



**An
Intelligent Systems Applications Study
For
Communities and Their Infrastructures**

**Workshop Findings and
Findings from Subsequent Research**

Prepared For:

precarn

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Communities and Their Infrastructures

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1. Workshop Findings and Findings from Subsequent Research

1.1. Introduction

Following the distribution of the Discussion Paper, a workshop on applications of intelligent systems to develop sustainable solutions for community infrastructures was held on January 27th at the Chateau Laurier Hotel in Ottawa, Ontario.

The early morning session was taken up with a series of presentations on a range of topics covering: Intelligent Transportation Systems, Environmental Systems, Energy Systems, Web Services, Knowledge Management and the Semantic Grid in the Broadband area.

Following the opening presentations, the participants divided into two breakout groups, one to discuss Intelligent Transportation Systems and the other to discuss Intelligent Environmental and Energy Systems.

Each of the groups was asked to recommend potential applications for intelligent systems in their respective infrastructure area and asked to identify social, environmental, technological, and economic aspects of the proposal. This was done in a more or less informal way in order not to impede the discussion or ideas.

Following the workshop, the findings were compiled from the notes and supplemented with additional research on topics that were deemed to be relevant but which were not raised during the workshop (Intelligent Technologies for Alternative Energy Sources for Communities). The manner of presentation of the findings is done using an interpretive style in order to clarify the context within which the discussion on a given topic took place. Explanations of points are often further supplemented with examples for clarification purposes.

Prior to submitting the report, the findings were reviewed by a number of participants who provided input for revisions.

This section summarizes the findings of the working groups and the supplementary research findings. The findings are presented in three sub-sections: the first being those related to Intelligent Transportation Systems; the second being those on Intelligent Environmental and Energy Systems; and the third on Broadband.

1.2. *Summary of Major Findings*

In surveying the recommendations provided by both of the discussion groups, a number of common themes emerged. These are summarized as follows and discussed in detail in the following sub-sections:

Planning Tools

Both groups acknowledged the applicability of intelligent systems for the use in complex integrated modeling systems such as transportation and urban planning. Such systems have been evolving for some time and are used for policy impact analysis and environmental impact analysis (as noted in the Discussion Paper).

Monitoring Tools

Monitoring systems such as the tools developed to monitor the Confederation Bridge, pipeline fault monitoring and water quality monitoring systems were each identified as opportunity areas. Systems with the capability to predict future performance levels were recommended as future areas for research and development.

Advanced Control Systems and Sensors

This is a major opportunity area for the application of intelligent systems technology. Application contexts range from greater intelligence in vehicle and network control rooms of traffic managers, to the control of wastewater bioreactor treatment facilities and in the management of building environments. Recent advances in sensor technologies can be used to increase the overall efficiency of transportation and structural systems such as bridge and pipelines and building monitoring systems, as well as in energy recovery systems such as solar array technology¹.

Asset Management and Inventory

Better methods for assessing and identifying the location, condition, and economics of infrastructure were identified as areas of need in order to introduce new efficiencies and lower the costs for infrastructure upgrade, replacement, and removal, as well as for leveraging the use of existing facilities.

Information Services

Information services applications were identified on the ITS side in areas such as traveller information services for road and weather condition information, and other commercial applications. The major barrier to the deployment of such services is the need for an integration layer to enable integration of disparate legacy systems – goals related to those concerned with the development of Web Services, the Semantic Grid, and Autonomic Computing.

¹ See, for example the announcements describing the revolutionary discovery of new sprayable detectors for solar arrays developed at the University of Toronto by a team led by Dr. Ted Sargent. (<http://www.freerepublic.com/focus/news/1318504/posts>)

2. Intelligent Transportation Systems (ITS)

The working group in the breakout session on Intelligent Transportation Systems was asked to suggest areas in the transportation system in which they considered there were problems to be addressed which may open up opportunities for the application of intelligent systems technologies. The group summarized its findings as follows:

1. Information saturation for vehicle drivers – how to synthesize;
2. Methods to deliver information to vehicle drivers;
3. Vehicle Tracking, Monitoring and Diagnostics;
4. Traveller Information Systems – Traffic Road and Weather Conditions;
5. Assessment of the Infrastructure Deficit - Need predictive technology;
6. Demand Responsive Public Transit;
7. Intelligent Control Room Operation;
8. Collision Avoidance at Intersections;
9. Integrated Transportation and Urban Planning Systems; and
10. Leveraging of Infrastructure to Develop Sustainable Solutions.

These are discussed in detail in the following pages.

