Intelligent Transportation Systems (ITS) functions. Each sensing application is characterized in terms of functional requirements, architecture, examples, and applicable standards. An outreach to selected industry contacts has resulted in a profile of the current and expected future state of technology for sensing applications. An assessment of domestic and foreign industry activity has yielded recommendations for Canadian industry pursuing ITS sensing markets.

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16. Résumé

Ce rapport définie les différents détecteurs d'infrastructure et sur véhicule qui doivent supporter les fonctions des Systèmes de Transport Intelligent (STI). Chaque détecteur est caractérisé en terme de demandes fonctionnelles, architecture, exemples et standards applicables. Une enquête sur le sujet s'est concrétisée dans un profile de l'état présent et futur de la technologie de détection. Une estimation de l'activité dans le domaine s'est ensuivie de recommandations pour l'industrie Canadienne sur les marchés de détecteurs STI.

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2. Assessment of Geographic Information Systems (GIS) Technologies for ITS
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3. Assessment of Positioning and Navigation Technologies for ITS
   by: IDI Ltd.
4. Assessment of Sensor Technologies for ITS
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5. Assessment of Display Technologies for ITS
   by: IBI Group
6. Assessment of System Integration and Intelligent Software for ITS
   by: IBI Group
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10. Assessment of the Demand, Markets and Commercial Development of Global ITS Industry
    by: SRI Consulting.
11. Strategy for the Development of an ITS Industrial Base in Canada
    by: Delphi Systems Inc.

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Assessment of Sensor Technologies for ITS - Final Report

EXECUTIVE SUMMARY

Sensors are critical to successful ITS deployment in that they provide the real-time data to support system functions. Credible and reliable ITS performance relies upon timely and accurate data. The sensor inputs required to support the variety of ITS functions are categorized as follows:

- **Infrastructure Sensors**, which include the field infrastructure required to monitor traffic flow, vehicle classification, vehicle emissions, and the ambient environment.

- **On-board Sensors**, which monitor the environment in the immediate vicinity of the vehicle for lateral/longitudinal control, road hazard/environment, vision enhancement, and intersection collision avoidance.

The primary market for infrastructure applications is traffic monitoring and vehicle classification. There are a variety of competent enabling technologies for these applications, including ultrasonic, infrared/laser microwave, and video image processing. The long term trend appears to be towards digital video image processing applications. The market for these sensors should remain stable in North America and Europe as system deployment continues. Demand for traffic monitoring sensors could be threatened through reduced public sector funding.

The most prevalent enabling technologies for on-board sensing applications are microwave radar, lidar, and ultrasonic. Some initial product offerings using these technologies for blindspot monitoring and obstacle detection are coming to market. These applications are primarily safety oriented and the market potential is strong, based on the observed public willingness to pay for added value safety features. Numerous automakers and niche technology firms are pursuing this market.

There are examples of Canadian companies serving the international market for selected infrastructure sensing applications. Canadian companies with unique expertise in the following areas could consider ITS applications:

- digital video image processing;

- satellite remote sensing;

- obstacle detection using microwave or infrared technologies;

- harmful emissions monitoring.

Such companies should consider accessing the international ITS market through strategic alliance with traffic control product distributors, large system integrators, and the automotive industry.

Industry Canada and Transport Canada should consider mechanisms aimed at:

- fostering the development of industry alliances to facilitate product development, marketing, manufacturing and support for the international sensor market for tolling, commercial vehicle, and traffic management applications;

- showcasing Canadian ITS expertise, including sensing applications;

- inducing ITS sensing research and development activities, focusing on video detection, vehicle probe monitoring, remote sensing and on-board radar or lidar;

- participation in foreign ITS programs and standards initiatives.

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Assessment of Sensor Technologies for ITS - Final Report

1.0 INTRODUCTION

This report presents an assessment of the current state of technology and industry activity associated with various sensing applications as required to support Intelligent Transportation Systems (ITS). This work forms part of a broader program sponsored by Industry Canada and Transport Canada to assess the technology and worldwide markets for enabling technologies for ITS. The primary objective of the overall program is to identify ways by which Canadian industry can compete successfully in foreign and domestic ITS markets.

The scope of work required to assess ITS sensing technologies includes:

- Definition of the various ITS sensing applications in terms of functional requirements, system architecture, technologies and example applications, and relevant standards/protocols.
- An assessment of candidate technologies for each sensing application in order to identify relative performance, costs, and market potential.
- A commentary on Canadian and foreign industry participation, including an assessment of barriers to accessing foreign markets, and recommendations to Canadian industry.

Industry participants contacted and/or referenced in the report have been documented in a standard format to support the development of on-line ITS industry listings.

2.0 SYSTEM DEFINITION

2.1 SENSING APPLICATIONS

Sensor applications may be divided into two groups:

- Infrastructure applications which include:
  - traffic flow/incident/congestion detectors;
  - vehicle identification/classification sensors for tolling, weigh-in-motion (WIM), and commercial vehicle preclearance;
  - vehicle emissions sensors;
  - ambient environment sensors.

- On-Board applications which include:
  - longitudinal/lateral control sensors;
  - road hazard/environment sensors;
  - vision enhancement sensors;
  - intersection collision avoidance sensors.

The sensor applications noted above support user services bundles defined by the U.S. National ITS Program Plan. Exhibit 2.1 maps the sensor technologies to the relevant ITS user service bundles.

The scope of the assessment of on-board sensors focuses on vehicle-to-roadside and vehicle-to-vehicle applications. Beyond these applications, there are a variety of on-board sensors to monitor the vehicle and driver performance. Examples would be wheel sensors to support anti-lock braking and oxygen sensors for vehicle emissions. These "intra-vehicle" sensing applications are developed by the automotive industry, not necessarily within the arena of ITS. This study only deals with these vehicle sensors to the extent that they interface with the ITS sensing applications.

The scope of this section includes functional requirements, physical and logical architecture diagrams, compatibility and interoperability issues and key example applications for each of the sensor types.

2.2 INFRASTRUCTURE SENSORS

2.2.1 Functional Requirements

The following summarizes the general functional requirements associated with field deployment of sensors for the various infrastructure applications:

- sensors should have minimal impacts on pavement integrity and be easily maintained with relatively few field visits required for inspection/maintenance activities (generally two routine visits per year);
- the accuracy and reliability of the data gathered from the sensors should be constant under various ambient environment conditions;
- field sensor subsystems should be readily configurable in terms of type of data provided, reporting cycle, and diagnostics, such that they can be tailored to suit specific current and future emerging applications.

EXHIBIT 2.1
ITS SENSOR TECHNOLOGY APPLICATION MATRIX

Bundles	Infrastructure Applications				On-Board Applications			
	Traffic Flow/Incident/ Congestion Detection	*Vehicle Identification/ Classification*	*Vehicle Emissions*	*Ambient Environment*	*Longitudinal/ Lateral Control*	*Road Surface Environment*	*Vision Enhancement*	*Intersection Collision Avoidance*
1. Travel and Transportation Management	X		X	X				
2. Travel Demand Management	X	X	X					
3. Public Transportation Operations	X	X	X	X	X	X	X	X
4. Electronic Payment	X	X						
5. Commercial Vehicle Operations/WIM/ Pre-Clearance	X	X	X	X	X	X	X	X
6. Emergency Management	X			X				
7. Advanced Vehicle Control and Safety Systems					X	X	X	X

Traffic Flow/Incident/Congestion Detection

Sensor technology in traffic management applications should be capable of providing lane specific speed, volume and occupancy data as input to processing algorithms. Typical processing applications include incident detection and congestion management.

Vehicle Identification/Classification Sensors

Vehicle classification sensors should be capable of identifying a variety of classifications:

- motorcycles;
- cars;
- small trucks;
- transport trucks (3-axle, 4-axle, etc.);
- buses;
- tractor trailers.

The classification parameters (such as vehicle weight, height or number of axles) must be configurable, such that the sensors may support a variety of ITS applications, including:

- electronic tolling;
- WIM;
- preclearance at inspection stations and border crossings;
- access control.

Vehicle Emissions Sensors

Vehicle emissions sensors should be capable of collecting information from passing vehicles instantaneously and without inconvenience to the driver. These sensors should identify excessive concentrations of harmful pollutants such as:

- hydro carbons (HC_x);
- carbon monoxide (CO);

- nitric oxides (NO_x).

Ambient Environment Sensors

Ambient roadway environment sensors include detection of low visibility, high winds, rain/sleet/snow, and icy pavement conditions. Dependant upon the application, the sensors may directly measure a given parameter (e.g., anemometer for wind velocity) or aggregate a series of measured inputs with a predictive algorithm. For example, the rate of change of ambient temperature and humidity can be monitored to predict icy pavement conditions.

2.2.2 System Architecture

All sensing applications employ a collection of field sensors interconnected to a local field processor which aggregates data for communication to a central system. Some newer technologies incorporate the local processor directly into the sensor unit to provide a low cost, self contained unit. Exhibit 2.2 identifies the various sensor technologies and the associated subsystem information transactions.

2.2.3 Technologies and Example Applications

The following is an introduction to the enabling sensor technologies for traffic management, identifying key characteristics that distinguish one technology from another.

Traffic Flow/Incident/Congestion Detection Sensors

The inductive loop is still the prevailing sensor technology for detection of traffic flow parameters. However, installation/maintenance challenges associated with in-pavement sensors has led many traffic authorities to seek off-pavement alternatives. Off-pavement sensors such as video image processing, infrared or microwave are typically mounted on an overhead structure (sign truss, pole or overpass) and hence, the installation and maintenance is less disruptive to traffic flow. The detection performance of over-pavement technologies has been steadily improving and these sensors are becoming more cost effective. Exhibit 2.3 summarizes the available traffic flow sensor technologies identifying their advantages and disadvantages and basic operational features.

Vehicle Classification Sensors

Vehicle classification sensors are required for regulatory compliance, automatic toll collection, commercial vehicle operations and historical data collection. Enabling technologies for vehicle classification include:

EXHIBIT 2.2
SENSOR TECHNOLOGIES - INFRASTRUCTURE APPLICATIONS

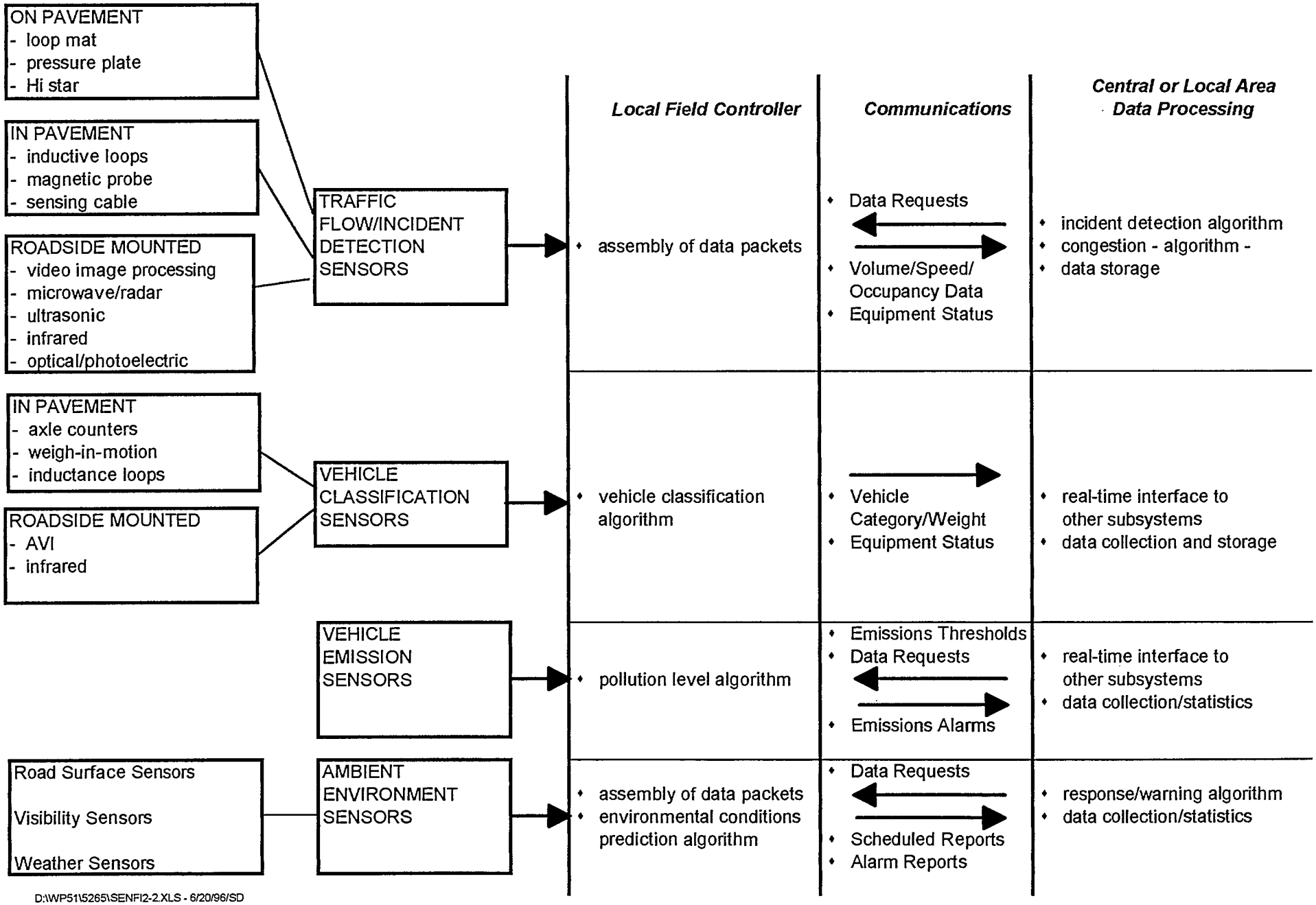

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EXHIBIT 2-3
ITS FIELD SENSOR TECHNOLOGIES

DETECTOR • Representative Products	TYPE	MEASURING CAPABILITY					METHOD OF OPERATION	ADVANTAGES	DISADVANTAGES
		Count	*Presence*	*Speed*	*Road Occupancy*	*Queue Length*			
Optical-Photoelectric	Over-Pavement	X	X	X	X		Passage of vehicle between light emitter and photoelectric cell interrupts transmitted beam.	i) Accurate for vehicle passage in a single lane.	i) Not well suited for multi-lane detection applications. ii) Not well suited for non-uniform lighting conditions.
Optical-Infrared • Microsense	Over-Pavement	X	X	X	X		Overhead transmitter/ receiver notes vehicle passage by change in signal reflection.	i) Does not require pavement-mounted sensors.	i) Sensitive to ambient light conditions and pavement colour. ii) Sensitive to weather and atmospheric conditions.
Ultrasonic - Continuous Wave • Tacel	Over-Pavement	X		X			Operates on Doppler principle for reflected waves.	i) Direct speed measurement. ii) Does not require pavement-mounted sensors.	i) Cannot detect presence. ii) Accuracy problems during congestion. iii) Sensitive to environmental conditions.
Ultrasonic-Pulsed • Sumitomo	Over-Pavement	X	X	X	X		Emits bursts of energy. Detection is based on reflections arriving within a certain time period.	i) Can be used where the pavement is unstable. ii) Can classify vehicle height. iii) Does not require pavement-mounted sensors.	i) Conical detection zone may result in inaccuracies. ii) Accuracy problems during congestion. iii) Sensitive to environmental conditions.
Microwave - Continuous Wave • Whelen	Over-Pavement	X		X			Operates on Doppler principle for reflected microwaves.	i) Direct speed measurement. ii) Does not require pavement-mounted sensors.	i) Performance may be impacted by other nearby microwave transmissions. ii) Cannot detect presence. iii) Accuracy problems during congestion.
Microwave-Presence • RTMS	Over-Pavement	X	X	X	X		Scans frequency range and looks for change in time for reflections.	i) Side-fire, multilane monitoring up to 12 lanes. ii) Direct speed measurement for overhead mounting. iii) Integral processor.	i) Calculates speed in side-fire mode. ii) Accuracy decreases for distant lanes.

