Canadian Space Agency | Agence spatiale canadienne

# SPACE TECHNOLOGIES: INVESTING IN OUR FUTURE

Canada

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# A WORD FROM THE PRESIDENT

*It is the nature of humanity to explore and to seek knowledge, and this already has had positive results for Canadians:*

- *Our telecommunications satellites connect Canadians to the world around them.*
- *Innovative technologies for space are leading to new applications and business opportunities here on earth.*
- *The International Space Station, which will be assembled by Canadian space robotics, represents an extraordinary window of opportunity to explore new frontiers and pave the way for new and exciting scientific breakthroughs.*

*We are now in a new space age marked by a transition from space-based to Earth-based applications of technology. To an ever increasing degree, in everyday life we use products and services that space research and technology have helped to develop.*

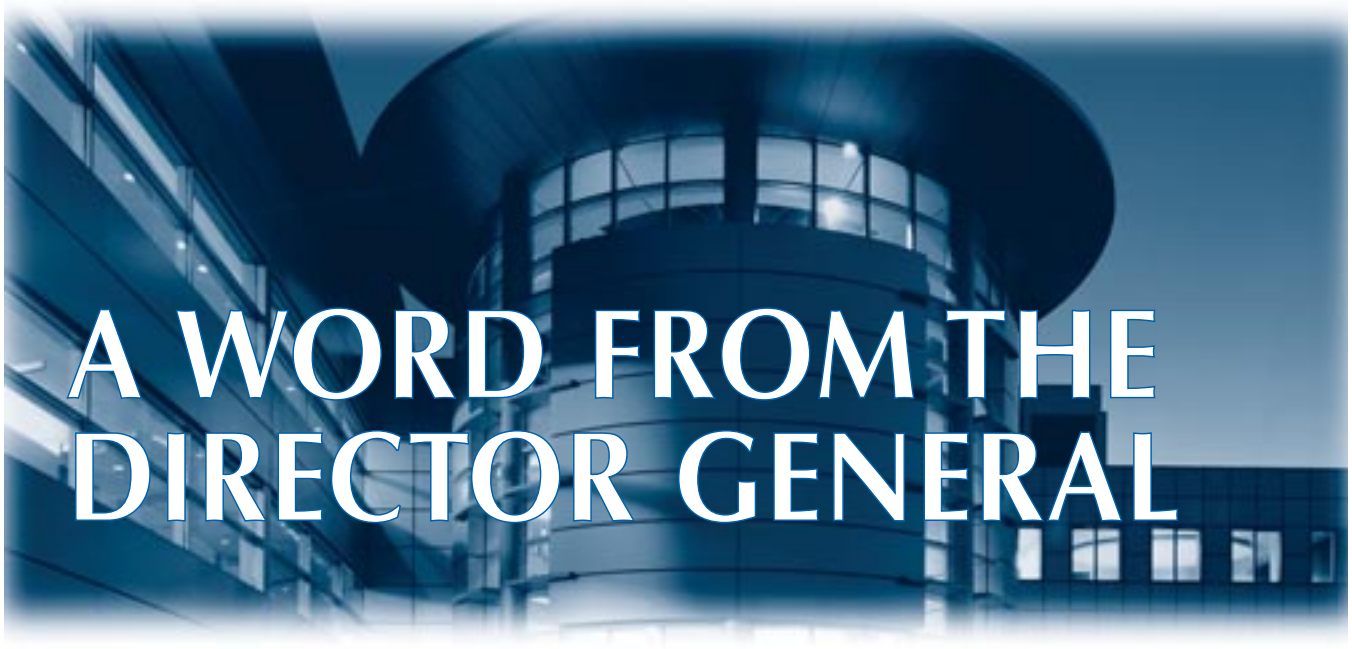
*Building on areas of industrial and technological competency, the Canadian Space Program seeks to foster an internationally competitive, export-oriented Canadian space sector, one that is open to a growing number of firms, often small and medium-sized enterprises.*

*Scientific discovery and the development of innovative, leapfrog technologies being pursued under the Canadian Space Program will help promote a more competitive space industry, generate spinoffs, develop high-tech expertise and create new job opportunities for Canadians from coast to coast.*

*More than ever, the main objectives of the Canadian Space Program are to develop and apply space technology to acquire fundamental knowledge, train highly qualified personnel, and utilize technology to meet Canadian needs, while maximizing the practical benefits that Canadians derive from space-based products and services.*

*In many ways, we have only just begun our journey of discovery in space technologies, a journey that promises enormous challenges and rewards. Much remains to be done and Canada is well positioned to maintain a leadership role.*