Transport Canada Survey of ITS Research and Development Priorities

In addition to the table discussion, the Transport Canada representatives referenced a survey that Transport Canada had carried out in 2003. The survey was intended to identify the ITS R&D priorities of six stakeholder groups in Canada -- federal government, provincial governments, municipalities, industry, service operators, and the academic community. The survey results were published in April 2003. The summary findings from that survey are contained in Appendix A of this document because of their immediate relevance and currency. For additional detail, the reader is referred to Appendix A (Survey of ITS Research and Development Priorities) of the document 'Intelligent Transportation Systems Research and Development Plan for Canada'¹

¹ INTELLIGENT TRANSPORTATION SYSTEMS RESEARCH AND DEVELOPMENT PLAN FOR CANADA INNOVATION THROUGH PARTNERSHIP, April 2000 available at www.its-sti.gc.ca,

2.1. Information Saturation for Vehicle Drivers

The point was raised that a lot of information is coming to the driver with more information services on the way (such as 511), so that the point is coming where the driver is over-saturated with information. Priority areas of study for addressing this issue would be to:

- Examine the need for restricting the use of devices in the vehicle (e.g. cell phones and LCDs);
- Promote standardization of in-vehicle devices and interfaces and, in particular, address the need to convince the automobile industry to look at standardizing in-vehicle devices such as LCDs, etc.

Pursuant to this, it was noted that there is a need for better tracking of drivers' activities using 'open' standardized devices with more functionality. This may entail significant capital costs to implement, as information would have to be beamed back to an expensive control centre.

2.2. Methods to Deliver Information to Vehicle Drivers

There are currently a variety of systems used to distribute information to drivers such as highway assisted radio, electronic highway signs, etc.

It was observed that there is a trend from satellite communications companies to offer better packages and so there are opportunities to build upon the use of GPS information to enhance traveller information services. For example, fuel taxes paid by commercial vehicle operators vary by jurisdiction across North America. Such operators can take advantage of knowing, while traveling through these different jurisdictions, the amount of fuel tax to be paid for downstream reporting purposes.

2.3. Vehicle Tracking, Monitoring, and Diagnostics

It was noted that intelligent systems could be applied to vehicle tracking, monitoring, and diagnostic applications. In this area, potential benefits could include:

- Reduction in the number of highway incidents using information gathered in monitoring repairs;
- Enforcement of use of highways upon which travel is restricted; e.g. need 3 or more passengers to use;
- Reducing incident response times for improved emergency response; and
- Locating lost or stolen vehicles.

2.4. Traveller Information Systems – Road, Bridge, and Weather Conditions

The application of intelligent systems for monitoring of bridge structural behaviour was demonstrated earlier in the day by Dr. David Lau of Carleton University in his presentation on the monitoring system he developed for the Confederation Bridge which spans the channel between the coast of New Brunswick and Prince Edward Island.

In the interest of public safety, transit of the bridge for some types of vehicles sometime needs to be suspended due to the de-stabilizing effect of high winds on the bridge. Monitoring of the structure under heavy weather conditions enables the operator of the bridge to determine, in the interest of public safety, when to implement special operational procedures for travelers, especially large trucks, in crossing the bridge. Such monitoring systems are thus an area of application.

In the area of Traveller Information Systems, recommendations were made to support the case that Intelligent Systems could find application in:

- Travel Management Information Systems. These are of value in providing the driver with information on where and when to travel given, for example, traffic, road and weather conditions on alternate choices for route. Such information not only benefits the driver but has implicit benefits such as reducing congestion and environmental emissions by making travel more efficient;
- Optimizing road conditioning operations; e.g. where and when and how much salt to put down during icy conditions;
- Enforcement – developing the capabilities to detect other types of violations in addition to those being detected today; and
- Tracking of traffic flow.

It was noted that there is a need to increase vehicle occupancy – there are too many vehicles with too few people in them. Inducements are needed to increase capacity such as tolls, road pricing schemes, etc. However, it was also noted that firstly, the technology to measure the number of riders in a given vehicle is not available and there probably would not be a business case for such technology. Secondly, there is currently a huge negative public perception of “tolling” in Canada. Other incentives are required such as car pool plans.

2.5. Assessment of Infrastructure Deficit – the Need for Predictive Technology

On this subject, the following recommendations were made:

- There is a need for technologies that are robust, reliable, and allow for uncertainties to assess the current state of infrastructure; e.g. sensors for pipelines, bridges and monitoring of other structures;
- R&D is needed in order to learn how to integrate assessment tools;

- We need to learn more on how to get more service life out of existing infrastructure?
- Starting with methodologies there is a need to look at how information from sensors is measured. Is information being measured relative to the issue? What is the degree of reliability? We need to identify and measure the risk that is associated with information that has been gathered;
- We need to have a better understanding of the factors which affect the effectiveness of efficiency of various infrastructure repair techniques. By using information gathered – use bridge monitoring as an example – better assessment tools and methodologies can be developed. This will be beneficial in reducing the number of interventions required.
- Communications methodologies and information technologies can be applied towards solutions for the infrastructure deficit problem.
- The methodologies and systems developed can be adapted to other applications/industries.