EXHIBIT 2-3
ITS FIELD SENSOR TECHNOLOGIES

DETECTOR • Representative Products	TYPE	MEASURING CAPABILITY					METHOD OF OPERATION	ADVANTAGES	DISADVANTAGES
		Count	*Presence*	*Speed*	*Road Occupancy*	*Queue Length*			
Video Image • Autoscope • Odetics • Peek • Rockwell	Over-Pavement	X	X	X	X	X	Digitized video image (from camera) is analyzed to determine relevant traffic information.	i) Greatest traffic parameter measuring capability. ii) Single camera can be used for multi-lane detection.	i) Expensive (requires fixed video cameras). ii) Sensitive to adverse weather or other visual interference.
Loop Mat • Gates Rubber	On-Pavement	X	X	X	X		Same as conventional inductive loops.	i) Easy to install.	i) Designed for temporary use only - unsuitable for long-term use.
Pressure Plate • IRD	On-Pavement	X					Roadwheels passing over sensor activates electrical contacts.	i) Well-defined detection zone. ii) Rugged and generally reliable.	i) Cannot measure most traffic parameters. ii) Counts axles, not vehicles.
Magnetometer • Hi-star	On-Pavement	X	X	X	X		Measures changes in Earth's magnetic field as vehicle passes over.	i) Easy to install. ii) Measures environmental conditions and can classify vehicles.	i) Proprietary unit. ii) Relatively untested. iii) Requires special radio link to roadside cabinet.
Self-Tuning Inductive Loop • Detector Systems • Microsense Sarasota • 3M/Canoga	Under-Pavement	X	X	X	X		Generates electromagnetic field which is disturbed as vehicle passes over.	i) Most commonly used type of detector. ii) Relatively easy to install. iii) Size and shape of detection zone can be customized. iv) Good presence detection.	i) Relocation requires installation of new loop. ii) Can be expensive if installed in small numbers. iii) Occasionally require manual re-tuning.
Magnetic Probe • 3M/Canoga	Under-Pavement	X					Vehicle passage over detector disturbs Earth's magnetic field.	i) Low maintenance. ii) Simple principle of operation.	i) Cannot measure most traffic parameters.
Sensing Cable • Atochem • Focas	Under-Pavement	X					Roadwheels compress piezo-electric cable which generates electrical signal.	i) Well defined detection zone.	i) Cannot measure most traffic parameters. ii) Measures axles, not vehicles.

	WIM	Vehicle Height	Vehicle Length	Axles
Inductance Loops			X	
Pressure Sensors	X			X
Profile Identifiers		X		
Automatic Vehicle Identification	X	X	X	X

Inductance loops can be used for classification on the principle that the percentage change in inductance can be used to determine the type of vehicle that passes over the loop. Loops are not as accurate as other classification technologies and traffic flow disruption during installation and pavement deterioration are additional drawbacks.

Pressure sensors using bending plate, single load cell or piezoelectric technologies are used extensively for weigh-in-motion-applications. These sensors are embedded in pavement and detect applied pressure by producing an electrical charge or identifying changes in resistance. Volume and speed parameters can also be determined.

Profile identifiers may include a variety of mounting configurations and technologies. Most applications are either mounted overhead or side-fired and utilize reflective beam technologies such as infrared, optical, ultrasonic or microwave/radar. A beam of energy is continuously monitored by the detection device which essentially measures the physical dimensions of a vehicle as it passes through the detection zone. Profile identifiers perform better at low speeds and performance may deteriorate in harsh environmental conditions.

The main components of an Automatic Vehicle Identification (AVI) system are in-vehicle transponder and roadside antennae, reader and controller. The data read from transponder by a roadside reader is transferred to the local controller and can be cross-referenced with the vehicle classification database by the central computer, to identify the corresponding vehicle. The installation cost is higher than other approaches to classification, however, much of this cost may be offset by the integration with other user services such as commercial vehicle pre-clearance and electronic tolling.

The following table presents examples of existing vehicle classification sensors applications:

	Agency	*Location*	*Sensor Type*
U.S.	Massachusetts Highway Department	Central Artery Tunnel Boston	Axle-Sensor Infrared Curtain Height Sensor AVI
	California Transportation Department	State Route 73, Orange County	AVI Light Curtain
	Kentucky Transportation Cabinet	I-95	AVI Pressure Sensors
Canada	Halifax-Dartmouth Bridge Commission	A. Murray MacKay Bridge	Pressure Sensors Axle-Sensors
	Ottawa-Carleton Regional Transit Commission	Ottawa Bus Terminal	AVI

Vehicle Emissions Sensors

Emission sensors are calibrated to detect a specific type of gas or particulate. Therefore, a series of sensors may be required for a given application. Some technologies are discussed below.

Gas sensors are responsive to certain gases, in particular those such as CO which are emitted from the exhausts of gasoline or diesel vehicles. Infrared opacimeters are used to analyze vehicle emissions for particulate concentrations.

Detection systems are typically comprised of a sensor head, transmitter and control unit. Should the sensing equipment detect a gas level above the set alarm point, this will initiate an alert signal immediately and continuously log the level detected throughout its duration until an acceptable level returns.

Emission detectors are typically implemented as dedicated facilities for voluntary testing or mandatory testing as part of vehicle licensing procedures. British Columbia, some of the U.S. states, and various European countries have implemented mandatory testing as part of licence renewal procedures.

Ambient Conditions Sensors

Ambient conditions sensors provide data on changing visibility or road surface conditions. Usually, these units need to be initially calibrated for local atmospheric conditions upon installation. Subsequently, they typically require little maintenance and calibration.

Ambient conditions sensor technologies include:

- pavement sensors;
- visibility sensors;
- roadside weather stations.

Pavement surface temperature and conditions are obtained from solid-state electronic devices installed in the roadway, flush with the pavement surface. These sensors provide an array of information including:

- pavement temperature;
- dry/wet above 0°C/wet below 0°C/icy conditions;
- dew;
- frost;
- absorption;
- relative amount of deicing chemical present.

Additional capabilities include:

- freezing point of water/chemical solution on the pavement surface;
- depth of water;
- percentage of ice present.

Subsurface temperature data is also available, by installing probes directly below the pavement at a depth of 40 cm. These probes provide frost depth data.

Road visibility sensors use either visible light or infrared light. Both types apply the forward scattered principle to a volume of sample air to measure the atmospheric extinction co-efficient. This co-efficient is proportional to visibility at the location of the sensor. Some sensors can achieve visibility measure from 3m to 20km.

Roadside weather stations are based on microprocessor technology with extensive processing capabilities. They can detect a variety of environmental parameters such as wind velocity, air temperature,

relative humidity, precipitation and freezing point. When interfaced with predictive algorithms, advance notice of adverse driving conditions is generated.

Applications of ambient conditions sensors are primarily in areas where ice, bad visibility or other conditions dramatically impact motorists safety, such as mountain passes or bridges. Some example applications include:

- Ministry of Transportation of Ontario - wind monitoring on Burlington Skyway with motorist advisory using variable message signs (VMS);
- California Department of Transportation and Washington State Department of Transportation - visibility detectors and road surface conditions detectors with warnings conveyed to motorists over advisory radio;
- Idaho Transportation Department is undertaking the Storm Warning project which will evaluate three sensor systems to be used to measure visibility during blowing dust and snow. Information will be automatically transmitted to VMS signs to warn motorists.

2.2.4 Standards and Interoperability

Most sensing applications employ separate sensor(s) and microprocessor based controller. The interfaces between the sensor units and the controllers are unique to the various sensing technologies and may incorporate proprietary manufacturer protocols. From the standpoint of overall ITS architecture, the controller and sensor(s) can be considered as a functional unit and hence the interface issue exists between the controller and the overall system architecture.

To date, the typical approach for collecting real-time data from sensor subsystems is to have dedicated trunk communications channels between the central system and the outlying field controllers. The central system and the field controllers incorporate custom communication software which polls each field controller site at prescribed intervals to collect data packets of a prescribed format. Many operating authorities, such as the Ministry of Transportation of Ontario, have specified and developed custom software to be used within their jurisdiction, supported by standard off-the-shelf controller hardware such as the type 170 controller. Few jurisdictions share common communications protocols, despite the fact that many of these jurisdictions are attempting to provide the same functionality. For example, most North American Freeway Traffic Management Systems incorporate the collection of current traffic volume, speed and lane

occupancy data at certain intervals for processing by incident detection algorithms.

The emerging trend for communications standards and interoperability for detection subsystems, and in fact all ATMS devices, is towards an open system architecture compliant with the Open Systems Interconnect (OSI) seven layer model developed by the International Standards Organization (ISO). The most notable efforts to date in this regard lie within the U.S. ITS program in the form of the National Transportation Communications for ITS Protocol (NTCIP). The accompanying table summarizes the proposed communications profile for each OSI layer. This standard, and in particular the data link layer and physical layer, facilitate interoperability among subscribing ATMS central systems communications subsystems, and field controllers for all ITS applications. This standard is presently under development, and working papers are available from the NTCIP Steering Group.

THE NTCIP PROTOCOL

OSI Model Layer	Communication Profile
Application Layer	Simple Mail Transfer Protocol (SMTP) & Simple Network Management Protocol (SNMP) OR File Transfer Protocol (FTP)
Presentation Layer	None
Session Layer	None
Transport Layer	Transmission Control Protocol (TCP) OR User Datagram Protocol (UDP) (optional)
Network Layer	Internet Protocol (optional)
Data Link Layer	High-Level Data Link Control (HDLC)
Physical Layer	RS232 OR Frequency Shift Keying (FSK)

Source: NTCIP Steering Group http://www-atms.volpe.dot.gov/ntcip/

The other noteworthy effort towards standards and interoperability also originates from the U.S. program. The Joint Program Office of the U.S. Department of Transportation recently announced a $15 million multi-agency initiative targeting the development of standards for all ITS components. The Institute of Transportation Engineers is charged with the responsibility for the development of standard specifications for traffic management field components, including the various sensing applications described herein.

It is imperative that Canadian sensor manufacturers, software developers, and system integrators participate and subscribe to the standards processes. Failure to do so will render Canadian industry uncompetitive within the North American market, and possibly abroad. At present, it is not clear whether the U.S. standards initiatives will be adopted elsewhere in the world, however compliance with the OSI model supports this transportability.

2.3 ON-BOARD APPLICATIONS

Many emerging ITS applications incorporate sensors within the vehicle that support motorist/vehicle interaction with the roadway environment and other vehicles. These sensing applications support Advanced Vehicle Control Systems, the leading edge area of the ITS program. Accordingly, these applications are typically research and development prototypes which will ultimately lead to full productization and widespread deployment.

The on-board sensing applications are categorized as follows:

- **Longitudinal/Lateral Control Sensors,** which support crash warning and control, intelligent cruise control, passing vehicle warning and blind spot monitoring. Sensor outputs are used to provide an alarm indication to the motorist and conceivably automatically activate vehicle controls such as braking and/or passenger safety systems such as air bags. Lateral and longitudinal control is also critical to automated highway system application to permit high speed vehicle platooning or fixed guideway control.

- **Road Hazard/Environment Sensors,** which monitor the ambient environment within the immediate vicinity of the vehicle to support safety notifications to the motorist.

- **Vision Enhancement Sensors,** which improve visibility and safety under night and/or inclement weather driving conditions.

- **Intersection Collision Avoidance Sensors,** incorporating vehicle-to-vehicle interfaces to identify crossing traffic and notify motorists for improved safety.

Each of these on-board sensing applications are discussed in terms of functional requirements, system architecture, enabling technologies and example applications, and emerging standards/protocols.

2.3.1 Functional Requirements

The following general requirements apply to all on-board sensors:

- the sensors must be suitably robust to withstand the harsh environment characteristic of external vehicle mounting;
- the sensors must be formatted such that they can be physically integrated into exterior body panels or undercarriage;
- the sensor processors must be configurable to provide the flexibility to support various evolving applications;
- the sensors should support integration with emerging on-board vehicle communications bus architectures.

Longitudinal/Lateral Control Sensors

Longitudinal and lateral control sensors are mounted on the external sides, front, and back of the vehicle to establish definable fields for object detection. The sensors should support interfaces with a variety of processors in order to perform multiple tasks simultaneously. For example, a forward looking longitudinal control detector may simultaneously support autonomous intelligent cruise control as well as head-on crash warning and control.

Certain longitudinal/lateral collision avoidance sensing applications require vehicle-to-vehicle communications:

- passing vehicle warning and control;
- cooperative intelligent cruise control.

Road Hazard/Environment Sensors

Road environment sensor technologies are typically mounted forward looking on the vehicle undercarriage to monitor:

- external temperature;
- moisture/humidity.

These inputs can be combined with predictive algorithms to advise of potential icy surface conditions.

Road hazard warning employs short range vehicle-to-vehicle or vehicle-to-roadside communications to give motorists advance warning of hazards such as accidents or emergency repairs.

Vision Enhancement Sensors

Vision sensors are forward looking sensors which improve the definition of fixed objects (e.g. guiderail) and moving objects (e.g. other vehicles) under conditions of reduced visibility. These conditions can include driving environment characterized by fog, snow, and/or nightfall. These sensors should actively improve the illumination and/or contrast ratio of objects in the motorist field of view without requirement for a separate video monitor in the vehicle.

Intersection Collision Avoidance Sensors

Collision avoidance sensors employ vehicle-to-vehicle communications coupled with vehicle-to-infrastructure communications in order to define the intersection environment for approaching motorists. The definition of the environment may include the nature and state of intersection control, vehicle right-of-way violation, and imminent collision detection.

The intersection collision avoidance function must integrate a series of sensor and communications input including:

- longitudinal/lateral control sensors;
- vehicle-to-vehicle communications;
- vehicle-to-roadside communications.

2.3.2 System Architecture

As the population of on-board vehicle processing applications and associated input/outputs continues to expand, efforts are underway to develop industry standards for in-vehicle high speed communication networks. This is critical to achieving functional integration, greater flexibility, plug and play component compatibility, and reduced wiring and hardware. Various automotive industry organizations such as the Society of Automotive Engineers, auto makers, and vehicle electronics producers are working towards the development of standard network architectures. A detailed discussion of this process is beyond the scope of this report, however it is relevant in the discussion of on-board sensors as various sensors support multiple ITS and vehicle operation functions. Exhibit 2.4 is an overview presentation of the types of sensors and associated functions supported.

2.3.3 Technologies and Example Applications

Longitudinal/Lateral Control Sensors

Microwave radar is the predominant technology employed for longitudinal/lateral control applications, as it is least susceptible to impact from inclement environment. Electromagnetic interference

could be a factor, particularly as the wireless communications spectrum becomes more crowded.

Longitudinal/lateral control sensors can be configured to suit specific applications in terms of range and sensitivity. For example, a forward looking longitudinal control sensor for head-on crash avoidance must have a relatively long range and low sensitivity as compared to a front pedestrian blind spot monitor for school bus applications.

Extensive research into longitudinal and lateral control systems is underway throughout the world. Notable efforts include specific auto makers such as Nissan and Volkswagen who have each demonstrated "driverless" vehicles whereby on-board sensors lock onto a fixed guiderail. In the United States the PATH program at University of California and the National Automated Highway Systems Coalition (NAHSC) spearheaded by General Motors are the leading research and development initiatives in this arena.

Some standalone sensor applications have been brought to market. For example Delco/Hughes is marketing the Forewarn system for side blind spot monitoring on commercial vehicles. Eaton Corporation has deployed over 2,000 VORAD collision warning systems for commercial vehicles incorporating microwave side and forward looking sensors.

Road Hazard/Environmental Sensors

The current state of technology for road surface sensors combines an array of temperature and humidity sensors coupled with predictions/processing algorithms. Road surface monitoring is achieved using infrared or microwave radar technology.