***Mr W. M. (Mac) Evans***
*President, Canadian Space Agency*



# A WORD FROM THE DIRECTOR GENERAL

*I am pleased to present some examples of recent success stories resulting from space technology development activities of the Canadian Space Program. The development of space technologies plays an important role in the continuing success of the Canadian Space Program and the Canadian space industry.*

*The CSA's industrial partners have played a major role, not only through the performance of contracted research and development, but also through their commitment to contribute their own funds, equipment, facilities, know-how and effort on many of our projects. Technology development contracts are awarded through a competitive process based upon a published set of criteria. These collaborative efforts along with funding from several partners, have enhanced Canadian industrial competitiveness.*

*The success stories presented in this package are examples of benefits resulting from the continuing commitment of the Canadian Space Agency to develop new technologies.*

***Virendra Jha***
*Director General, Space Technologies*


Space. For many, it remains the final frontier, mysterious and exciting: infinity scattered with islands of matter. Space challenges the bounds of human intelligence and knowledge; it makes us rethink the premises of our own origins, and of our evolution into the new millennium and beyond. Development of new technologies is essential to realize the dreams and the promises offered by this final frontier.

Nations around the world have invested in space to ensure that the evolving needs of their citizens can be met. They have created the space infrastructure necessary for the full development of human and natural resources. Space technology development has allowed us to more effectively manage food production, resources, environment and natural disasters. It has enabled global communications, navigation, search and rescue, defence and human exploration beyond earth, and it has advanced our knowledge profoundly about our world and our universe.

Similarly, technology advances have brought into existence the entire field of satellite communications, the catalyst of our new global and knowledge-based society. New technologies will bring further advancements as constellations of dozens or even hundreds of interconnected communications satellites make it possible for instantaneous, practical and affordable audio-visual and data transmission from any point of the globe to any other point, at any time of day.

In the same way, the unique vantage point of space enables us to instantly monitor events, activities and changes on earth and its environment, however remote the location, or however dense the cloud cover or darkness. Space technology development is a key element in the understanding and solution of some of the world's most urgent problems: drought, climate change, the greenhouse effect, ozone depletion and pollution.

These developments also result in terrestrial applications for the benefit of all Canadians. The Canadian Space Agency through its technology development programs is truly investing in our future.


# ECONOMIC BENEFITS

# MATCHING HUMAN EYE PERFORMANCE FOR ROBOTS

The human eye has exceptional capabilities; it provides us with low-resolution information about a very wide area, our peripheral vision, as well as very accurate and precise information about the point of focus area. This duality allows us to quickly and continuously grasp our surroundings while performing very accurate tasks. Such a vision system would be ideal for robotic applications. However, vision sensors normally have a uniform resolution throughout their field of view, which implies that to get both high accuracy and a wide field of view one has to develop a very large high-density vision sensor. Furthermore, this sensor would produce a very large amount of data, which could not be treated in real time to support robotic applications.

To address this challenge, the CSA along with the Atlantic Canada Opportunities Agency (ACOA) and the province of Newfoundland and Labrador, funded Canpolar East, an engineering company specialising in industrial sensors and automated process machinery, to develop vision technologies for robotic systems. Canpolar East developed a machine vision system that utilises a low-resolution wide field camera plus a high speed high resolution narrow field camera that is able to match human visual performance in industrial inspection tasks. Low-resolution wide field of view images are quickly and continuously searched for points of interest, while high-resolution narrow field of view images are acquired around these features for accurate measurements.

This self-contained vision system packaged for use in demanding operating environments is an ideal replacement for the human observer in simple, routine observation tasks. The robust design allows for operations under difficult conditions, which translates into an important competitive advantage in the marketplace.


The Vision System is capable of autonomous object recognition and tracking. Its applications range from underwater fish counting and fish inspection to structural monitoring of space systems. Used as a stiffness monitor, the system can detect a 2-micrometre deflection over a 3-metre length. Other examples of terrestrial applications include aircraft inspection where it could improve flight safety by quickly detecting ice on aircraft.