2.6. Demand Response Public Transit

It was suggested that innovation is required in Demand Responsive Transit systems, which presents an opportunity for the application of intelligent systems.

It was proposed that intelligent tools could make current systems more efficient in the following areas:

- Emerging Vehicles, e.g. smart cars;
- Bus Priority;
- Fuel management systems already in place;
- Provisioning of fire trucks with the technology to be able to communicate with traffic lights;
- Railway Crossings - a high priority is detecting objects at intersections and communicating the information back to the train in order to reduce accidents and improve safety; and
- Convergence of emergency and public vehicles, of network infrastructures, interfaces and information.

2.7. Intelligent Control Room Operation

It was suggested that there is room for improvement in traffic control room operations. One indication of this are the number of operators currently required to staff such centres.

On this subject, it was further recommended that we examine the case for using the Internet to reduce costs and to look at what others are doing internationally.

2.8. Collision Avoidance at Intersections

Collision avoidance at intersections has an impact both on improving safety and reducing congestion at accident scenes. Because of this, it was recommended that intelligent systems technologies could be applied in the following types of application areas:

- Collecting information and relay it to users of intersections;
- Smart Vehicles - more intelligence in the vehicle could make the intersection safer;
- Planning & analysis; and
- Origin/Destination Planning.

It was noted that achieving such levels of sophistication requires integration and transformation of information.

2.9. Integrated Transportation and Urban Planning Applications

Integrated Transportation and Urban Planning Systems were mentioned in the Discussion Paper. Although such systems are not formally considered as Intelligent Transportations Systems, the need for these types of systems was acknowledged by the group, especially those involved with policy impact analysis.

2.10. Leveraging of Infrastructure for Sustainable Development

Leveraging of infrastructure to develop sustainable solutions was discussed in other contexts earlier in the session. However, the following example was presented as it provides an example of how social, environmental, and economic criteria can be met to a very high degree.

The suggestion was to leverage the use of bridge structures such as the Confederation Bridge and the bridges along the St. Lawrence River as transmission towers in order to deliver high speed wireless connectivity to rural villages along the shorelines as well as to marine traffic.

Delivering high-speed Internet connectivity to rural communities helps bridge the digital divide by the provision of universal access to government, health and educational services. The environmental footprint due to the erection of towers along the shorelines would be eliminated; the cost of provisioning the network would be lower and could provide the bridge operator with a subsidizing revenue stream.

3. Intelligent Environmental and Energy Systems

The results of the breakout session group discussion on applications of intelligent environmental and infrastructure systems technologies were summarized by the group facilitator and are summarized below with explanatory comments. Following the workshop, additional research on intelligent alternative energy systems was also undertaken and is included here as these important topics were not covered in the workshop.

3.1. *Intelligent Water/Wastewater Technologies*

Discussion in this area centred on the transition of the environmental market, principally water and wastewater systems, transitioning into a new phase whereby intelligent systems will play a key role in the evolution of newer and smarter infrastructure. This market has been historically "compliance" driven, where municipalities and industry are required to meet a certain standard. This is in contrast to a "requirement" driven market where a purchase decision is based on economics. The environmental market is in a period of change because infrastructure has become largely unaffordable and municipalities and provinces are incurring large levels of debt. Most importantly, legislation such as the forthcoming Ontario "Sustainable Water and Sewage Systems Act" will require the full pricing of water and wastewater thereby forcing the market into a requirement driven mode. Full pricing will force inefficiencies from infrastructure and has the potential to propell intelligent systems to the forefront.

The following areas were discussed and should be considered for investment:

Intelligent Control Systems. The lack of intelligent control systems results in increased chemical consumption costs due to inefficiencies, higher labour costs due to monitoring and a risk to the population where viruses, bacteria and parasites are not detected or detectable on line and in real time. New control technologies should be developed and implemented that maximize plant efficiencies and protect human health. The on-line detection of contaminants holds great promise. In addition, the operation of water/wastewater infrastructure should be technically possible on-line over the internet or LAN.

Membrane Technology. Membrane technology is a sound means of removing contaminants from water and polishing wastewater. Full cost recovery of infrastructure services combined with ever tightening environmental standards will create a broader market for membrane technologies. These can be employed in water treatment as well as wastewater treatment. This is an exciting technology as it permits the separation of individual molecules from one another. This level of sophistication requires intelligent technologies to operate and maintain the equipment.