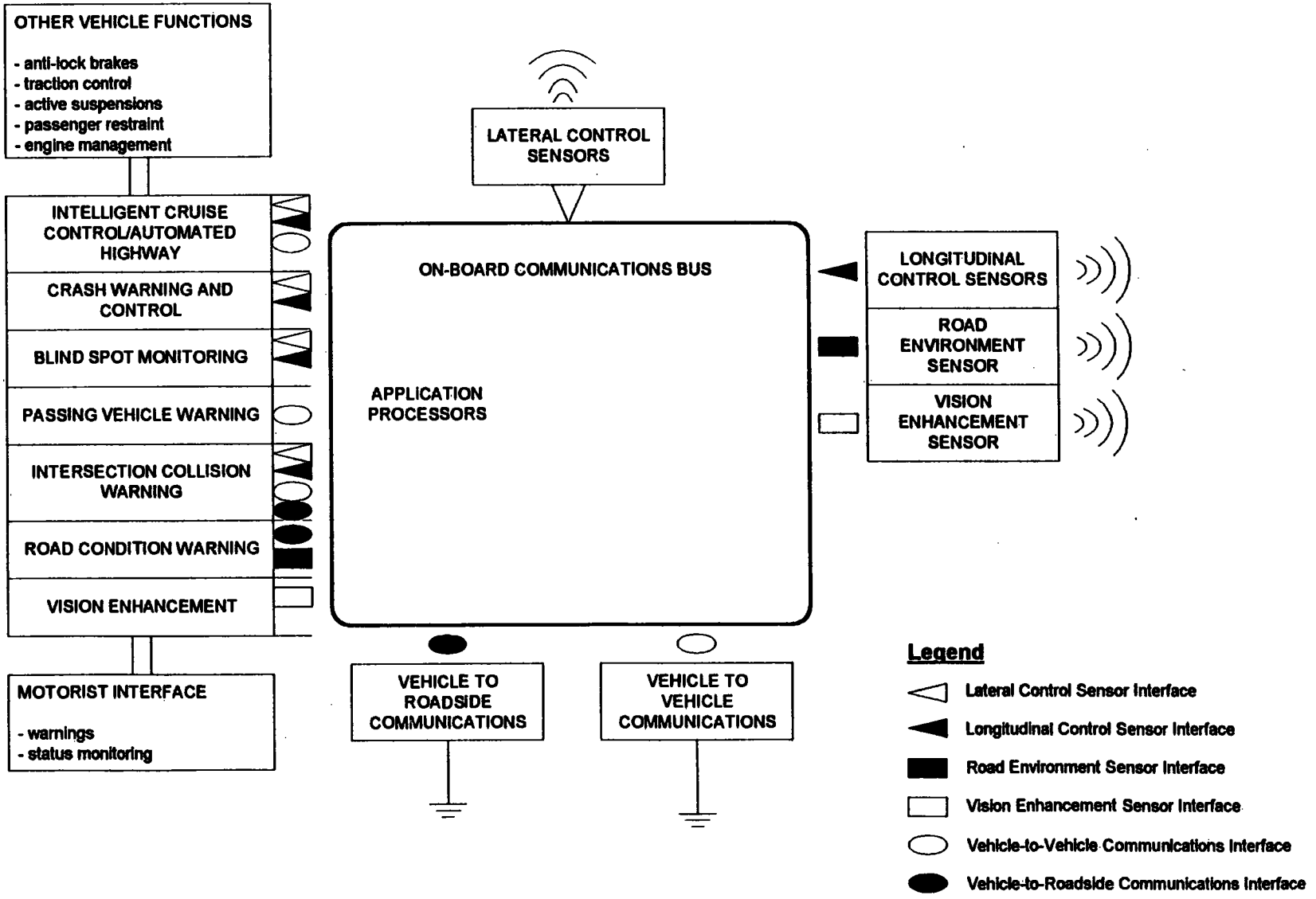
Various luxury auto makers such as Volvo offer road surface/ environment monitoring as optional or standard features. The present challenge is to further promote deployment throughout product ranges and promote integration with other on-board ITS functions.

Vision Enhancement Sensors

Vision enhancement is achieved through the use of forward looking infrared illuminators or video image processing.

Some systems under development combine the on-board technology with custom reflective markings which must be integrated into guiderail or lane markings. Conceivably, if standards in this regard emerge, the marginal cost for integration of such markings into new road construction would be relatively low.

EXHIBIT 2.4
ON-BOARD ITS SENSOR ARCHITECTURE



Intersection Collision Avoidance

Intersection collision avoidance is a constituent of the development of advanced vehicle control and safety systems, and the U.S. National Automated Highway System (NAHS). These applications incorporate a variety of inputs including:

- presence detection from on-board longitudinal and lateral control sensors;
- vehicle-to-vehicle communications between crossing traffic;
- vehicle-to-roadside communications to indicate upcoming intersection control and signal status where applicable.

2.3.4 Standards and Interoperability

As Exhibit 2.4 reflects, any given on-board sensor may interface with a variety of application processors. For example, lateral control sensors might concurrently support automated vehicle control, collision avoidance, and blind spot monitoring. An on-board local area network is required to integrate ITS sensors and processors, with other vehicle processing functions. Considerable effort has been expended towards the development of standards for high speed serial communications interfaces among processors for all types of on-board applications. The Society of Automotive Engineers (SAE) J-Bus initiative represents a series of Recommended Practice Specifications governing high speed serial communications within the vehicle. This ongoing international standards development process has been underway for several years, and supports interoperability among original equipment and after market vehicle electronics components. This standards process has been effective in facilitating globalization of automakers and the automotive components industry. The J Series specifications provide design parameters focusing on the physical layer, data link layer, and application layer of the OSI model.

3.0 TECHNOLOGY ASSESSMENT

The purpose of the sensor technology investigations is to assess the state of various sensing technologies within the Intelligent Transportation Systems (ITS) industry, and to identify the potential future industry trends. The sensor technology review also identifies international variances in standards and market preferences.

An outreach to selected contacts was conducted to establish the current state of technological development on an international scale. The approach consisted of preparing a shortlist of 20 authorities to be contacted, providing a cross-section of the ITS industry to include:

- companies active in ITS or related industries with new technological developments, e.g. Schwartz Electro-Optics;

- traffic authorities with a wealth of experience, e.g. Ministry of Transportation, Ontario (MTO);
- industry bodies, e.g. Japan Traffic Management Technology Association (TMTA);
- Canadian firms active in ITS or related industries, e.g. International Road Dynamics (IRD);
- research bodies, e.g. University of California Program for Advanced Technologies for Highways (PATH).

Standard format survey questionnaires were developed and faxed to those on the contact list. Copies of the surveys are included in Appendix A. The ITS technology survey was designed in three sections with specific questions relating to each section as follows:

- general information;
- sensor technology;
- distribution and operations.

The survey format was established for both infrastructure and in-vehicle technologies, and also custom-tailored for the various industry roles:

- transportation agencies/authorities;
- universities;
- product manufacturers/suppliers.

Follow-up contact by telephone was made with the contacts in order to conduct the survey and answer any questions the contacts may have. The outreach findings were assembled and analyzed to identify relative performance, costs, and current and future development trends. Of the 20 contacts, 13 agencies responded with useful input to the study. It is estimated that 400-500 companies participate in the worldwide market for ITS sensing applications. Relevant industry contacts in ITS Yellow Pages directory format are included as Appendix B.

3.1 INFRASTRUCTURE SENSOR APPLICATIONS

3.1.1 Traffic Flow Detection

The most prevalent traffic flow sensor in use today outside of Japan is still the in-pavement inductive detector loop. Although loop sensor reliability and data accuracy is still quite high in comparison to competing technologies, the installation and maintenance requirements result in traffic flow disruption, and the performance of the sensors is subject to pavement deterioration. The long term performance of inductive loop detectors has been improved through the use of preformed loops which can be constructed in the base course of new roadway construction sections. Because of the large number of detector loops required at a typical site installation, the cost for the sensor system remains quite high and is expected to remain around the $15,000 range into the next five years.

Most traffic authorities are actively searching for off-pavement technologies to serve as a replacement for the inductive loop as the sensor of choice for freeway and arterial applications. The most promising off-pavement field sensor technologies for traffic management applications include:

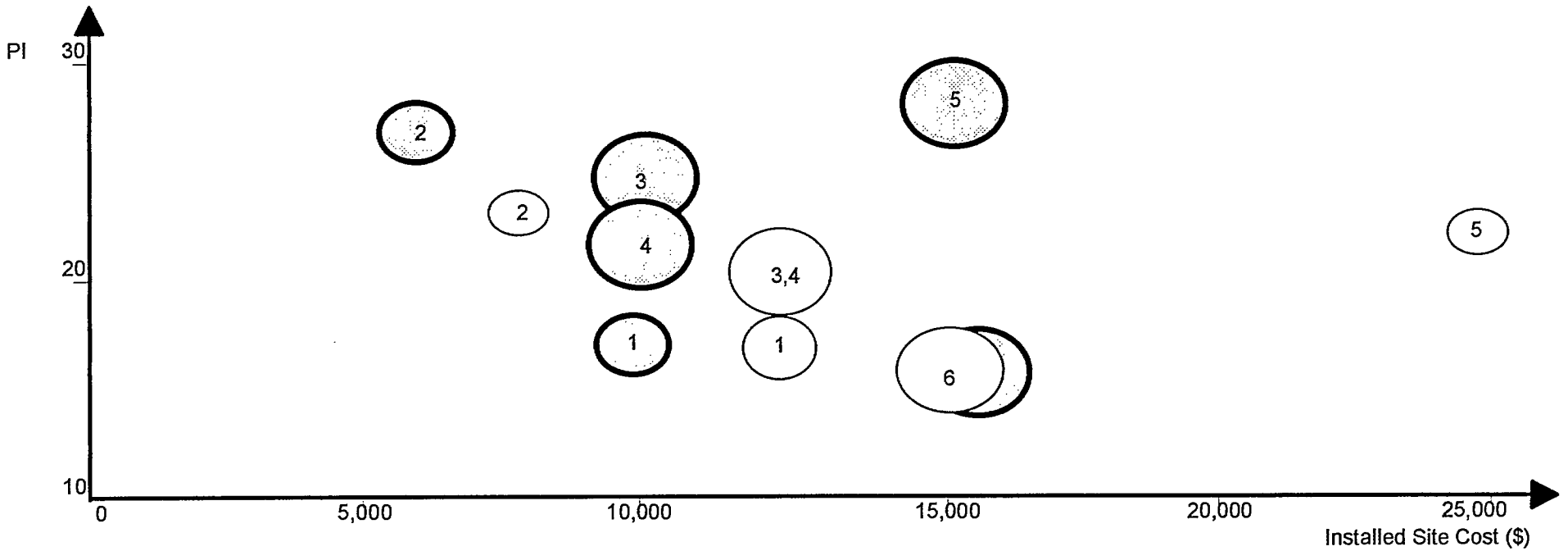
- Doppler/microwave radar;
- true presence microwave radar;
- infrared/laser;
- ultrasonic, and;
- video imaging.

Some traffic authorities will attempt to abandon the conventional approach to field sensing architecture in favour of:

- using VRC equipped vehicles as network probes;
- area-wide monitoring using satellite remote sensing.

Exhibit 3.1 is a comparative assessment of alternative field sensor technologies, as well as in-pavement detector loops. Exhibit 3.2 presents a comparative assessment of market penetration and site installation costs, based on IBI Group's subjective interpretation. Estimated site installation costs are based on a typical 6 lane freeway.

EXHIBIT 3.2
ITS TRAFFIC FLOW SENSORS
TECHNOLOGY ASSESSMENT



Key		
1	Doppler Radar	- Whelan
2	FMCW Radar	- RTMS
3	Laser/Infrared	- Autosense
4	Ultrasonic	- Smartsonic
5	Video Imaging	- Autoscope
6	Detector Loops	- Detector Systems

Year

1996

2001

Installed Base

< 1,000 Units

< 10,000 Units

> 10,000 Units

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EXHIBIT 3.1
ITS TRAFFIC FLOW SENSORS
TECHNOLOGY ASSESSMENT

Performance Criteria	Performance Index (PI)**					
	Doppler Microwave Radar	FMCW Microwave Radar	Laser/Infrared	Ultrasonic	Video Imaging	In-Pavement Detector Loops
Functional Capabilities	2	4	4	4	5	4
Performance/Accuracy	4	4*	4*	3	3*	4
Reliability	3	3	3	3	3	3
Routine Maintenance	4	4	3	4	3	2
Connectivity	2	4	3	2	4	2
Physical Integration	3	4	3	3	4	1
Total Performance Index (PI)	18	23	19	19	22	16
Comments	- required overhead mounting - distinguishes between approaching/receding traffic - accurate speed measurement independent of mounting height - cannot detect presence	- side-fire or overhead mounting - ease of installation and integration	- side-fire or overhead mounting - speed accuracy dependent on mounting height - sensitive to ambient environment	- requires overhead mounting - performance is a function of the environment at longer ranges	- allows for visual evaluation of traffic flow - ability to obtain traffic flow information for multi-lane, multi-zone applications - user-definable detection zones and parameters - some accuracy problems due to changing ambient lighting/environment	- traffic disruption due to in-pavement installation - road surface degradation limits lifespan

* Areas where improvements are anticipated.

** Performance Index Ranking
1 ... 3 ... 5
Poor Average Excellent

Doppler Microwave Radar

Doppler radar sensors provide very accurate speed measurements and can distinguish between approaching and receding traffic. The technology is robust, and performs well under all ambient environment conditions. Many traffic authorities use this sensor when collection of speed data is a priority, such as for travel time monitoring. The principal drawback characteristic of this technology is the inability to measure presence and hence the performance degrades under congested conditions. A typical site installation requires an overhead sensor for each lane, resulting in a estimated site cost of $12,500.

True Presence Microwave Radar

True presence microwave radar using frequency modulated continuous wave (FMCW) technology is represented by the RTMS unit manufactured by EIS. The RTMS sensor detects volume, presence and calculates speeds over multiple independent zones. Unlike Doppler microwave radar sensors, the RTMS can be mounted in a side-fire configuration. The advantages of the RTMS sensors are its ease of installation and integration into existing systems, its high accuracy, programmability to support a variety of applications, and its low cost. The RTMS sensor retails for approximately $7,000 and has considerable potential for widespread applications in the near future.

Laser/Infrared

An advantage of a laser detection system is that it utilizes a very narrow beam width, which allows for the spatial positioning of a vehicle on the road and the resolution of the vehicle shapes within an accuracy of ±10cm. Laser based sensor technologies offer high accuracy and reliability, however this is sensitive to mounting height and sensor position over the roadway. One drawback is the requirement for a high signal to noise ratio in all prevailing weather conditions in order to reliably process a reflection from the vehicle target.

A promising new product from Schwartz Electro-Optics of Florida, known as Autosense, is able to operate remotely with batteries and a solar panel. A spread spectrum radio link can transmit traffic data from the remote site to a traffic control data collection/transmission location.

The current site installation cost for laser/infrared sensor technologies is in the range of $12,500, however this cost is expected to come down in the next five years as the installed base increases and performance is improved.

Ultrasonic Sensing

International Road Dynamics Inc. (IRD) is a Canadian firm that is active in the ITS market and has broadened their horizons by purchasing AT&T's sensor technology, the Smartsonic vehicle sensor. This sensor transmits and receives an acoustic wave which is analyzed to determine vehicle volume. A local microprocessor processes the data to determine vehicle speed, occupancy and some limited vehicle classification. Smartsonic is reported to provide vehicle volume within 97% accuracy and vehicle speed within 94% accuracy. Current routine maintenance experience is at a rate of once every 5 years, and the present cost is in the range of $12,500.

Currently, IRD is focusing on expanding the Smartsonic's vehicle classification capabilities. At present, IRD's sensors are being used by transportation, toll, turnpike and transit agencies across the U.S., as the U.S. market accounts for 80% of their sales. In 5 years, the target cost of the sensor is expected to be the same as at present, however, IRD expects a future growth rate of approximately 20% per year.

Video Imaging

Video image processing sensors utilize the visible light and near infrared bandwidths to sense various user-configurable traffic parameters. Video imaging allows for traffic flow information to be obtained for multi-lane and multi-zone applications. For example, one Autoscope unit from Econolite can be programmed for up to 40 detection zones. The requirement to digitize the video images and invoke pattern recognition routines requires significant processing power in the field. The autoscope controller is essentially a field rugged Intel 486 PC, and as such, offers the capability for Econolite to bundle their product with various value-added processing routines, such as incident detection and traffic signal control.

Autoscope and other video imaging sensors represent a very promising future standard for traffic flow detection, due in part to steadily improving performance, increased features/flexibility and decreased costs.

At present video image processing systems remain quite costly. An installed Autoscope unit costs in the range of $25,000. It is expected that the cost will drop in the near future to be comparable with detector loops, as both the performance of video imaging sensors improves and as their use becomes more widespread.

Future Trends

Intelligent Transportation Systems are generally input data intensive and transportation authorities will continue to seek low cost, reliable, accurate means of collecting real-time traffic flow data. The experience of authorities in Japan and more recently in North America, indicate that the trend in detection is most definitely away from in-pavement technologies such as the inductive loop. In the near-term, the trend is towards a variety of low cost overhead sensors using microwave radar, infrared or ultrasonic technologies. There is no dominant leader in this core group of technologies. Preference will be directed at technologies which further improve cost effectiveness through the capability to monitor multiple lanes from a single unit. An example currently in the marketplace is the Remote Traffic Microwave Sensor from Electronic Integrated Systems of Toronto.

Most industry analysts are in agreement that the long term trend is towards video image processing. The flexibility and user friendliness of this technology are critical advantages, and industry will continue to draw upon the rapid pace of development in digital image compression and machine vision technologies to provide low cost solutions with improved performance.