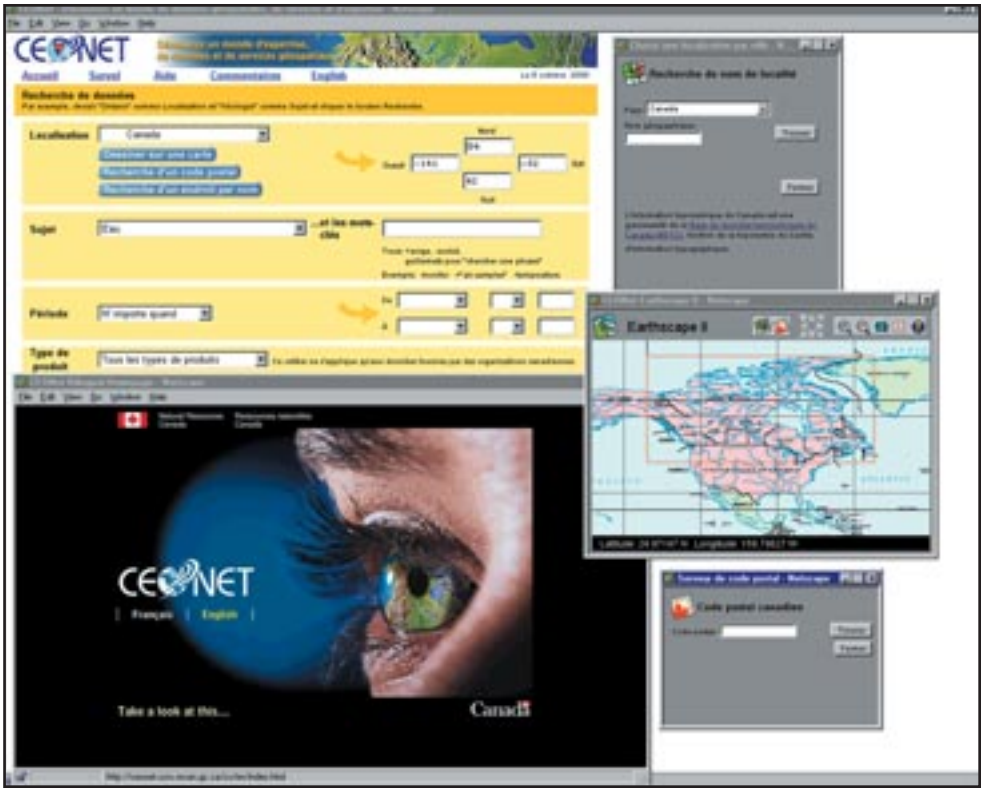
# ONE STOP SHOPPING FOR ALL EARTH OBSERVATION NEEDS

Nations around the world have been gathering Earth Observation (EO) data for many years. The amount of information delivered every day is staggering, and its use multifold. From disaster relief organizations to mining corporations to the shipping industry, all types of organizations use Earth Observation data in a variety of ways. To meet this challenge, one needs efficient, convenient, and cost-effective access to geospatial data through a single access point.

The Canadian Space Agency supported the development of CEONet (Canadian Earth Observation Network) to track ever-changing geospatial data catalogues and to enable users to order products or services from web browsers on their desktops.

This is a "start-to-finish" solution for providing widespread access to distributed geospatial data products and related services. The technology enables organizations to discover, evaluate, order, purchase and obtain a product or service hosted remotely at a supplier's site conveniently from the web browser on a desktop. Users can execute simultaneous searches against several supplier catalogues to find individual data products that meet specified spatial, temporal and attribute constraints.

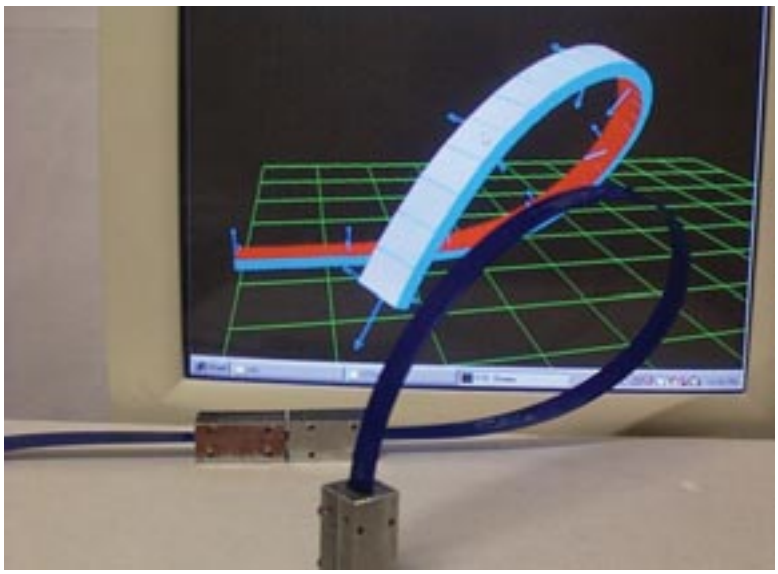
MacDonald Dettwiler (MDA) has become a leading supplier of operational Earth Observation Centre systems for high-resolution, optical, hyperspectral and synthetic aperture radar EO missions. MDA has sold CEONet systems to the department of National Defence, to the Alberta government and have been contracted by the European Space Agency (ESA) to develop the Multimission User Information Services.