Wastewater Biotechnology. A recently emerging field with few competitors and significant promise, wastewater biotechnology holds the promise for economically recycling wastewater to potable water quality at a very reasonable cost. This technology is suitable for industrial re-use applications as well as municipal applications such as golf course irrigation, 3-Pipe applications such as toilet flushing, washwater, landscape and other general purposes. The recently commissioned wastewater plant in Manotick (part of the City of Ottawa) serves as an example of this technology.

The total gross value of telecommunications infrastructure is dwarfed by the value of environmental infrastructure but without the accompanying R&D spending and emphasis on intelligent technologies. Governments at all levels cannot financially sustain current levels of inefficiency and intelligent solutions hold the promise, more than any other, to reduce costs and to unleash technological innovation. This market is potentially the largest new technology market in North America.

3.2. *Intelligent Building Management*

The benefits of using Intelligent Building Management Systems were noted earlier in the Discussion Paper. In summary, social benefits can be realized in terms of healthier working environments; environmental and economic benefits can be realized in terms of lower utilization of energy by optimizing heating, lighting, and building water management systems.

In order to achieve the full potential of Intelligent Building Management, innovative ways of detecting the deterioration of performance of equipment and systems are required, as well as algorithms to optimise them. It was pointed out that one of the hurdles to overcome in the development of the market for such technologies is the fact that tenants are paying for heat, hydro, etc. which is why landlords are not as sensitive towards saving energy as they should be. However buildings that are generally associated with public infrastructure, such as hospitals, schools, municipal buildings as well as provincial and federal buildings, do not fall into the same category and could form the basis for implementing these new technologies providing the momentum necessary to spread their use to the commercial sector as well. It is therefore important to develop decision-support tools for design engineers and building managers that would encourage them to apply these technologies.

3.3. *Intelligent Infrastructure Asset Management and Inventory*

Discussion in the workshop addressed the need for better community infrastructure asset management starting with the requirement to get a better inventory of Canada's infrastructure. This includes improving our knowledge of:

- Physical profiles such as location, type of structure, components, etc.;
- Condition or remaining useful life before there is a need to upgrade, replace or remove the infrastructure;
- Economic profile such as capital cost, operation and maintenance costs, and replacement/removal costs over the life of the infrastructure;
- The interdependencies of the different infrastructure components;
- Diagnostics tools for infrastructure assessment; and
- A "central depository for asset inventory information" because infrastructure components are so interlocking and interdependent.

Mechanisms for learning from failures and successes was also identified as a need¹ (see footnote).

¹ Certainly, one such mechanism is the recently announced series of national workshops on 'Innovations and Best Practices for Municipalities' based on InfraGuide Best Practices reports. These workshops will be presented in 2005 by

Much of the discussion was consistent with and reflected the aspirations of the Technology Road Map for Civil Infrastructure Systems, a document which summarizes a national consensus on preserving Canada's community infrastructure¹. The document lists the technology needs for asset inventory and condition, which, because of their great relevancy, we quote here:

- "Non-destructive, non-invasive technologies for the inspection of above- and below-ground infrastructure;
- Methods for accurately locating existing infrastructure;
- Accepted methods and tools for the valuation of CIS assets;
- Development and maintenance of a national inventory of infrastructure, including geographic location;
- New technologies for the analysis of system components or of the system as a whole;
- Methodologies to determine which components require inspection, and establish frequency of inspection;
- Uniform/common condition indicators and rating systems that can be used in prediction models, asset management systems, and decision making processes;
- Sensor and associated communications and analysis systems for real-time monitoring of infrastructure condition; and
- Deterioration models".

3.4. *Intelligent Autonomic Processes in Infrastructure Management and Other Areas*

Autonomic computing is a systemic approach to systems design modeled along the lines of a self-regulating organism. In this approach, systems are designed to be self-managing with a minimum of human intervention. The term derives from the body's autonomic nervous system that controls key functions of the body without conscious awareness or involvement.

The autonomic computing paradigm evolved in response to the growing problem in which the demand for IT skills is growing much faster than the supply. This is due to the growth in the rate of proliferation of computer devices and the growth in the complexity and global reach of systems, networks, and applications.

The autonomic computing paradigm has been embraced by IBM, who has established its realization as a goal in its vision of the future of computing. An extensive presentation providing an overview of their vision, discussion of why the current approach to systems design has to be changed, why the autonomic computing paradigm offers a solution, and the benefits of this approach is provided on IBM's website at:

<http://www.research.ibm.com/autonomic/>

the Canadian Society for Civil Engineering and the Educational Programs Innovations Centre (for more information, visit their website at www.csce.ca).

¹ **Civil Infrastructure System Technology Road Map**, published by the Technology Road Map Steering Committee and available from the Canadian Society for Civil Engineering.