3.1.2 Vehicle Identification/ Classification

Vehicle classification sensors can be located either within the pavement, or overhead mounted. The overhead vehicle classification sensors include:

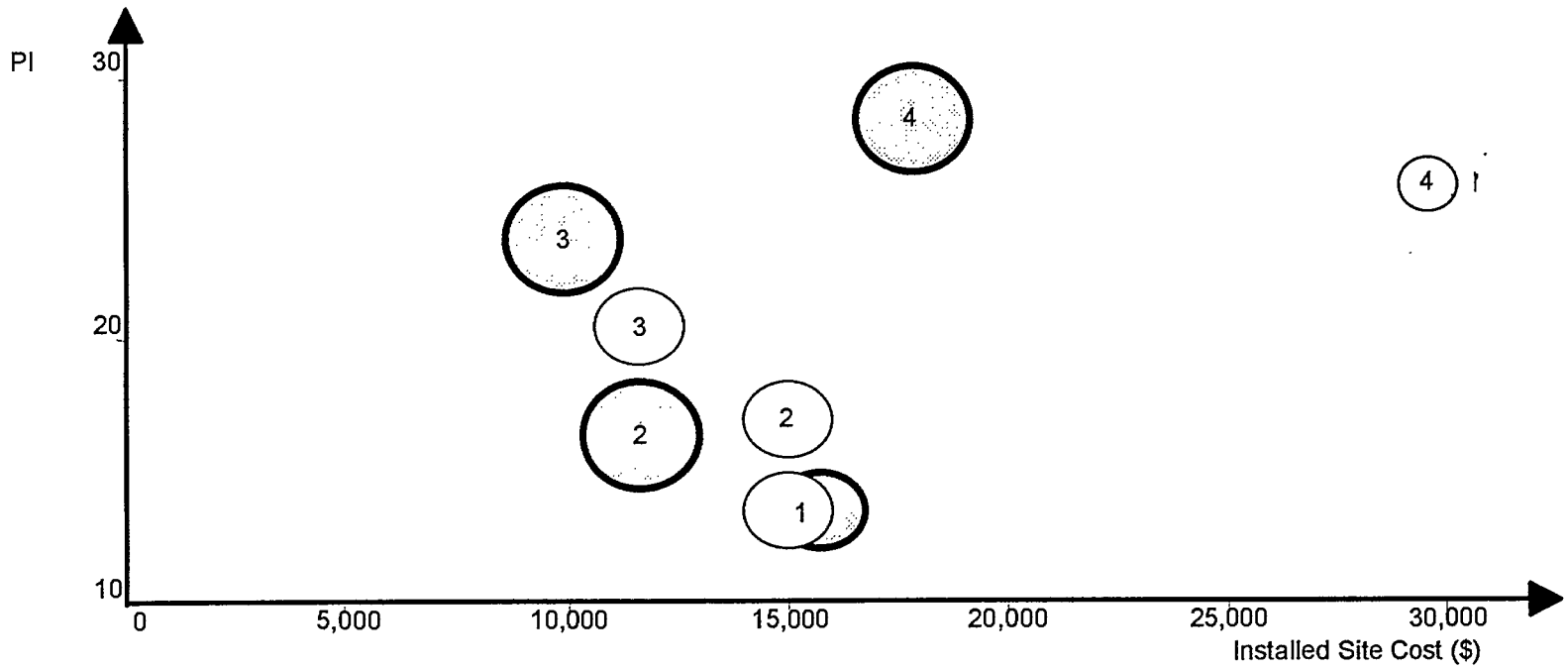
- automatic vehicle identification (AVI);
- profile identifiers.

The in-pavement sensors investigated as part of this study include:

- pressure sensors;
- inductance loops.

In the past, the trend for vehicle classification sensors was to locate them within the road surface. However, with the emergence of such technologies as lidar (light detection and ranging) and ultrasonic sensing, overhead profile identifiers have become more prevalent. Exhibit 3.3 is a comparative assessment of both in-pavement and off-pavement classification sensors, based on IBI Group's subjective interpretation. A graphical representation of the various technologies with respect to site installation cost and market share is shown in Exhibit 3.4. The application of an appropriate classification technology

EXHIBIT 3.4
ITS VEHICLE CLASSIFICATION SENSORS
TECHNOLOGY ASSESSMENT



Key	
1	Inductance Detector Loop
2	Pressure Sensor
3	Profile Identifier
4	AVI

Year

1996

2001

Installed Base

< 1,000 Units

1,000-5,000 Units

> 5,000 Units

EXHIBIT 3.3
ITS VEHICLE CLASSIFICATION SENSORS
TECHNOLOGY ASSESSMENT

Performance Criteria	Performance Index (PI)**			
	Inductance Loop	Pressure Sensors	Profile Identifiers	Automatic Vehicle Identification
Functional Capabilities	2	3	4	5
Performance/Accuracy	3	4	4*	5
Reliability	3	3	4	4
Routine Maintenance	2	2	3	4
Connectivity	2	3	3	4
Physical Integration	1	1	3	3
Total Performance Index (PI)	14	16	21	25
Comments	- use of existing traffic control infrastructure for classification purposes - road surface degradation limits lifespan - traffic disruption due to in-pavement installation	- better accuracy and performance than loops - road surface degradation limits lifespan - traffic disruption due to in-pavement installation	- installation and maintenance not disruptive to traffic flow - performance better at lower speeds, and degrades in harsh environmental conditions	- installation and maintenance not disruptive to traffic flow - high installation cost - benefit from integration with other user services, e.g. Electronic Tolling

* Areas where improvements are anticipated.

** Performance Index Ranking
1 ... 3 ... 5
Poor Average Excellent

is to a large degree dependant on the required classification parameters.

AVI

The current generation AVI systems are active vehicle to roadside communications (VRC), as opposed to passive sensors. This technology is relevant to vehicle classification, as vehicle attributes are typically read from the vehicle tag in VRC applications. As an identification tool, the approach is typically bundled with other user services such as electronic tolling and commercial vehicle preclearance. It is worthwhile noting that although the AVI transponder typically provides vehicle classification information, electronic toll and CVO applications require classification sensors to confirm this information.

Profile Identifiers

Profile identifiers utilize technologies as described in Section 3.1.1, including infrared sensing, ultrasonic sensing, and microwave radar. Schwartz Electro Optics (SEO) have developed two laser based traffic flow detection sensors, Autosense I and Autosense II. It is important to note that the development of the Autosense sensor was partially funded by the U.S. federal government, under the ITS IDEA program.

Autosense I is a vehicle presence, height and speed detector which utilizes two fixed laser beams to give a two dimensional vehicle profile. Autosense II is an integrated vehicle detection and classification unit which utilizes two scanning laser beams to give a three dimensional vehicle profile. It can be used for vehicle detection, classification, vehicle separation and lane position, and also to provide camera trigger information to a roadside electronic toll collection system. Both the Autosense units I and II are typically mounted over the centre of a lane at a height of approximately 6m to 7m, however the unit can also be operated in side-firing mode.

The laser based sensor is highly accurate and reliable, and because it is mounted above the roadway, installation and maintenance are not disruptive to traffic. However, the sensor's performance is better at lower speeds and tends to degrade in harsh environmental conditions.

Autosense sensors have been incorporated into the world's first all electronic toll systems, namely California SR 91 Highway, and Ontario Highway 407.

Pressure Sensors

Weigh in motion sensors are typically accurate to a range of ±1% to ±8% of the vehicle gross weight depending upon the technology type (single load cell versus piezoelectric). Routine maintenance for both technologies varies between 1 to 3 years.

IRD is a world leader in the production of weigh in motion and axle counter sensors. Future applications for their weigh in motion sensors include contraband detection at border control stations. At present, these vehicle classification sensors are fairly costly, ranging from $15,000 US to $50,000 US for piezoelectric axle counters and single load cells respectively. These costs are projected to remain high in the near future.

Inductance Loops

Inductance loops are also utilized to classify vehicle types, primarily for historical data collection. The significant advantage to using inductance loops for vehicle classification purposes is that existing traffic control infrastructure can be utilized, and thus no new equipment is required.

Future Trends

Vehicle classification sensors comprise an important and significant segment of the ITS market because they are utilized in self-funding programs such as electronic tolling and commercial vehicle operations (CVO). These vehicle to roadside communications (VRC) applications are gaining widespread acceptance worldwide and exponential growth is anticipated in the years to come, particularly as interjurisdictional standards evolve. Multi-state electronic toll systems are already in place, such as the Interagency Group E-ZPass in New York, New Jersey, Delaware and Pennsylvania. Furthermore, there are multi-jurisdictional commercial vehicle preclearance programs in operation such as ADVANTAGE I-75 and the NAFTA border crossings. These applications require classification monitoring for purposes of verification/enforcement. Although from this investigation, there does not appear to be one clear dominant technology emerging, SEO's Autosense laser sensor is a noteworthy product development. IRD's weigh in motion sensors currently occupy a substantial portion of the market, but they will need competitive off-pavement approaches to maintain their market position.

3.1.3 Vehicle Emissions

A variety of enabling technologies have been developed outside of the ITS arena to detect harmful vehicle emissions. These include conductive polymers, fibre optic, and infrared sensors. The challenge in bringing these technologies to ITS is one of application and integration. Specifically, sensor(s) must be configured such that they can distinguish specific pollutants, and must be bundled with related field components and processing. The best example to date is the Hughes SMOGDOG system used in California, where the emission sensors are used to trigger license plate readers with optical character recognition for passive emissions enforcement on freeway entrance ramps. The market for this type of application is presently quite limited, however it is expected to increase as more authorities take a proactive approach to dealing with vehicle pollution, particularly in emerging markets.

3.1.4 Ambient Environment

Various technologies are required to monitor environmental parameters, as discussed in the System Definition Technical Memorandum. For the most part, these technologies are fairly established and the focus for ITS deployment is on integration with other field subsystems. For example, Washington State DOT combines road weather stations with advanced field controllers to locally trigger the variable message signs in the Snoqualmie Pass. These types of applications are typically limited to northern climates, mountainous regions, coastal areas characterized by dense fog, and major bridge/causeway links, such as the new PEI fixed link.

3.2 ON-BOARD SENSOR APPLICATIONS

The SRI study projects that the current proportion of a total vehicle's value devoted to electronics is between 10% to 12%, and is expected to grow to 20%, with the majority of that related to ITS. At present, virtually every major automaker has some sort of demonstration project on-going which uses a combination of radar, lidar, video image processing and ultrasonic sensors for driver awareness enhancements. Virtually all of the on-board ITS sensing applications are directed at improving safety.

3.2.1 Longitudinal/Lateral Control

Longitudinal/lateral control sensing is predominantly a research and development area, with a few products currently emerging into the ITS market. Microwave radar, lidar, ultrasonic and video image processing are the enabling technologies for these applications, with some better suited to certain applications than others. Exhibit 3.5 is a comparative assessment of these four technologies. Exhibit 3.6 is a graphical depiction of installation costs and market penetration based on IBI Group's subjective interpretation.

Currently, the trend in on-board sensor technology is focused on radar and lidar technology. On-board radar sensors typically operate at 77 GHz, can be mounted behind glass, and have the ability to penetrate inclement weather. However the most significant disadvantage is that

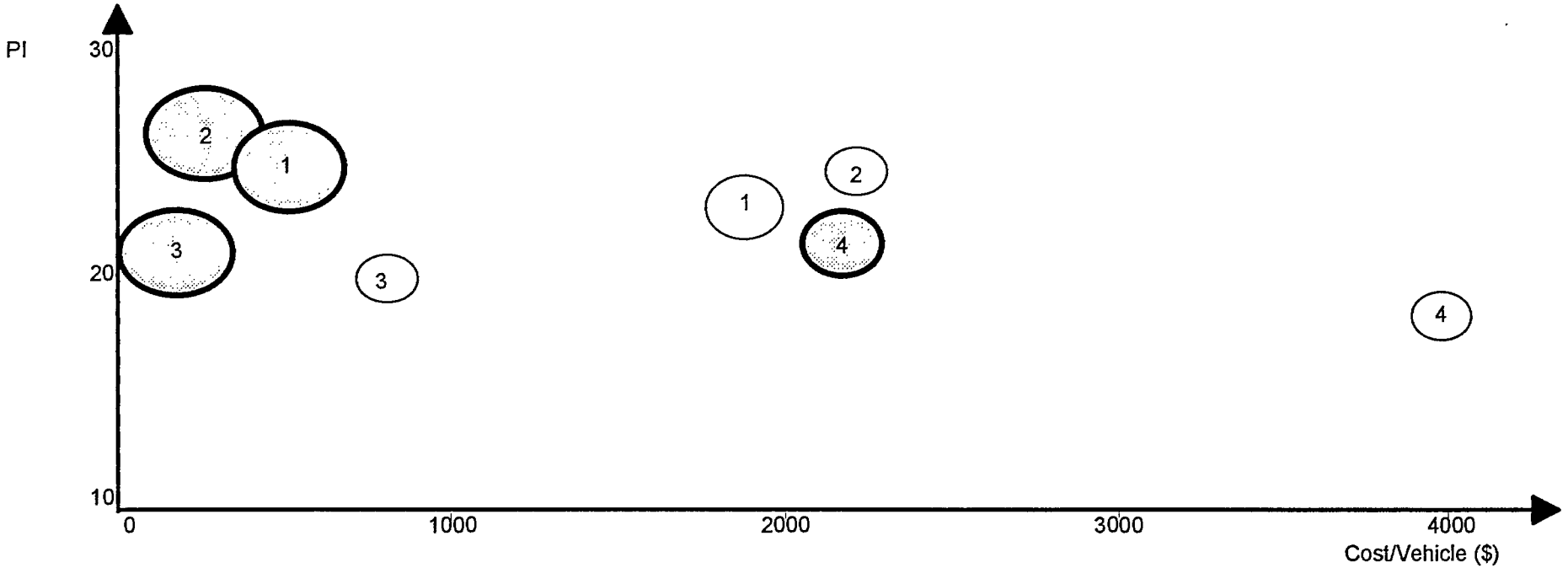
EXHIBIT 3.5
ITS LONGITUDINAL/LATERAL CONTROL SENSORS
TECHNOLOGY ASSESSMENT

Performance Criteria	Performance Index (PI)**			
	Microwave Radar (76-77GHz)	Lidar (850 Nm)	Ultrasonic	Video
Functional Capabilities	4	5	1	4
Performance/Accuracy	3*	3*	3	3*
Reliability	4	4	4	3
Routine Maintenance	4	4	4	3
Connectivity	4	4	4	4
Physical Integration	3*	4	3	2
Total Performance Index (PI)	22	24	19	19
Coments	- beam dispersion reduces object definition capabilities - map not accurately detect non-metallic objects - minimal impacts from poor visibility - proven technology	- performance deteriorates in poor visibility - very compact - evolving technology	- primarily used for short range applications (e.g. parking assistance) - proven technology	- performance deteriorates in poor visibility - can provide video image to driver - evolving technology

* Areas where improvements are anticipated.

** Performance Index Ranking
1 ... 3 ... 5
Poor Average Excellent

EXHIBIT 3.6
ITS LONGITUDINAL/LATERAL CONTROL SENSORS
TECHNOLOGY ASSESSMENT



Key		
1	Radar	- Delco Forwarn - Eaton VORAD - Rockwell - Raytheon
2	Lidar	- Leica - Siemens - Mitsubishi
3	Ultrasonic	- Bosch - BMW
4	Video	- Nissan

Year

1996

2001

Installed Base

Prototype

< 10,000 Units

> 10,000 Units

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they have limited angular resolution of numerous targets and they may not detect non-metallic objects. The most promising alternative is lidar (light detection and ranging) using high power 850 nanometre infrared lasers. Lidar sensors are very compact compared to radar. A narrow beam gives very good angular resolution, however the drawback is that they can be impacted by adverse weather conditions.

- **Microwave Radar**

Eaton Technologies has produced VORAD, a commercially available microwave collision warning sensor. Eaton has applied doppler microwave radar technology, originally developed for the aerospace industry, to a collision warning sensor which may also be used for passing vehicle and blind spot warning, and at some later date intelligent cruise control.

The sensor is a microwave radar transceiver which is mounted at the front and right side of a vehicle. The sensor module functions by transmitting and receiving a doppler wave, to determine closing distance and unsafe following distance. The warning information is relayed to the driver by flashing lights and an audible alarm via a dashboard mounted module. Data is processed through a high speed processing unit. Eaton's sensor is accurate to ±0.5% at speeds between 0.25 mph and 100 mph.

The sensor is in commercial use on the 1996 Freightliner Century Class truck (class 8), and is being used on prototype heavy trucks and some prototype passenger cars in the U.S. The current unit cost ranges from $2500 US for the basic system which is sold in a kit to the OEM, to $7500 US for a factory installed system. The cost of the system is expected to drop in the next 5 years to approximately $500 US to the OEM, or $1000-$2000 US to the customer. Eaton believes their sensor system occupies 100% of the North American market share (they only market in the US), but they expect this rate to drop off to 80% in 2 years and 70% in 5 years as General Motors enters the marketplace. GM/Delco are currently marketing a similar system on the 1996 Cadillac Seville.

Other such similar applications of radar technology include Northrop Grumman's collision warning sensor using millimetre wave technology, and Safety First System's Smart Sensor for back-up/blind spot warning, which utilizes microwave radar. While Northrop's sensor is still in the development stages, the Smart Sensor has been implemented on prototype vehicles in the U.S. and Canada. The cost for either system in the next 5 years has been targeted at $500 US.

Lidar

Detection and ranging using the infrared spectrum is a newer technology as compared to microwave radar. Firms such a Leica in Switzerland are actively developing this technology for vehicle control, and anticipate an ultimate target cost of $200. The University of Michigan is currently demonstrating and evaluating advanced vehicle control using Leica sensors. Current development efforts are focusing on improving the accuracy of the sensors under varying inclement weather conditions.

Ultrasonic

Ultrasonic technology is ideally suited to applications requiring low closing rate distances, such as parking aids, passing vehicle warning and blind spot warning.

The U.S. firm Armatron International Incorporated has developed the Obstacle Detection System which transmits and receives pulses of ultrasonic energy via two sensors. The sensors can be configured for either a rear system or side system depending on the application. The sensors can resolve a range within 10cm.

All new Federal Express trucks in the U.S. are currently using Armatron's on-board sensors, providing an installed base of approximately 1000 vehicles. The present system cost is $200 US, which should drop to $150 US for fleet vehicles in the next 5 years. Armatron plans to expand into the commercial truck fleet market, as well as into passenger vehicles such as minivans and sport utility vans in the next 5 years. In the upcoming 10 year period, Armatron envisages having 50% of the passenger vehicle market and 30% of the commercial vehicle market. Both Volkswagen and BMW are also developing inexpensive short range ultrasonic sensors for parking assistance applications.

Video Image Processing

CCD cameras, combined with on-board video image processing, have been developed for prototype vehicle control systems by a variety of Japanese auto makers. These systems offer the advantages of offering live video to the driver, however performance is subject to ambient environment visibility, and the systems are more costly and difficult to integrate into the vehicle.

Future Trends

Radar and lidar will continue to be the prevalent enabling technologies for longitudinal/lateral control applications. Ongoing research and development activities are focusing on improving the all-weather accuracy of lidar and providing more compact radar sensors with improved object definition capabilities.

3.2.2 Road Hazard/Environment

A variety of manufacturers are incorporating systems to monitor outside temperature, pavement moisture and pavement surface integrity. Enabling technologies including infrared, acoustic, and vibration sensors.

Road hazard warning is a roadside to vehicle communications application. Cobra Electronics Corporation is believed to be the only company currently marketing radar for emergency communications with their Safety Alert System. The Safety Alert System was developed as an out-growth of Cobra's radar detector product line, and is comprised of a transmitter, receiver, and digital data display. The unit alerts drivers of on-coming emergency vehicles, stationary roadside hazards or construction zones. It has been implemented on emergency vehicles, including ambulance, fire and police vehicles, throughout the U.S.

The transmitter is typically mounted within the light bar of emergency vehicles, while the receiver/detector is windshield mounted in the driver's vehicle. Both a visual and audio alarm is used to warn drivers. Because the unit is mounted internally, it does not have to withstand harsh environmental conditions.

The Safety Alert System is currently only available in the U.S., and is being distributed through a light bar manufacturer in St. Louis, Missouri. The system costs between $100-$200 US, and it is expected that the cost will remain the same over the next 5 years, although the market penetration rate is expected to increase between 5%-10% in the next 2 years. In terms of future enhancements, Cobra plans to improve the range sensitivity of their system.

Eaton plans to apply microwave radar technology used in their vehicle collision warning system to roadway communication as a future application.

3.2.3 Vision Enhancement

Presently, the technologies being developed for vision enhancement applications are:

- infrared;
- video image processing;

- ultraviolet headlamps.

Exhibit 3.7 is a comparative assessment of the various technologies in terms of performance. Exhibit 3.8 is a graphical comparison of the market penetration, and vehicle installation cost, based on IBI Group's subjective interpretation.

Infrared is the preferred technology for night vision sensors because of its highly rated performance, level of accuracy and functional capabilities. It is based on the principle of heat detection from pedestrians or vehicles, and requires a HUD or LCD display to alert drivers. Commercially available infrared illuminators driving a HUD or LCD display may be available by 1998. The present cost is approximately $2,500, but as market penetration increases the cost is expected to be driven down in the near future.

Video sensing using the visible and near visible spectrum incorporates CCD cameras and image processing algorithms to provide the driver with an expanded range view. These systems are characterized by added costs and complexity as compared to infrared illuminators, and are similar in the sense that a dedicated motorist display is required.

Volvo, Saab and Ford are developing ultraviolet headlights which improve the visibility of fluorescent or light coloured objects. The main advantage of UV headlights are their relatively low cost which is expected to drop even further into the near future, although significant increases in performance are not likely. A considerable drawback is the possible necessity of infrastructure and vehicle markings.

3.2.4 Intersection Collision Avoidance

The lack of universal standards for both vehicle to vehicle and vehicle to roadside communications is a prohibiting factor to the development of technologies for intersection collision avoidance applications, particularly in the U.S. and Canada. Spectrum allocation for short range vehicle communications is emerging on a regional basis as follows:

- North America - 900MHz;
- EU - 5.8GHz;
- Japan - Infrared.

The most commonly cited standard for compliance is the U.S. Federal Communications Commission (FCC), which regulates microwave frequency bandwidth. The sensor products produced by Cobra, Eaton and Northrop use microwave technology and must comply with the

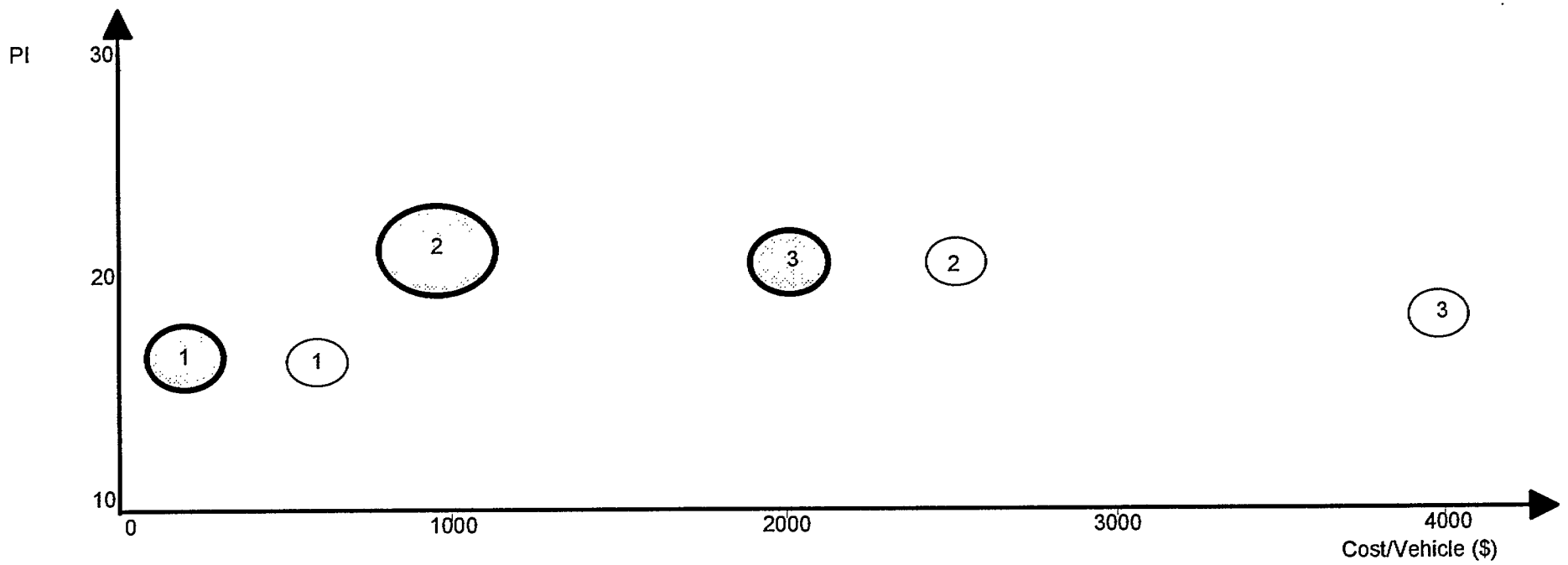
EXHIBIT 3.7
ITS VISION ENHANCEMENT
TECHNOLOGY ASSESSMENT

Performance Criteria	Performance Index (PI)**		
	UV Headlamps	Infrared	Video
Functional Capabilities	2	4	3
Performance/Accuracy	3	4*	3*
Reliability	3+	4	4
Routine Maintenance	3+	4	3
Connectivity	3+	3	3
Physical Integration	3+	3*	2
Total Performance Index (PI)	17	22	18
Comments	- illuminates fluorescent or light colours - may require program to outfit infrastructure and vehicle with markings	- detection of heat from vehicles or pedestrians - requires HUD or LCD display	- expanding range of view using CCD cameras and image processing - requires monitor or LCD display

* Areas where improvements are anticipated.
\+ Data not available.

** Performance Index Ranking
1 ... 3 ... 5
Poor Average Excellent

EXHIBIT 3.8
ITS VISION ENHANCEMENT
TECHNOLOGY ASSESSMENT



Key		
1	UV Headlamps	- Ultralux
		- Ford
2	Infrared	- Nissan
3	Video	- Toyota

Year

1996

2001

Installed Base

Prototype

< 10,000 Units

> 10,000 Units

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FCC standard. The other standards noted were ISO and the America Standard for Testing and Materials (ASTM).

4.0 INDUSTRY ASSESSMENT

The following section provides insight into the expected market, potential dynamics, and characteristics associated with ITS sensing applications. Exhibit 4.1 summarizes some of the principal ITS sensor manufacturers, classified according to type of sensing application and primary geographic market.

4.1 MARKET OVERVIEW

4.1.1 Infrastructure Applications

The principal market for ITS field infrastructure sensors is vehicle detection and classification. This market is well established and expected to remain stable. Demand for off-pavement technologies will continue, with expanded ATMS deployment in North America and Europe. Japan, in comparison is to a large degree already instrumented. Some market opportunities are anticipated as North American and European road authorities replace existing inductive loop systems when they reach their lifecycle.

Any growth opportunities in this market could be tempered by uncertainty over future levels of public sector funding for system infrastructure. The exception may be vehicle identification and classification sensors which will be required for self funding applications (i.e. road pricing, WIM, and commercial vehicle pre-clearance at weigh stations and border crossings).

Vehicle emissions monitoring is expected to be a growth market. At present, funding for congestion relief programs in the U.S. is linked to air quality improvement legislation. Other western economies such as Germany and Scandinavia are placing increased emphasis on emissions management. The emerging markets of Latin America and Southeast Asia will also create increased demands for this type of application, particularly when World Bank funding may be contingent upon demonstrated emissions reductions.

Traditionally, the traffic sensor manufacturing industry was characterized by homegrown companies operating in each of the three major western markets (e.g. Detector Systems - North America, Microsense - Europe, Sumitomo - Japan). The global ITS movement of the 1990's has acted as a catalyst for a more international industry. At present, it is very much a technology driven industry that is breaking down international borders. The Toronto firm Electronic Integrated Systems (EIS) is an example of a Canadian company with a unique sensor technology that is attempting to attain international acceptance. Even though their installed base is under 1,000 units, EIS has

EXHIBIT 4.1
SENSOR TECHNOLOGY
INDUSTRY ASSESSMENT

Applications	Key Industry Participants				
	ITS Sensor Manufacturers				Related Canadian Companies
	U.S.	EU	Japan	Canada	
Infrastructure					
1. Traffic Flow	Whelan Detector Systems Econolite Schwartz-Electro Optics	Weiss Microsense Peek Plessey	Sumitomo	EIS IRD Applied Silicon	
2. Vehicle Classification	Schwartz-Electro Optics Detector Systems			IRD Applied Silicon	
3. Vehicle Emission	Hughes				
4. Ambient Environment	Climatronics				
On-Board					
1. Longitudinal/Lateral Control	Safety First Northrop Grumman Raytheon Eaton Technologies GM/Delco Rockwell Armatron	Leica Siemens Bosch BMW Volkswagen	Mitsubishi Nissan		Allied Signal GM Canada
2. Road Hazard/Environment	Cobra Electronics				
3. Vision Enhancement	Ford Ultralux	Volvo Saab	Nissan Toyota		
4. Intersection Collision Avoidance					

installations throughout the world. Large turnkey systems firms act as catalysts for this globalization. For example, the European firms Peek Traffic and Plessey Controls are bringing their video detection systems to North America to compete with Autoscope.

Increasingly, successful ITS field sensor suppliers will offset ITS product development costs through sharing or transporting the technology to/from other related industries. The classic example is the evolution of machine vision applications for industrial process control to outdoor traffic monitoring applications, such as with Computer Recognition Systems line of products.

The U.S. ITS program is deployment oriented and system developers are continuously searching for improved means of monitoring traffic conditions. Any introduction of new sensor products or demonstration/evaluations of detection systems receives widespread interest from the ITS community. The supplier industry in the U.S. is populated with a variety of capable off-pavement products such as the Whelen microwave sensors and the aforementioned SEO Autosense products. The U.S. is also home to the most advanced video detection system on the market worldwide, namely Autoscope. The history of development of Autoscope tracing back over ten years is an exemplary case study for new product development. Originating with the work of Dr. Panos Michalopoulos at the University of Minnesota, the Autoscope digital image processing routines became commercialized in the late 1980's, through the formation of Image Sensing Systems (ISS). ISS has evolved into a publicly traded company which continues to foster the advancement of video detection work under the direction of Dr. Michalopoulos. The productization, marketing, distribution, and support of Autoscope has been carried out through a joint venture with an established international traffic control distributor, Econolite of California. Together ISS and Econolite represent the worldwide market leader in video detection systems.

Initial ITS initiatives in Europe undertaken since 1987 through DRIVE and PROMETHEUS programs have been criticized for not being deployment oriented. In recent years, ATMS deployment has been expanding in the UK, France, Germany, and Italy. There are a number of competitive microwave and infrared sensor manufacturers particularly in the UK. Furthermore, large system contractors such as Peek and Siemens are presently marketing video detection systems developed in academia, along the lines of the Autoscope model.

In comparison to Europe and North America, Japan is very well instrumented with traffic sensors. SRI Consulting indicates nearly 88,000 detectors are in place throughout the country, resulting from an intensive urban traffic management system program. Japanese

authorities have long recognized the advantages of off-pavement sensors relative to inductive loops; most of the installed base of traffic sensors utilize ultrasonic, microwave and infrared technologies.

4.1.2 On-Board Applications

SRI Consulting suggests that the long term market potential for on-board sensor applications is favourable in North America, Europe and Japan. The principal factor which will drive demand for these products is the association with improved safety. The experience in introducing airbags and anti-lock brakes in the North American market has demonstrated that the public is willing to pay for, in fact demand, value added safety features.

Numerous companies are active in this market in all of the western economies. Generally, the industry participants can be characterized as one of the following:

- automakers such as BMW and Nissan;
- large automotive industry suppliers such as Eaton Technologies and Bosch;
- aerospace and defence contractors such as Raytheon and Northrop Grumman;
- boutique speciality technology firms such as Safety First.

With most products at the prototype stage, the industry is relatively fragmented. As deployment evolves, industry alliances and leading products will emerge.

At present, it would appear that the greatest level of activity is within the U.S., possibly as a result of the conversion of defence industry imaging and obstacle detection technologies. While there is presently no large scale model deployment, the market in the U.S. is characterized by a number of products becoming available from automakers and their suppliers. Examples include aforementioned collision warning systems from Eaton and Delco and other systems from TRW, Rockwell and Raytheon under development. A driving factor behind the U.S. market is the quest for demonstrated safety benefits attributed to ITS. The industry as a whole is attempting to be more accountable in terms of quantified benefits and safety is considered a high priority among transport authorities and motorists. The issue of manufacturer liability for collision warning systems needs to be addressed to permit widespread market penetration in that country.

In Europe, the EU sponsored an 8 year program known as PROMETHEUS which involved major European automakers and

resulted in a series of demonstration vehicle safety and control systems. What is presently lacking is a follow-up program to pursue the productization and marketing of the prototype applications.

Safety is becoming a greater concern in the Japanese ITS program. Through the 1990's, the Japanese Ministry of Transport has assembled the major Japanese automotive manufacturers under the Advanced Safety Vehicle (ASV) program which has demonstrated a variety of ITS applications including collision warning and vision enhancement.