It was argued in the session that as infrastructures age, there has to be some risk-based intelligent system to indicate failure will occur (how much maintenance action is/will be required and what the risk is of it failing over some period of time).

It was also noted that there are other areas not related to infrastructure that are important to Canadians, such as safety, security, and aging/wellness/health care where such systems find application.

It was recommended that Precarn emphasize research and development in this area, and encourage industry and academia to create more partnerships around these systems and technologies. In fact, IBM plans to fund a regular stream of academic grants to support research in the area of autonomic computing, and it is calling on others in the IT industry to do the same.

There was discussion at the workshop that autonomic computing systems could potentially reduce the complexity and improve the manageability of large infrastructure facilities, leading to greater reliability and more efficient and effective use of such facilities. One example discussed was managing energy consumption in large buildings or complexes of buildings. Other examples where such computing capabilities could apply would be in water and wastewater systems, or large electrical distribution systems. Underlying the discussion was the notion of relieving operators of the burden of dealing with the large amounts of data that such infrastructure facilities generate and permitting operators instead to deal with higher-level infrastructure management issues.

Although Precarn's main focus today is on technology development, there should be opportunities for interesting projects to start investigating the application of these technologies as they are developed.

3.5. *Intelligent Pipeline Analysis for Life-Cycle and Risk Assessment*

Investment in research and development in intelligent technologies for pipeline analysis, life cycle and management of risk assessment was recommended as being of great importance. The following paragraphs explain why this recommendation carries such significance. It reviews an article in InfraGuide on water leakage in municipal water distribution systems as an illustration.

Reducing water leakage is a major concern to municipalities. In fact, a recent InfraGuide article¹ states that "leakage is a serious problem across Canada where between 10% and 50% of potable water is lost due to leaking pipes in the distribution system. In older cities, deteriorating municipal infrastructure causes potable water leakage to be as high as 30% to 50%". This is not only a waste of a precious resource but also valuable tax dollars.

The article went on to describe the benefits accrued to the City of Halifax by adopting a holistic approach to reducing leakage in their water distribution based on a practice they developed for this purpose (Water Use and Loss in the Distribution System). The approach is centered on leak detection, metering, speed and quality of repairs, and asset management to reduce leakage. According to the article, the City of Halifax managed to reduce the leakage of potable water from its distribution system by 6 million gallons per day or almost 30 million liters per day providing savings of up to half a million dollars a year.

¹ InfraNet, Volume 2 No 1, the official newsletter of InfraGuide can be found at <http://www.infraguide.ca/>.

Reducing leakage reduces wear and tear on the system so that its life cycle is extended. Other direct benefits associated with reduced leakage listed in the article include deferral of capital investment to increase plant capacity, less disruption of service to customers, and a drastically reduced liability due to reduced risk of streets and adjacent property being damaged from aggravated leakage.

Another InfraGuide best practice, Speed and Quality of Linear System Repairs, details the tools and technologies that can be used to reduce such leakage effectively.

The best practices on Water Use and Loss in the Distribution System, Establishing a Metering Plan to Account for Water Use and Loss, and Speed and Quality of Linear Repairs can be found on the InfraGuide website where they can be downloaded:

http://www.infraguide.ca/bestPractices/PublishedBP_e.asp#pw

A summary of specific recommendations is as follows:

- Use of intelligent inspection/monitoring systems to collect critical condition assessment information of pipeline, i.e. leakage, distress, active deterioration, etc. : (this should be also covered by another Recommendation, Intelligent Inspection System for Pipeline Condition Assessment);
- Use of intelligent systems for integrating condition assessment information with other pipeline operating and environmental information, using intelligent asset management system, such as GIS based Pipeline Asset Management System;
- Use of intelligent systems for conducting the intelligent analysis on all available information to predict the life cycle, especially the remaining life of the pipeline, and assess the risk of pipeline operation; and
- Use of intelligent systems to implement cost-effective risk management plans.

3.6. *Intelligent Infrastructure; i.e. Smart Pipes, Bricks, Sensors, Capital versus Operation and Maintenance Trade-offs*

Pre-fabrication of infrastructure with built in sensors and the transport (fiber) to transmit information from the sensors was discussed. As these technologies are just emerging, it is not known if there is a business case for these technologies as of yet.

3.7. *Leveraging of Infrastructure to Achieve Sustainable Solutions*

Net or reverse metering is a term used to describe the process whereby surplus electricity from a local generation system, when not NEEDED by the person/organization generating the power, is sent into the electricity grid and his meter is rolled back to credit the contribution. This SURPLUS electricity turns back the electrical meter (hence the terms 'reverse metering'). A situation in which reverse metering might be used could be one in which a person installs a solar array to heat his or her swimming pool during the summer months. During the winter, when the pool is not in use, he sends the surplus power into the local grid. Another situation might be one in which a factory has a local generation plant which provides some or all of the power to

the factory during production times and diverted to the grid when the factory has a SURPLUS. See www.eesi-energy.com for more information on such energy saving systems.