4.2 CANADIAN INDUSTRY PARTICIPATION

4.2.1 ITS Sensor Manufacturers

The following is a discussion of the principal industry participants in Canada.

Electronic Integrated Systems markets the unique remote traffic microwave sensor (RTMS) internationally. The product is capable and cost effective, and is achieving widespread exposure and acceptance. EIS is an example of effective transfer of military industry skills/technologies to the transportation sector, supported by public sector investment. For Canadian companies contemplating supplying sensors in the international market, EIS' experience is illustrative in the sense that:

- supplying hardware to foreign transport authorities requires intensive lobbying and exposure in order to influence tender specifications to accommodate one's product;
- international markets can be accessed through alliances with system integrators and turnkey system providers acting globally.

IRD is a Canadian company with a strong presence in the ITS sensor market. IRD occupies a large segment of the vehicle identification and classification market with their weigh-in-motion and pressure sensors. In order to maintain a competitive advantage in this industry, IRD will need to focus on developing a cost effective off-pavement sensor solutions. IRD is in the process of expanding the classification capabilities of the Smartsonic sensor purchased from AT&T.

Applied Silicon Incorporated is a Canadian company with potential for future involvement in the ITS sensor market. The company has developed a video image processing and compression unit which can be used for vehicle flow detection and classification applications. The unit facilitates the transmission of high quality video images over low

bandwidth, and also has networking capabilities. To date, the unit has been demonstrated by Caltrans for vehicle detection and motion purposes. Although Applied Silicon's compression unit does not currently occupy a share of the ITS market, future enhancements such as frame relay support and image recognition capabilities, indicate a potential niche for Applied Silicon.

Allied Signal has developed an on-board night vision enhancement sensor using infrared technology. The sensor is unique because it incorporates cryogenically cooled technology. Allied Signal has also developed an infrared video camera for release in 1999. Allied Signal is one of the largest ITS suppliers in the United States. Although Allied Signal is an American company with its head office in Maryland, the infrared sensors are produced in Montreal.

4.2.2 Related Industries

A variety of high technology industries in Canada have technology and expertise which are relevant to the ITS industry. Specific technological areas which are important to the development of ITS sensors are listed as follows:

- **Digital Video Image Processing.** Firms such as ABL have considerable expertise in the digitizing and compression of video images for applications such as video conferencing.
- **Satellite Remote Sensing/Imaging.** Canada has considerable expertise in this area. The current Radarsat program includes firms such as Spar Aerospace, AlliedSignal Aerospace, Canadian Astronotics, SED Systems, and MacDonald Dettwiler and Associates.
- **Microwave Radar and Infrared Lidar Obstacle Detection.** A variety of aerospace and defense firms operating in Canada have expertise in this area.
- **Harmful Emissions Sensing.** Firms such as American Sensors are leaders in the detection of harmful emissions such as carbon monoxide.

4.3 THREATS TO CANADIAN INDUSTRY

There are a number of threats to the Canadian ITS sensor industry which arise from activities in foreign countries, summarized as follows:

Government Programs

ITS programs in other countries are better organized and better funded as compared to Canada. In particular, the U.S. program originating in 1991 under the Inter-modal Surface Transportation Efficiency Act (ISTEA) is well organized/funded. $200-$300 million U.S. annually has

been allocated to ITS initiatives at the federal level, with contributing funds at the state level. The program includes specific initiatives to foster research, development, productization, and showcasing of ITS technologies including sensors. Specific components of the U.S. federal program include:

- **ITS IDEA** (innovations deserving exploratory analysis). This program fosters the transfer of technologies from other industries in order to develop ITS products. Funding for successful proposals ranges up to $250,000 U.S. The SEO Autosense detectors were developed under this program, and are presently considered one of the world's best classification sensors. The world's only all-electronic toll roads, Highway 407 in Toronto and SR-91 in California, both use this product.

- **Research Projects.** Tens of millions of dollars are devoted to research and development annually, primarily involving U.S. federal government laboratories such as Fairbanks, Oakridge and Volpe as well as large automotive and defense interests such as Rockwell and TRW. Canadian firms must position themselves to access these U.S. R&D programs because the order of magnitude direct investment simply cannot be achieved within Canada.

- **Research Centres of Excellence.** Partnerships between the federal government, universities, and private industry interests have yielded ITS research centres of excellence (RCE) at the University of Michigan, Texas A&M, Virginia Tech and the University of Minnesota. The Minnesota RCE has been instrumental in the field operational testing of the Autoscope video detection system.

- **Operational Tests.** Proof of concept for new and emerging ITS applications and components are provided through selected field deployment and operational evaluation initiatives. For example the $3.5 million U.S. Transmit operational test in the New York City/New Jersey area is demonstrating the use of VRC-equipped vehicles as network probes to monitor route travel times.

- **Model Deployment.** Most recently, under the Intelligent Transportation Infrastructure initiative, three model deployment sites will be selected to feature a broad range of ITS applications deployed across an entire urban area. The resulting showcase of ITS features and benefits will

serve as a model for other cities, building public support and awareness.

In Japan, the ITS program is extremely centralized, involving some five central government ministries. This centralized approach gives the Japanese tight control over institutional issues, standards, system architecture, etc. which has yielded a program which is considered quite closed to foreign industry. Furthermore, the Japanese are well positioned to market exemplary full scale ITS deployment solutions in other parts of the world, with a particular presence in the Asia-Pacific emerging markets.

Private Sector Funding From Abroad

ITS programs in Japan, Europe and the U.S. are designed to emphasize public/private partnerships. Typically large automotive and defense interests are well represented in terms of project participation and investment. In the case of the European DRIVE programs, often these partnerships are designed to foster unity among EU nations by incorporating a cross-section of public and private agencies from member countries. In the U.S., a good example of private sector investment of resources is the National Automated Highway System Consortium incorporating:

- Bechtel;
- California Department of Transportation;
- Carnegy Mellon University;
- Delco Electronics;
- General Motors;
- Hughes Aircraft;
- Lockheed Martin;
- Parsons Brinckerhoff;
- University of California PATH Program;
- Federal Highway Administration.

Clearly with this core participation, it is unlikely that firms outside the consortium are well positioned to compete with Hughes/Delco in providing the on-board sensor technologies which are so critical to the

automated highway functions. In effect, corporate research and development investment will shut out competing interests, particularly from foreign countries.

Foreign Industry Organizations

Again, looking to the U.S. example, ITS America has done an unrivalled job of bringing together various industry interests promoting ITS and providing a forum for information exchange. While the organization invites participation from the world, it is largely populated with U.S. industry interests.

Regional Standards

The European and U.S. programs are actively pursuing the implementation of standards for technical specifications and information exchange. Canadian industry must participate and subscribe to these processes or risk exclusion from future deployment.

Public Sector Funding

Deployment of infrastructure sensors for traffic management relies heavily on public sector funding. Current indications are that public sector budgets here in Canada and internationally are coming under scrutiny and are decreasing. This could threaten the rate of ITS deployment, particularly if the industry does not do a better job of demonstrating the benefits attributed to ITS applications.

Lack of Presence Within the In-Vehicle Market

Canadian industry is not well represented in the market for on-board sensors. Accordingly, Canadian industry may not be able to access the future growth and public sector funding characteristic of the long term in-vehicle systems market.

4.4 BARRIERS TO ACCESSING INTERNATIONAL MARKETS

Canadian ITS sensor manufacturers must export in order to remain in business. A firm such as IRD does the vast majority of their business outside of Canada. Accordingly, manufacturers must respect and attempt to address the barriers associated with doing business internationally.

Lack of Standards

The application of infrastructure and on-board sensors are not governed by regional or international standards addressing the transmission of data and technical specification of components. This lack of standards hinders the transportability of technologies among

various nations and renders difficult for any one manufacturer to build a product for the worldwide market.

Local Presence

Local representation is critical, particularly in marketing infrastructure sensors to transportation agencies and toll road authorities. Typically a large degree of lobbying and liaison with purchasing authorities is required in order to influence and anticipate specifications prior to the tender process. This is particularly critical in the sensor industry because of the wide range of candidate technologies. The selection of a video detector system as opposed to microwave sensors over each lane will have far reaching impacts on the overall system design, specifically civil works for mounting, power supply, and communications bandwidth.

Local presence is also a consideration at the time of installation, setup and support. Infrastructure sensors typically require an alignment and calibration process which requires technical expertise from the manufacturer.

Industry Alliances

As suggested in the preceding section, the development and operational testing of new ITS applications typically involve alliances of private and/or public sector organizations. As an example, every major automaker leads some form of team effort in prototyping advance vehicle control applications such as obstacle detection. Canadian firms that have relevant sensing expertise risk being shut out of the market if they are not participating within industry alliances early in the product development cycle.

For infrastructure applications, it is important that sensor manufacturers network with system integrators, contractors and other vendors such that they can participate in the delivery of turnkey solutions in particular for emerging markets. For example, Hughes Transportation Management Systems is marketing their advanced electronic toll collection technology worldwide. SEO has worked with Hughes supplying laser classification sensors and conceivably will continue to supply their product wherever Hughes is successful in development of new electronic toll road applications, anywhere in the world.

5.0 SUMMARY & RECOMMEND-ATIONS

5.1 SUMMARY OF FINDINGS

Infrastructure Applications

The primary transportation infrastructure sensing applications are traffic flow sensors for traffic management and vehicle identification/ classification sensors for tolling and various commercial vehicle operations. The industry trend for traffic flow and identification/ classification sensors is toward off-pavement technologies. Enabling technologies include ultrasonic, microwave, infrared, and video image detection. At present, all of these technologies compete in the marketplace without a prevalent market leader. The long term trend is towards video based systems.

Other infrastructure sensing applications include the application of established technology to monitor vehicle emissions and ambient environment conditions. Recent developments in the vehicle emissions arena include the introduction of portable monitoring stations and passive roadside monitoring stations.

The worldwide market for infrastructure sensing applications is expected to remain stable, and will benefit from expanded ATMS deployment programs in North America and Europe. The market will increasingly rely upon sensing requirements in support of revenue generating applications such as toll roads, commercial vehicle preclearance, and emissions enforcement.

Canadian industry has some niche success stories in this field, most notably EIS and IRD. There are many manufacturers in the worldwide marketplace, with a wide variation in technologies; competition is intense. Canadian sensor manufacturers with competitive products face challenges in marketing within foreign jurisdictions. Industry alliances are critical to achieving local representation and product awareness in markets outside Canada. Furthermore, sensor manufacturers must consider alliances with international system integrators/contractors for toll systems, traffic management systems, and commercial vehicle management systems.

On-Board Sensors

The primary applications for on-board sensors are lateral/longitudinal obstacle detection and vision enhancement. Key enabling technologies are microwave radar, lidar, and infrared sensing.

The long term market prospects are good for the advanced vehicle control features supported by the sensing applications. The motoring public emphasizes safety and has demonstrated a willingness to pay for value-added safety features. At this point in time, products such as collision warning are early in their product lifecycle and time will tell if they can receive the same degree of public acceptance as other recent safety innovations such as airbags and anti-lock brakes.

Canadian industry is not well represented in this market. In order to compete, Canadian industry must consider niche opportunities with automakers or suppliers, focusing on radar and lidar technology and/or related application software.

5.2 CANADIAN INDUSTRY STRENGTHS AND WEAKNESSES

Infrastructure Sensors

The Canadian ITS industry has some individual successes in niche sensing areas which could provide related industry opportunities, or serve as examples to other companies. Specifically, IRD is a world leader in the supply of commercial vehicle weigh stations, including related sensors. IRD is presently attempting to expand the scope of their services to full ITS applications. EIS markets a unique microwave sensor which can monitor up to 12 lanes of traffic, which makes it one of the most cost effective off-pavement sensor technologies in the world. The present challenge for EIS lies with inserting their product into worldwide markets, raising awareness and influencing specifications. Canadian industry strengths within other areas of the ITS arena provide opportunities for sensor manufacturers. Working relationships with system integrators such as Delcan and IBI Group or Mark IV Industries (electronic toll systems) provide opportunities for sensor manufacturers.

The primary weakness of the current ITS sensor industrial base in Canada is lack of breadth and depth. Canada is not well represented in all sensor technologies and applications, including the traditional inductance loop based systems. Most concerning, is the lack of industry presence in the video based systems which are expected to prevail in the long term.

Another weakness of Canadian industry is the ability to showcase technologies in the home market. Examples include:

- the all electronic Highway 407 toll road which will serve as a showcase to the world utilizes VRC readers, classification sensors, and license plate reading equipment imported from the U.S.;

- where authorities are expanding urban ATMS programs, inductive loop technology is still being used. EIS microwave sensors have been endorsed by a number of U.S. transportation authorities and overseas markets as far reaching as Hong Kong, but are yet to be accepted as the standard sensor in the home market of Ontario. By comparison, there are dozens of Autoscope installations operating in Minneapolis.

On-Board Sensors

Canadian industry is not well positioned in the on-board sensor market, and Canada is generally under represented in the ongoing development of on-board ITS applications as spearheaded by the world's automakers.

There is expertise in related industries, most notably aerospace and defense, which could help Canadian industry to establish a presence in the on-board market. Furthermore, Canadian automotive industry suppliers such as Magna could help to provide a means of access to the international automotive industry. Canada in general has a well developed software and communications networking industry which could seek niche participation in the data processing and integration requirements associated with various in-vehicle applications.

5.3 OPPORTUNITIES FOR CANADIAN INDUSTRY

Where Canadian industry has demonstrated technical leadership, such as with the products from EIS, more resources are required to effectively market the technology internationally. Furthermore, the expertise that does exist in Canada could be better aligned to facilitate turnkey system delivery in international markets. For example, IRD (WIM, sensors), Mark IV (vehicle to roadside communications) and IBI Group (software and system integration) could together provide complete solutions for toll systems and commercial vehicle preclearance systems.

With respect to video image processing, Canada has enough related industry expertise to participate in the creation of competitive products. As the experience with the emerging industry of tele-medicine suggests, if the will exists to develop a comprehensive family of imaging products for transportation, Canadian industry can be competitive.

Some signals in the industry, most notably ongoing research in Japan, suggests that the long term trend is away from station based monitoring (i.e. field sensors). One means of satisfying the input data requirements for comprehensive ITS features is to have full area-wide monitoring through satellite remote sensing. As noted earlier, Canada is a leader in this area and the ongoing or future Radarsat initiatives could address transportation monitoring.

Regarding on-board sensing applications, Canadian industry can focus on niche opportunities for optimizing the performance, packaging, and/or integration of microwave radar and lidar technologies.

5.4 RECOMMENDATIONS AND PROPOSED COURSE OF ACTION

The following section presents recommendations for each stakeholder for the advancement of an ITS sensor industry in Canada. Each recommendation is supported by candidate measures which could be undertaken in order to address the recommendation.

Industry Canada and Transport Canada

1. **Foster the development of industry alliances to facilitate product development, marketing, manufacturing, and support for the international market for infrastructure sensors.** This study has identified a number of Canadian ITS industry interests with globally competitive ITS solutions. These resources should be better aligned in order to access Asian and European markets for applications such as electronic tolling and traffic management. Alliances should include Canadian firms and related industries and local partners overseas. Specific measures which should be considered include:

   - represent Canada's ITS capabilities in trade missions to the Asia-Pacific region;
   - introduce ITS industry participants to selected high technology firms that are actively targeting emerging markets, such as Nortel;
   - use the Strategis Website as a mechanism for exchanging information on ITS sensing capabilities and market opportunities;
   - use Canadian Trade Missions in various countries to gather information on upcoming toll and traffic management projects, and potential local partners including electrical contractors, tele-communications industry, and system integrators.

2. **Provide a showcase for Canadian ITS expertise, including sensing components.** The experience with the Ministry of Transportation of Ontario COMPASS program suggests that ITS applications can be deployed to meet local Canadian needs while serving as a showcase to the world market and generating significant export benefits. This showcase approach, or "model deployment" is the current thrust of the U.S. program and

provides the opportunity to bring together various ITS industry strengths to demonstrate interoperability and operational benefits. Examples in the Canadian ITS arena could include an ATMS/ATIS for Vancouver or a Canada-wide commercial vehicle preclearance program which might include weigh stations and U.S. border crossings. Specific measures which should be considered include:

- work with targeted provincial, regional and/or municipal levels of government to promote model deployment;
- provide funding for model deployment possibly through direct assignment of fuel tax revenues or development of an information technology infrastructure program.

3. **Provide incentives for ITS sensor research and development in Canada, targeting vehicle probe and remote sensing monitoring approaches.** Faced with intensive levels of public and private R&D funding under foreign programs, domestic programs must focus on specific niches with demonstrated market opportunities. Building upon Canada's successes in vehicle to roadside communications and satellite remote sensing, Canadian industry may have an opportunity to advocate alternatives to traditional station-based traffic sensing approaches. Specific measures would include:

   - use monitoring incentives such as R&D tax breaks and access to Canadian research facilities to encourage automakers to increase their levels of research and development within Canada;
   - fund research and product development through programs such as NSERC, and NRC IRAP;
   - discretely identify ITS as a target area within the Technology Partnerships Canada Program to encourage public/private partnerships for research development and productization;
   - establish a program similar to the U.S. ITS IDEA program which encourages the transfer of technologies from related applications to the ITS arena;

- spearhead the development of a research centre of excellence along the lines of the U.S. model drawing upon the ITS expertise at University of Calgary, McMaster University and Queen's University;

- support the inclusion of travel time monitoring operational tests with other VRC initiatives such as the ADVANTAGE I-75/AVION commercial vehicle preclearance system;

- establish links to Japanese traffic remote sensing research and approach Radarsat participants with a view to establishing a joint development program to utilize satellite remote imaging to monitor traffic conditions.

4. **Foster transportability of video and communications technologies from other applications, such as tele-medicine.** This report identified a series of firms such as ABL which have expertise relevant to the development of video image processing for vehicle detection. Specific measures would include:

   - use of the Strategis Website to promote awareness of technical capabilities and international ITS market opportunities;

   - use of NSERC, NRC and TPC programs to fund prototype development.

5. **Participate in foreign ITS programs and standards initiatives in order to help facilitate access by Canadian industry.** For example, Transport Canada and the Ministry of Transportation of Ontario participate in the Enterprise consortium of U.S. state departments of transport. This provides the opportunity for Ontario ITS firms to participate in, or have access to, Enterprise-sponsored research and development activities. Specific measures to be considered include:

   - assume a more active role in proposing, funding, and directing R&D initiatives within the Enterprise consortium;

   - use the Strategis Website as a gateway to provide access to other on-line databases as sponsored by the U.S. DOT, federal laboratories such as Turner-Fairbanks, and U.S. research centres of excellence;

- actively participate in standards processes including U.S. national ITS architecture, U.S. DOT Joint Program Office standards for ITS, and the EU DRIVE programs.

6. **Update this review of technology on a regular basis.** This report identifies an array of enabling technologies supporting a wide range of ITS sensing applications. Some emerging technologies/applications such as video detection are developing very rapidly. Periodic (e.g. annual) update bulletins to amend the contents of this report will help to keep this report useful as a reference tool for Industry Canada and the Canadian industrial base.

7. **Create an ITS Office within Industry Canada.** An ITS Office would serve as a national ITS industry focal point in order to:

   - track the progress of foreign and domestic ITS activities;
   - ensure that the recommendations as set forth herein are acted upon;
   - foster cooperation and information sharing among various industry participants;
   - showcase Canadian ITS achievements and activities within the international community;
   - represent Canadian industry/interests in international activities such as standards development;
   - support the coordination of international conferences, workshops, etc.

Other Public Sector

1. **Provide the opportunity to showcase Canadian ITS capabilities including sensor components.** The role of other levels of government and transit authorities would include establishment of a demonstration project scope, site and capital and operations funding. Other public sector agencies should accommodate the demonstration of advanced ITS sensor applications within their capital programs. Specific measures should include:

- identification of roadway and transit system sensor requirements and review of the international market with respect to products available and other agency experiences;
- scope the operational testing of prototype traffic management sensor systems, such as the RTMS Demonstration Project in Toronto;
- provide funding for operational tests;
- increase exposure to operational tests through objective evaluation, publications, conferences, etc.

2. **Provide incentives for increased research and development.** Specific measures to be considered include the provision of monetary incentives, and access to Canadian research facilities/ universities.

Industry Participants

1. **Seek to identify niche technological advances in machine-vision and video communications.** Technologies can be adapted from plant automation, security, aerospace and defense and tele-medicine to prototype a video vehicle detection system. Consideration should be directed at collaboration with existing system vendors.

2. **Develop existing products for travel time monitoring.** Develop existing ITS and non-ITS products for area-wide travel time monitoring. Example opportunities include the development of travel time read/write software for Mark IV transponder readers.

3. **Develop industry alliances to foster the productization, marketing, manufacturing, and support of ITS sensor products for the international market.** Existing sensor manufacturers should seek to establish a presence in the European and Asia-Pacific market through:

   - partnering with local traffic product distributors;
   - combined marketing efforts with large high technology firms seeking to expand market share in these regions;
   - participation in international trade missions.

Access to the on-board sensor system market could be achieved through the establishment of ties to the auto parts industries (e.g. Magna).

Research Organizations

1. **Foster the development of enabling technologies for ITS applications, and other related applications.** Specific technologies include digital video compression, machine-vision, microwave radar, lidar, infrared sensing, and emissions/ environment monitoring.

2. **Strengthen links to industry in order to focus research on market needs and market products resulting from successful R&D programs.** Experience with other ITS solutions developed in academia, (such as Autoscope video vehicle detection originating from U of Minnesota) suggest that representation from the ITS industry is necessary to lend direction to research, and provide channels for productization, and international marketing, distribution and support.

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APPENDIX A

ITS SENSOR TECHNOLOGY SURVEY QUESTIONNAIRES

ITS TECHNOLOGY SURVEY
FIELD SENSOR TECHNOLOGIES

GENERAL QUESTIONS

1. What are your company's primary products and/or services?

2. In addition to sensors, what other Intelligent Transportation Systems products does your company produce?

3. Is/was your company involved in the production/development of sensors for other applications?

4. What specific strengths does your company bring to the Intelligent Transportation Systems market?

SENSOR TECHNOLOGY

1. How long has your company been involved in producing sensor technology?

2. What type of sensors does your company produce?

3. How are they typically applied?

4. How does each sensor function? Is additional supporting infrastructure required for operation?

5. Where is data processed?

6. What type of processing device is used to process data from each type of sensor?

7. How accurate are your sensors? What tolerance levels are considered acceptable?

8. How well do your sensors stand up to harsh environmental conditions?

9. What other future applications might your sensors have? Are your processors configurable to support evolving applications?

10. How often do your sensors require routine maintenance?

11. What types of new sensor technologies or enhancements to existing products is your company currently working on or will begin developing over the next five or ten years?

DISTRIBUTION AND OPERATIONS

1. What agencies currently use you products? What is your installed base? What countries are your products available in? What is the unit cost of each sensor technology?

2. What North American and International market share do your products currently occupy?

3. How do you envisage your products and services changing over the next five years? What market penetration rate do you anticipate for your products in two years, five years and ten years?

4. Have any specific barriers been encountered by your organization in selling your products and services on International markets?

5. What do you think the target cost of sensors will be in five years?

6. What are the primary domestic and international standards, regulation and laws which govern the production and marketing of your products and services?

ITS TECHNOLOGY SURVEY
ON-BOARD SENSOR TECHNOLOGIES

GENERAL QUESTIONS

1. What are your company's primary products and/or services?

2. In addition to sensors, what other Intelligent Transportation Systems products does your company produce?

3. Is/was your company formerly involved in the production/development of sensors for other applications?

4. What specific strengths does your company bring to the Intelligent Transportation Systems market?

SENSOR TECHNOLOGY

1. How long has your company been involved in developing sensor technology?

2. Which of the following sensors has your company been actively involved in?

   Road Surface/Environment Sensors
   - temperature
   - humidity
   - tire pressure
   - vehicle dynamic behaviour

   Vision Enhancement Sensors

   Longitudinal/Lateral Control Sensors
   - crash warning and control
   - intelligent cruise control
   - passing vehicle warning
   - blind spot warning
   - intersection collision warning
   - emergency communications
   - parking aid

   Occupant Sensors

   Voice Interactive Vehicle Navigation Systems

   Global Positioning Sensors

   Other

3. What type of technology is used by each (e.g. infrared, microwave radar) and why?

4. Where are the sensors located on the vehicle? How many sensors are required?

5. How does each sensor function? Are roadside infrastructure or markings required for operation?

6. What sensor information is made available to the driver and how is it communicated to the driver?

7. What type of processing device is used to process data from each type of sensor?

8. How accurate are your sensors? What tolerance levels are considered acceptable?

9. How well do your external mounted sensors stand up to harsh environmental conditions?

10. What other future applications might your sensors have? Are your processors configurable to support evolving applications and capable of being integrated with emerging on-board communication bus architectures?

11. How often do your sensors require routine maintenance?

12. What types of sensor technology will you be developing over the next five or ten years?

DISTRIBUTION AND OPERATIONS

1. Are any commercially available vehicles currently using your on-board sensors? What is the installed base? What countries are your products available in? What is the additional unit cost of each on-board sensor technology?

2. Are your sensors in use on prototype vehicles?

3. What North American and International market share do you products currently occupy?

4. How do you envisage your products and services changing over the next five years? What market penetration rate do you anticipate for your products in two years, five years and ten years?

5. Have any specific barriers been encountered by your organization in selling your products and services on International markets?

6. What do you think the target price of sensors will be in five years?

7. What are the primary domestic and international standards, regulation and laws which govern the production and marketing of your products and services?

LISTING OF FIRMS CONTACTED

Allied Signal
Armatron
Amerigon
AT&T
Cobra
Delco
Easton
EIS
Insys
International Road Dynamics
Japanese Traffic Management Association
Leica
Millitech
Ministry of Transportation, Ontario
Northrop Grumman
SSI
Safety First
Schwartz
Sparton
University of California PATH

APPENDIX B

INDUSTRY CONTACTS

B1 Canada
B2 U.S.
B3 EU
B4 Asia-Pacific

B1 Industry Contacts - Canada

ALLIEDSIGNAL, Inc.

ADDRESS: 240 Attwell Drive
Etobicoke, Ontario
M9W 6L7

CONTACT: Peter Keyer
Tel: (416) 798-6679
Fax: (416) 798-6866

KEYWORDS: Infrared Sensors

HISTORY: AlliedSignal is serving the automotive, aerospace and engineered materials markets. The company expanded into Canadian market with two plants located in Montreal and Toronto. Infrared sensors are produced by the AlliedSignals plant in Montreal. The Toronto office primarily manufactures aircraft cabin temperature and air flow sensors.

ITS CAPABILITY: AlliedSignal Inc. is involved in manufacturing the following ITS technologies:

- infrared image enhancement sensors adaptable for heads-up display;
- inductive loops, microwave, infrared, acoustic sensor systems;
- video surveillance, transmission, switching and display;
- traffic controllers;
- fibre optic, copper and RF/microwave communication systems;
- client-server computer systems;
- local area communication networks;
- variable message signs;
- lane control signals;
- signal system control.

ITS PERSONNEL: No data.

GROSS SALES: 1995 - $14 billion
Infrared sensors produced in Montreal generate sales of $5 million per year.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: AlliedSignal Inc. is actively involved in ITS market and its main projects include:

- San Antonio Advanced Traffic Management Systems;
- Boston I-93 Integrated Motorist Information and Traffic Control System;
- Texas Traffic Responsive Automated Corridor ITS Operational Test;
- Intersection Collision Avoidance Research Program.

B1 Industry Contacts - Canada

APPLIED SILICON INC., CANADA

ADDRESS: 220-2427 Holly Lane
Ottawa, Ontario K1V 7P2

CONTACT: Tel: (613) 738-2434
Fax: (613) 738-0750

KEYWORDS: VIDEOVISE; the Video Termination Unit (VTU) and the Video Monitoring System (VMS).

HISTORY: The company has been manufacturing image processing system for four years.

ITS CAPABILITY: The company designs and manufactures VideoVise System, that consists of two interrelated systems; the Video Termination Unit (VTU) and the Video Monitoring System (VMS).

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Applied Silicon Inc. installs their system around the world.

B1 Industry Contacts - Canada

ELECTRONIC INTEGRATED SYSTEMS, INC.

ADDRESS: 150 Bridgeland Ave.
North York, Ontario M6A 1Z5

CONTACT: Dan Manor
Tel: (416) 785-9248
Fax: (416) 785-9332

KEYWORDS: The remote traffic microwave sensor (RTMS), the radar vehicle detector (RVD).

HISTORY: No data.

ITS CAPABILITY: Electronic Integrated Systems designs and manufactures the remote traffic microwave sensor (RTMS) and the radar detector.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: The RTMS has been tested by several independent organizations:

- Ministry of Transportation, Ontario
- Hughes Aircraft on behalf of the U.S. Federal Highways Administration

Its clients include:

- The City of Mississauga, Ontario
- The City of Toronto
- The City of Philadelphia

B1 Industry Contacts - Canada

INTERNATIONAL ROAD DYNAMICS INC.

ADDRESS: 702-43rd Street
Saskatoon, Saskatchewan
S7K 3T9

CONTACT: Mr. Rod Klashinsky, Marketing/Sales Manager
Tel: 306-653-6600
Fax: 306-242-5599

KEYWORDS: Traffic data collection, vehicle detection, weigh station, weigh-in-motion (WIM) systems, commercial vehicle operations (CVO), TransView™ global position system (GPS)/automatic vehicle location (AVL), traffic management services.

HISTORY: IRD has been incorporated for 15 years, and has produced sensors not only for traffic control, but for security applications. IRD has recently purchased AT&T's ultrasonic sensor technology, the Smartsonic vehicle sensor.

ITS CAPABILITY: IRD is a multi-disciplinary engineering company with specialists in the areas of civil transportation planning, computer hardware and software applications and mechanical weigh scale design. IRD says it integrates diverse technologies into functional system which parallel the 1990's ITS initiatives. The company offers design, manufacturing, project management, construction and system maintenance.

ITS PERSONNEL: Number of ITS-dedicated staff - 80

GROSS SALES: 1995 - $12 million

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: The company's customers include U.S. and Canadian companies. IRD was involved in the following projects:

- Automated Port of Entry Facilities and CVO Systems throughout North America;
- Truck Roll-Over Warning System, Virginia, Maryland;
- Truck Down-Grade Warning System, Colorado;
- HELP and I-75 CVO Weigh-in-Motion Systems;
- Two-Way Vehicle Communications, Oregon PASS, HELP;
- Oregon Green Light CVO System Integrator and Supplier;
- Arizona CVO Enforcement Study;
- Saskatchewan Abilities (paratransit) Automatic Vehicle Location and Wireless Dispatch System;
- Orlando Toll Road Classification System.

B1 Industry Contacts - Canada

MARK IV INDUSTRIES

ADDRESS: 6020 Ambler Drive
Mississauga, Ontario
L4W 2P1

CONTACT: Mr. Kelly Gravelle, VP
Tel: (905) 624-3025
Fax: (905) 624-4572

KEYWORDS: Electronic Toll Collection, Vehicle to Roadside Communications

HISTORY: No data

ITS CAPABILITY: VMS, vehicle roadside communications, transit passenger information systems.

ITS PERSONNEL: No data

GROSS SALES: No data

PLANT SIZE: No data

EQUIPMENT: No data

ITS EXPERIENCE: Long Island INFORM, Ministry of Transportation Ontario, IAG E-Z Pass, HELP.

B1 Industry Contacts - Canada

Other Contacts (Ref. the International ITS Index, 1996)

ABL Canada, Inc.
8550 Cote de liesse
St. Laurent, Québec
H4T 1H2

Tel: (514) 344-5432
Fax: (514) 344-5439

AMERIGON INC.

ADDRESS: 404 East Huntington Drive
Monrovia, California 91016-3600

CONTACT: Zaya Younan, Vice President, Sales and Marketing
Tel: (818) 932-1200
Fax: (818) 932-1220

KEYWORDS: Voice interactive vehicle navigation system, advanced occupant climate controlled systems and ultra-wide band radar sensing technology.

HISTORY: No data.

ITS CAPABILITY: Amerigon Inc. developed expertise in the design and manufacturing of the following ITS systems:

- voice interactive vehicle navigation system;
- voice control module for vehicle control option;
- advanced occupant climate controlled systems.

The company also developed ultra-wide band radar sensing technology for the following vehicle applications:

- intelligent cruise control system;
- parking aid;
- side vision aid;
- occupant sensing;
- forward collision warning.

ITS PERSONNEL: 42 engineers dedicated to ITS and advance electronics.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Eleven automakers are evaluating Amerigon's vehicle navigation system for vehicle introduction.

ARMATRON INTERNATIONAL INC.

ADDRESS: 2 Main Street
Melrose, Massachusetts 02176

CONTACT: James Cherry, Vice President, Engineering
Tel: (617) 321-2300
Fax: (617) 321-2309

KEYWORDS: Obstacle detection/crash avoidance products.

HISTORY: AII is a 75 year old company that has been involved in developing sensor technology for the last five years. Prior to developing sensors for the ITS market, AII was involved in the automotive electronics industry.