There are two benefits to net metering. Firstly, the consumer will lower his overall cost of electricity. Secondly, as the generation plant will be designed and upgraded over time with increasing demand to handle projected peak capacity loading, the upgrade costs of the grid will be lowered.

Given these observations, it was recommended that Precarn consider investing in emerging "smart" metering technologies for such purposes. Such systems used in conjunction with other devices such as thermostats, etc., would incorporate intelligent algorithms to automatically control the system switchover in real time in order to optimize the savings.

3.8. *Intelligent Technologies for Alternative Energy Sources for Communities*

There is a movement worldwide to replace fossil fuels with alternative, renewable energy sources. The drivers are to reduce the polluting effect of CO₂ emissions, the current high cost of fossil fuels as well as the fact that, ultimately they will run out. Several examples of newly emerging technologies responding to these concerns that are relevant to community infrastructures systems are:

- The use of new highly efficient solar arrays combined with intelligent solar array control systems; and
- The use of intelligent technologies in systems that harvest energy from ocean waves and are now being deployed to provide electricity to coastal communities.

Due to the renewable nature of the power generated by technologies and their minimal environmental impact, their technical and economic feasibility and the fact that these technologies were not discussed at the Workshop, some examples of the opportunities in these areas are noted here.

Intelligent Solar Array Control Systems and Advanced Sensor Materials

An example of such a system is the solar array at the Mauna Lani Resort in Hawaii installed to supply power to run the water pumping facility¹. Mauna Lani is located on the Kohala Coast of Hawaii, an island where electrical power is generated primarily by burning diesel fuel and where electricity costs are among the highest in the United States. The control system tracks the sun from east to west on a tilted axis, generating the maximum energy possible. Mauna Lani's solar electric generation system maximizes the sun's available energy by capturing 30% more daylight than fixed systems as the tracker follows the sun from early morning to late afternoon.

By avoiding the purchase of fossil-fuel generated electricity, solar electric systems spare the environment from thousands of tons of harmful emissions, such as nitrogen oxides, sulfur dioxide and carbon monoxide, which are major contributors to smog, acid rain and global warming. It is estimated that over the 25-year lifetime of the photovoltaic system,

¹ **The Mauna Lani Bay Hotel and Bungalows** is part of the 3,200-acre Mauna Lani Resort, located 25 minutes north of the Kona International Airport on the Big Island of Hawaii. See www.maunalani.com or www.panpacific.com.

the solar-generated electricity will reduce emissions of carbon dioxide by almost 12,000 tons.

Advanced Solar Cell Sensor Materials

Current photovoltaic cell technologies are about 6% efficient when they are aligned correctly with the sun. By using intelligent control systems to continuously maintain the array in optimal alignment efficiency, gains of up to 30% can be realized.

According to Dr. Ted Sargent of the University of Toronto, “Existing cell technology has given us solution-processible, light-sensitive materials that have made large, low-cost solar cells, possible, but these materials have so far only worked in the visible light spectrum”. However, further advances in solar-cell materials technologies such as the discovery by Dr. Sargent and his team at the University of Toronto¹ open the door for future devices which will operate with up to 30% efficiency as they can extract energy from light in the infrared portion of the spectrum.

Wave Energy Systems

A number of systems have been developed for extracting the energy from ocean water waves. They can be classified as shoreline systems, near-shore systems and deep ocean current energy extraction systems. An excellent survey of these systems can be found in the paper² “Offshore Alternative Energy Generation”, by Rob Bioletti and Ian Potter. The authors concluded that “the potential for wave energy, tidal energy, marine current energy and ocean thermal energy conversion to be an alternative source of energy has been proven at the experimental level. Although each technology is theoretically feasible, economics has been the obstacle towards commercialization. As with many other alternative energy technologies, the capital cost of the equipment is a major deterrent for commercial application. Wave energy, tidal energy, marine current energy, and ocean thermal energy conversion may not be economically feasible now, but ongoing research could lead to improvements that may make these technologies more economically attractive in the future.”

However, according to a report on the Strategis website³, “British Columbia Hydro has initiated demonstration projects using wind technology, micro and small hydro, biomass, and ocean wave generation. As part of the Vancouver Island Green Energy Project, BC Hydro is planning to implement 3-4 MW of ocean wave energy by early 2004.”