ITS CAPABILITY: AII is involved in developing Ultrasonic obstacle detection system, consisting of a transmitter, central computer and receiver, which features a warning signal to alert a driver to the presence of an obstacle in the monitored zone.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: AII was involved in National Highway Traffic Safety Administration (NHSA), A Study of Commercial Motor Vehicle Electronics-Based Rear and Side Object Detection Systems. AII clients include major national fleets (i.e. Fed Ex) and Original Equipment Manufacturers (OEMs).

COBRA ELECTRONICS CORPORATION

ADDRESS: 6500 W. Cortland Street
Chicago, Illinois 60635

CONTACT: John Pohl, Vice President, Marketing
Tel: (312) 889-8870
Fax: (312) 794-1930

KEYWORDS: Safety alert systems.

HISTORY: CEC was founded in 1954.

ITS CAPABILITY: The company describes itself as a focused marketer in the telecommunications and mobile electronics fields, with expertise in radar and laser detection systems. CEC produces a safety alert system which has been implemented on emergency vehicles throughout the U.S.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

ITS EQUIPMENT: No data.

ITS EXPERIENCE: CEC markets products in the U.S. and around the world. Their safety alert system is implemented on emergency vehicle light bars by a light bar manufacturer in St. Louis, Missouri.

DELCO ELECTRONICS CORPORATION

ADDRESS: One Corporate Centre, E110
Kokoma, Illinois 46904-9005

CONTACT: John McComas, Staff Engineer, ITS Technologies
Tel: (317) 451-1921
Fax: (317) 451-1340

KEYWORDS: "Forewarn" radar collision warning devices, night vision system, Telepath 100 navigation system, radio data system (RDS) receiver and electronic tolling and traffic management.

HISTORY: Delco Electronics and General Motor's sister company Hughes Aircraft (which together form the GM subsidiary Hughes Electronics) have jointly formed the HE Microwave to develop and market Forewarn radar-based object detection systems for the automotive market.

ITS CAPABILITY: DEC designs and manufactures automotive electronics, audio sound systems, air controls, air bag and anti-lock brake modules, semiconductor devices and integrated circuits, electronic engine controls, vehicle displays and instrumentation.

ITS PERSONNEL: 30,000 employees

GROSS SALES: 1994 - $5.2 billion

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: DEC was involved in the TravTek project. The Forewarn sensor system has been implemented on the Lexus L5400 and by GM on the 1996 Cadillac Seville.

B2 Industry Contacts - U.S.

DETECTOR SYSTEMS, INC.

ADDRESS: 11650 Seaboard Circle
Stanton, California 90680

CONTACT:
Tel: (714) 895-6366
Fax: (714) 895-6145

KEYWORDS: Vehicle detection systems, inductance detector loops, the vehicle identification system and the traffic logging system.

HISTORY: The company has been operating for over 16 years.

ITS CAPABILITY: Detector system designs and manufactures the vehicle detection systems, the vehicle identification system and the traffic logging system.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: No data.

EATON VORAD TECHNOLOGIES, L.L.C.

ADDRESS: 10802 Willow Court
San Diego, California 92127

CONTACT: Mark Harmon, Field Service Support Manager
Tel: (619) 674-1200
Fax: (619) 674-1355

KEYWORDS: Eaton VORAD EVT-200 Collision Warning System; adaptive cruise control, automatic braking, trip/event recording.

HISTORY: Founded in 1972 as Radar Control Systems Corporation, Eaton VORAD is an Eaton Corporation majority owned venture company formed between VORAD Safety Systems, a subsidiary of IVHS Technologies and Eaton Corporation.

ITS CAPABILITY: Eaton VORAD Technologies, L.L.C. designs and manufactures the EVT-200 Collision Warning System, it also offers adaptive cruise control, automatic braking and trip-event recording systems.

ITS PERSONNEL: Number of ITS-dedicated staff - 50

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: EVT-200 Collision Warning System is commercially available, and has been installed on 1996 Freightliner Century Class trucks (class 8) in the U.S.

ECONOLITE CONTROL PRODUCTS INC.

ADDRESS: 3360 East La Palma Avenue
Anaheim, California 92806-2856

CONTACT: Tel: (714) 630-3700
Fax: (714) 630-6349

KEYWORDS: Autoscope video image system, ScopeServer and automated incident detection.

HISTORY: Econolite Control Products, Inc. has provided products for advanced systems of traffic control for more than 60 years.

ITS CAPABILITY: ECPI designs and manufactures the following ITS products and systems:

- Autoscope video imaging system for wide-area detection at intersections and freeways;
- Autoscope video image system for automated traffic counts;
- ScopeServer for automated traffic data collection from Autoscope;
- Automated incident detection using Autoscope for wide-area detection.

Other products and services:

- traffic controllers;
- distributed arterial control systems;
- emergency traffic preemption systems;
- traffic control cabinet assemblies;
- LED signs and signals;
- vehicle and pedestrian signals.

ITS PERSONNEL: No data.

GROSS SALES: 1995 - $12 million

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: The company participated in the various ITS projects including:

- FAST-TRAC, Oakland County, Michigan
- Guidestar, Minnesota Department of Transportation
- Video Detection Incident Management System, Georgia DOT
- Houston Area Freeway Traffic Management System

Its client list also includes:

- City of Lancaster, California
- Minnesota DOT
- Houston Metro Transportation Authority

B2 Industry Contacts - U.S.

INSYS

ADDRESS: 1437 7th Street, #300
Santa Monica, California 90401

CONTACT: Peter Cowen, U.S. Marketing
Tel: (310) 451-2475
Fax: (310) 458-9307

KEYWORDS: Driver alertness monitor, piezoelectric sensors and ultrasonic ranging.

HISTORY: Insys Ltd. is a privately owned company founded in 1989.

ITS CAPABILITY: No data.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: No data.

MILLITECH CORPORATION

ADDRESS: South Deerfield Research Park
P.O. Box 109
South Deerfield, Massachusetts 01373

CONTACT: Naresh Deo, Vice President, Business Development and Sales
Tel: (413) 665-8551
Fax: (413) 665-4831

KEYWORDS: Collision avoidance vehicle radar, all-weather night vision systems, vehicle-to-vehicle and vehicle-to-roadside communication systems.

HISTORY: Millitech Corporation was founded in 1982, and is privately owned by two major corporations, venture capital firms, and Millitech management and employees.

ITS CAPABILITY: Millitech designs, develops and manufactures components, assemblies and systems. Millitech's millimetre wave product line includes:

- collision avoidance radar;
- all-weather vision systems;
- vehicle-to-vehicle and vehicle-to-roadside communication systems;
- passive and active imaging systems using starting focal plane arrays or scanning sensors;
- sensors systems;
- communication systems;
- remote sensing.

ITS PERSONNEL: 10 out of a total staff of 135 is ITS-dedicated.

GROSS SALES: 1995 - $15 million

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Millitech Corporation was involved in the following programs and systems:

- all-weather night vision program;
- Prometheus communication program;
- Forward-looking object detection system.

NORTHROP GRUMMAN CORPORATION

ADDRESS: Advanced Technology and Development Centre
8900 E. Washington Boulevard, MS:N560/XA
Pico Rivera, California 90660-3783

CONTACT: Clifford Hickel, ITS Program Manager
Tel: (310) 942-3221
Fax: (310) 948-9485

KEYWORDS: Infrared traffic sensors, acoustic traffic sensors, drowsy driver sensors and millimetre wave (MMW) components for collision avoidance and communications system.

HISTORY: Northrop Grumman was formed in 1994 when Northrop Corporation (founded in 1939) of Los Angeles acquired Grumman Corporation (founded in 1929) of Bethpage, New York. Prior to developing sensors for ITS applications, the company produced sensors for the military defense industry.

ITS CAPABILITY: NGC develops and manufactures the following products and systems:

- millimetre wave (MMW) components for collision avoidance and communication systems;
- infrared traffic sensors;
- acoustic traffic sensors;
- drowsy driver sensor.

ITS PERSONNEL: NGC employs more than 45,000 people including 25 ITS personnel.

GROSS SALES: 1994 - $8.7 billion

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: NGC participated in the various products including:

- Federal Highway Administration (FHWA) Precursor Systems Analysis of Automated Highway Systems: Automated Check-In Task
- ITS Innovations Deserving Exploratory Analysis (IDEA) Study; "Interference Resistant Signals for Collision Avoidance RADAR"
- ITS IDEA Study; "Three-In-One Vehicle Operator Sensor" (drowsy driver sensor)
- Advanced Research Projects Agency Technology Reinvestment Program; "Development and Application of Advanced Dual-Use Microwave Technologies for Wireless Communications and Sensors for IVHS Vehicles" (MMW collision warning radar development)
- Advanced Technology Transit Bus (ATTB) concept definition and design validation for the Los Angeles County Metropolitan Transportation Authority
- Infrared traffic sensors for the Dowling College (Long Island, New York) National Aviation Transportation Center's continuous flow intersection
- Operational test of infrared traffic sensors on the New York State Information for Motorists (INFORM) Traffic management system on Long Island
- Intelligent vehicle management system for the Seoul Korea Police

B2 Industry Contacts - U.S.

SAFETY FIRST SYSTEMS, LTD.

ADDRESS: 42 Santa Barbara Drive
Plainview, New York 11803

CONTACT: Alan Hersh, President
Tel: (516) 681-3653
Fax: (516) 938-6558

KEYWORDS: Smart sensor microwave back-up alarm, smart sensor lane change warning system.

HISTORY: SFS was started in 1985 to manufacture and market vehicular obstacle detection systems. SFS has a joint venture with General Microwave Corp. to produce their vehicle sensor system.

ITS CAPABILITY: SFS designs and manufactures smart sensor microwave alarm systems.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: SFS participated in NHTSA crash avoidance program. Its strategic alliances and joint ventures include:

- General Microwave Corporation
- Chrysler Corporation
- Ford Motor Company
- NHTSA
- Motorola Corporation

SCHWARTZ ELECTRO-OPTICS INC.

ADDRESS: 3404 N. Orange Blossom Trail
Orlando, Florida

CONTACT: Terry Myers, Product Director
Tel: (407) 298-1802
Fax: (407) 297-1794

KEYWORDS: Autosense (Versions I, II and III)

HISTORY: No data.

ITS CAPABILITY: SEO's Autosense employs a pulse time-of-flight laser range-finder to monitor vehicle presence, speed and classification. The on-board microprocessor is used to provide time-tagged data for count, presence, speed, average speed and vehicle classification. These data are accessible in real-time or as stored data through a computer interface.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: ITS project participation:

- Demonstration Project #93: Traffic Control Equipment and Software for FHWA
- Detection Technology for ITS; U.S. DOT, FHWA
- "Design of a Sensor to Detect and Classify Highway Vehicles Using Laser Imaging Techniques", National Research Council ITS-IDEA Program
- "Overhead Infrared Vehicle Detector" Phase 1 U.S. DOT SBIR (Small Business Innovative Research) Program

ITS Clients:

- AUTOSENSE I: Indiana DOT
- AUTOSENSE II: MFS Network Technologies
- AUTOSENSE III: British Columbia, Ministry of Transportation

SPARTON ELECTRONICS

ADDRESS: 2400 E. Ganson Street
Jackson, Michigan 49202

CONTACT: Robert Gerrish, Director of Business Development
Tel: (517) 787-8600
Fax: (517) 787-8046

KEYWORDS: Rear-Obstacle Detection System (RODS) and Side-Obstacle Detection System (SODS).

HISTORY: Sparton Electronics is a 95 year old company which has been involved in acoustics for more than 50 years and is currently applying signal processing to acoustic systems.

ITS CAPABILITY: Sparton has teamed with Muth Advanced Technology to jointly develop both RODS and SODS as a turnkey system. Sparton is a full-service contract design and manufacturing facility, capable of taking a product from concept through the decision and development phases and into high-volume production. Other services include:

- redesign of existing products for cost reduction and ease of assembly;
- complete design and manufacturing capability for electronics, mechanical design, sensors, computers and electro-chemistry.

ITS PERSONNEL: Number of ITS-dedicated staff - 15

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: No data.

SURFACE SYSTEMS INC.

ADDRESS: 11612 Lilburn Park Road
St. Louis, Missouri 63146

CONTACT: S. Edward Boselly III, Director of Marketing, Strategic Planning and Training
Tel: (314) 569-1002
Fax: (314) 569-3567

KEYWORDS: Road/Runway Weather Information System (RWIS), Surface Condition Analyzer (SCAN) Cast.

HISTORY: RWIS was first used on highways in the early 1980's; today there are 146 highway agencies and over 130 civil and military airports in the U.S. using the technology. SSI received several international awards.

ITS CAPABILITY: SSI is a high technology company that manufactures and markets advanced weather sensing systems and weather forecasting services to the transportation industry. According to SSI, SCAN Cast Weather Center is the only dedicated pavement specific weather forecasting facility in the world. The SCAN System and the SCAN Cast assist in proactive decision making to ensure public safety and reduce maintenance cost and are being incorporated into the emerging intelligent traveller information and traffic management system.

ITS PERSONNEL: Number of ITS-dedicated staff - one.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: SSI's system is being utilized in four ITS operational tests and projects:

- ADVANCE, Chicago
- Idaho Storm Warning System
- Travel-Aid, Washington State
- CHART Project (Chesapeake Highway Advisories Routing Traffic), Maryland State Highway Administration

B2 Industry Contacts - U.S.

Other Contacts (Ref. the International ITS Index, 1996)

3M Traffic Control Systems
3M Safety and Security and Security
Systems Division
3M Center, Building 225-4N-14
St. Paul, Minnesota 55144-1000

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Fax: (612) 736-2298

AMP, Inc.
Piezo Film Sensors
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Fax: (610) 666-3509

Cohu, Electronics Division
5755 Kearny Villa Road
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Fax: (619) 277-0221

Condition Monitoring Systems
2412 E. First Street
Long Beach, California 90803

Tel & Fax: (310) 438-4875

E-Lite Limited
5341 Derry Avenue, Suite N
Agora Hill, California 91301

Tel: (818) 889-2302
Fax: (818) 889-6941

Electronic Control Measure (ECM) Inc.
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Fax: (512) 272-4966

American Dynamics
10 Corporate Drive
Orangeburg, New York 10962

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Burle Philips Communication & Security Systems (CSS), Inc.
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Fax: (717) 295-6097

Computer Recognition Systems, Inc.
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Detection Systems & Engineering Co.
1450 Temple City Drive
Troy, Michigan 48084

Tel: (810) 649-1310
Fax: (810) 649-1508

Eastman Kodak Company
Motion Analysis Systems Division
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Fax: (619) 481-9142

Handar, Inc.
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Intelligent Highway Systems, Inc.
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Jamar Technologies
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Jaycor
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M/A-Com, Inc.
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Mirage Systems
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Imaging Systems
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Javelin Systems
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Laser Technology, Inc. (LTI)
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Microwave Sensors, Inc.
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MZB Video Solutions, Inc.
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Never-Fail Loop Systems
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Transformation Systems, Inc.
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Trindel America Corporation
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Whelen Engineering Company
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KEYWORDS: Intelligent cruise control (ICC) and infrared range finder technology.

HISTORY: Leica AG, based in Switzerland with offices in the U.S., is a dominant player in the ITS market with its infrared technology. The company has been involved in the ITS market since 1988, beginning with their activities in the Prometheus project in Europe. The development of their infrared sensors is a spin-off of their world renowned surveying technology.

ITS CAPABILITY: The company is specialized in optics and electronics. It's automotive and transportation sensor groups cooperates with car manufacturers and system suppliers on intelligent cruise control. Leica says it has its own fleet of ICC test cars that have on-road experience of over 400,000km. Leica currently has their sensors implemented on 8 vehicles, one of the largest fleets.

ITS PERSONNEL: Number of ITS-dedicated staff - 10

GROSS SALES: 1995 - $900 million

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Leica AG participated in the following projects:

- Fostering the Development, Evaluation and Deployment of Forward Crash Avoidance System (FOCAS);
- European Research Programs (Telematics, BRIGHT EURAM);
- International Standards Organization (ISO) Standards Committee.

B3 Industry Contacts - EU

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Valencia
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Henley-on-Thames
Oxfordshire
UK-RG9 1EL
United Kingdom

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Philips Automation SpA
Via G. Casati 23
Monza
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Italy

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Philips Communications and Security Systems
Cromwell Road
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B3 Industry Contacts - EU

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R+H Systems BV
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Rotterdam
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SIAT
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Racal
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Sensys Traffic AB
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SFIM Traffic Transport
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Simulation Systems
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B3 Industry Contacts - EU

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B4 Industry Contacts - Asia-Pacific

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