In pursuit of this, BC Hydro has (according to a report on the McMaster University website)⁴ signed a memorandum of understanding (MOU) with U.K.-based wave energy development company, Ocean Power Delivery (OPD) to become a joint venture partner in the ocean wave energy demonstration project on Vancouver Island. OPD has developed a floating offshore wave energy converter called the Pelamis, a semi-submerged, articulated machine that has several hinged joints each with a hydraulic pump inside. The relative motion of the sections, due to wave action, activates the pumps, which drive electric generators.

¹ **Solution-processed PbS quantum dot infrared photodetectors and photovoltaics**

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doi:10.1038/nmat1299 (see <http://www.nature.com/cgi-taf/DynaPage.taf?file=/nmat/journal/v4/n2/index.html>).

² **Offshore Alternative Energy Generation**, by Rob Bioletti and Ian Potter, Carbon & Energy Management Alberta Research Council, Edmonton, Alberta, Canada T6N 1E4.

³ Source: <http://strategis.ic.gc.ca/epic/internet/inimr-ri.nsf/en/gr106727e.html>.

⁴ Source: <http://mailman.mcmaster.ca/mailman/private/cdn-nucl-l/0204.gz/msg00028.html>.

According to the same report, BC Hydro has already signed a similar MOU with Energetech Australia to demonstrate a different shore-based ocean wave technology also on the Island. Energetech utilizes oscillating water column technology to generate electricity from ocean waves. The company's design features a parabolic wall to focus incoming waves, maximizing wave height, and a specially designed turbine to increase generation efficiency.

3.9. Use IS to Improve Government (and Government Decision Making)

The major recommendations that came out of the discussion on this topic were:

- To give policy makers the tools and techniques for making the right decisions for Canada so governments can make efficient, effective, well-informed policy changes with less bias and political motivations. Specifically, invest in the research and development of “Intelligent Decision Modeling” planning tools for government planners.

Examples of such systems are the integrated transportation and urban planning systems using micro-simulation modeling techniques. The ILUTE system developed at the University of Toronto under the direction of Dr. Eric Miller was described in the Discussion Paper. Another example is found in the tools developed by Adept Transportation Solutions in Victoria, British Columbia.

- Invest in the research and development of “Intelligent Management of Information” – for example, the intelligent management of information about emergency preparedness. The ability to move information from hospital to hospital and so on, from fire departments to police. Note that President George Bush has recently announced the goal to computerize hospital patient records within the next few years.

3.10. Other Comments and Recommendations

A number of other recommendations are noted as follows:

- Information overload - it was noted that sensor systems generate too much data and not enough timely information. As such, more efficient and more intelligent sensor systems are required as opposed to adding more of the same. (It is interesting to note that this theme of information “infoglut” was discussed in the transportation systems working session in another context);
- Investing in development of intelligent surveillance systems for schools, etc. to ensure greater safety than provided by video surveillance systems was recommended;
- Although not discussed in the workshop, there is a very large market for more efficient electricity distribution wire and transformer technology due to losses in the electrical grid versus growing demand throughout the world. New high temperature transmission wire has been developed that is 140 times more efficient than existing copper wire and is being used to replace existing transmission lines and to develop much smaller, more efficient electrical motors, including motors for large scale

applications such as ship propulsion¹. Grid stabilization is also a major issue today especially with the blackouts experienced in recent years in the North American electrical grid. It is perhaps in this area where intelligent systems technologies can be developed and applied to advantage.

¹ See for example, products developed and sold by American Superconductor at www.amsuper.com.

Appendix A: Transport Canada Survey of ITS R&D Priorities

Transport Canada Survey of ITS Research and Development Priorities

In April, 2003, Transport Canada published its findings resulting from a survey of ITS R&D priorities across six stakeholder groups in Canada -- federal government, provincial governments, municipalities, industry, service operators, and the academic community.

The survey questionnaire addressed ITS needs and gaps, R&D priorities, and collaboration and partnership interests. The summary of R&D priorities is reproduced here. For additional detail, the reader is referred to Appendix A (Survey of ITS Research and Development Priorities) of the document Intelligent Transportation Systems Research and Development Plan for Canada¹.

Analysis of R&D priorities across stakeholder groups suggests seven underlying themes:

Safety and Human Factors

Safety is a primary focus of many ITS applications, and human factors play a major role in many ITS safety issues. Safety and human factors issues emerged as R&D priorities in all six ITS stakeholder groups. Specific examples of R&D topics under this theme include:

- In-vehicle communication devices;
- Communication of RWIS safety information to drivers;
- Vehicle inspection & compliance;
- Speed control;
- Work zone safety issues;
- Highway-railway crossings;
- Pedestrian/bicycle detection and safety;
- Wildlife control;
- Hazard warnings;
- Driver distraction issues; and
- Improved train control.

Traffic Management and Control

The theme of traffic management and control covers a broad range of topics, and hence a wide range of interests. While all six stakeholder groups identified traffic management and control issues, provincial governments, municipalities and industry showed relatively greater interest. Specific examples of R&D topics involving traffic management and control include:

- Technologies and applications to reduce travel time;
- Congestion management tools;
- Traffic counting and monitoring techniques and tools;
- Emergency vehicle response and priority;
- Freeway and arterial traffic management strategies;
- Adaptive traffic signal control;
- Low cost solutions for lower traffic roads;
- Non-intrusive vehicle sensing;

¹ INTELLIGENT TRANSPORTATION SYSTEMS RESEARCH AND DEVELOPMENT PLAN FOR CANADA INNOVATION THROUGH PARTNERSHIP, April 2000 available at www.its-sti.gc.ca,

- Palm pilot for real-time Advanced Traveler Information Systems (ATIS) for both roads and transit;
- Canada 511 information system;
- Electronic payment systems (including inter-operability);
- Work zone traffic management;
- Enforcement systems (including red light cameras);
- Global Positioning System (GPS)-supported collision reporting;
- Archived data management;
- Affordable cost-effective systems; and
- Measures of effectiveness.

Public Transit

Five of the six stakeholders groups (all but service operators) included public transit issues among their R&D priorities, with the strongest interest shown by municipalities and by industry. Specific examples of R&D topics under the public transit theme include:

- Costs and benefits of public transit ITS applications;
- Management of transit fleets;
- Smart cards and electronic fare payment systems;
- Simple methods of vehicle location and tracking;
- Transit signal priority;
- Automated and integrated transit information; and
- Information warehousing.

Security/Border Crossings/Commercial Vehicle Operations

Security and border crossings are the new areas of ITS application. Efficient border crossings are essential to Canada's economy, a challenge made all the more salient by heightened security concerns. CVO was an early ITS application and continues to be important. All stakeholder groups identified needs in one or more of the listed security/ border crossing/CVO R&D issues, with the strongest interests identified by the federal government, service operators, industry, and academia. Specific examples of R&D projects under this theme include:

- Supply chain networks;
- E-seals;
- Inter-operable technology;
- Driver-vehicle ID linkage;
- Application of Closed-Circuit Television (CCTV) and optical licence readers;
- Travel information systems for CVO;
- Electronic payment systems, including inter-operability;
- Tracking of hazardous goods;
- Communication of emergency detour route information;
- Aggregation of data from shippers and carriers, and archived data management;
- Cost-effective border crossing clearance and security;
- Pre-clearance of vehicles; and Management of inter-modal freight.

Environment and Energy (ITS & Kyoto)

One of the benefits often attributed to ITS is the reduction in energy consumption (fewer GHG emissions) and reduced impact on the environment. This attribution is based on ITS-improved transportation efficiency yielding smoother flow, less delay, and better operating speeds. It should be noted, however, that unless preventive measures are adopted, these improvements can lead to increased urban sprawl and more dispersed living and working patterns, which in turn can result in increased energy consumption and emissions.

The federal government, industry, and academia expressed the strongest interest in energy and environmental issues. Examples of possible ITS R&D projects under the energy and environment theme include:

- ITS and sustainable transportation;
- Tools for evaluating the impact of ITS applications on the environment;
- Long-term versus short-term effects of ITS on the environment; and
- Travel demand management.

Methodological Issues

Under this theme, a number of loosely related issues have been brought together. They include modeling techniques, methodological issues, institutional and organizational issues, forecasting techniques, and cost-benefit evaluation. All six stakeholder groups identified one or more of these issues among their R&D priorities, with the strongest interests identified by the provincial governments, industry, and academia. Examples of ITS R&D priorities falling under the methodological theme are:

- Integration of ITS in transportation planning;
- Predictive travel time modeling;
- Real-time traffic micro-simulation;
- Improved incident detection algorithms (both freeways and arterials);
- Modeling of ITS network control strategies;
- Optimization strategies and models;
- Integration of freight flows; and
- Cost-benefit models and evaluation frameworks.

Architecture and Standards

While the main task with respect to architecture is maintenance, much more work remains to be done on ITS standards. Five of the six stakeholder groups (all but academia) identified R&D needs in architecture and standards, with the strongest interests expressed by the federal government, service operators, and industry. Specific examples of R&D topics in architecture and standards include:

- DSRC standards and inter-operability;
- Smart card standards and inter-operability;
- Intelligent border crossing protocols and standards;
- CVO data exchange protocols;
- Centre-to-centre data exchange communication standards and protocols;
- Wireless communications;
- Compliance, verification and certification; and
- ITS standards across various technologies.