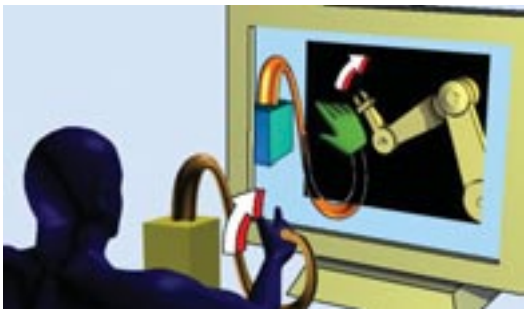


# CAPTURING HUMAN MOTION

Precisely commanding sophisticated robotic systems such as the Canadian Space Station Remote Manipulator System (SSRMS or Canadarm-2) and the Special Purpose Dexterous Manipulator (SPDM) is a very complex task for which astronauts rely exclusively on two joystick-like hand controllers. Substantial training is required for astronauts to develop the specific skills necessary to effectively use them. Availability of a more intuitive and natural command interface and a means for direct human motion capture would greatly facilitate the commanding of complex robotic motion.

To address this challenge, the CSA funded Measurand Inc., which develops and manufactures flexible fibre optic curvature sensors, to develop SHAPE TAPE™, a sensor tape which conforms to surfaces to capture, in real-time, their shape and movement. SHAPE TAPE™ is a flexible ribbon containing an array of patented fibre optic based curvature-sensors. A computer transforms the curvature-sensor signals of the tape into a precise 3D digital image of the tape's shape and orientation.





Motion capture is becoming an increasingly important and powerful tool in a great variety of fields from robotics to medicine, to artistic endeavours, even in videogames and in movies. It can be used to improve automotive airbag deployment based on crash circumstances, or to measure spinal deformation in ejection seats.

This technology may eventually assist astronauts in accomplishing complex tasks on the International Space Station (ISS), possibly from the Mission Control Centre here on Earth. The interface electronics and sensor materials have already flown successfully in a NASA shuttle mission. As a result of this success, Measurand Inc. has dramatically increased its market share and has acquired a number of prestigious clients including General Motors, NASA, Ford Visteon, Eastman Kodak, MIT Media Lab, Veridian, and the Mayo Clinic. This technology was also licensed to Northern Digital Inc. of Waterloo Ontario, for medical applications.

# NAVIGATING SAFELY

A space robot must frequently perform its tasks in a cluttered and changing environment and must avoid collision. This requires intelligent systems capable of assessing and predicting their environment and modifying their paths appropriately. This same technology has been applied to the problem of automatically steering ships in crowded, heavily travelled waterways.

Traditional marine autopilots are designed to maintain a pre-defined heading: the captain of the vessel charts a course and issues course changes based on his or her experience. CORETEC Inc., an applied research and development engineering firm, developed with CSA support, the Advanced Ship Autopilot System (ASAS), as a terrestrial spin-off of robotics steering technology. ASAS is a manoeuvring and control system capable of maintaining a ship on pre-set tracks. In addition to improving marine and navigation safety, it also increases fuel economy and equipment life.

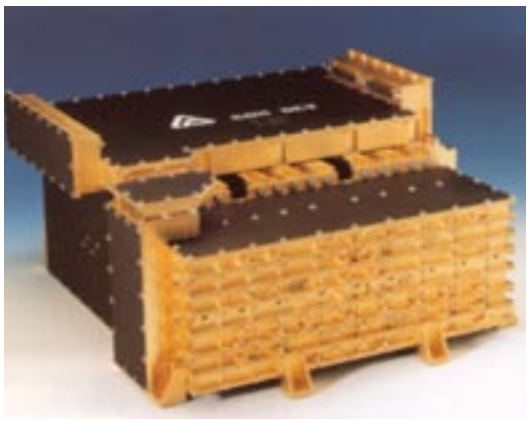
The technology consists of two major components: a vessel trajectory predictor and a controller. The use of an intelligent system accurately predicts not only the ship's heading but also its actual track through the water. The controller makes the necessary adjustments to the vessel's steering controls in order to maintain a predetermined trajectory or "track" through the water. Existing systems are designed to maintain only the ship's heading and not its actual track. ASAS therefore represents a significant improvement over existing automated systems.

ASAS has enabled CORETEC to develop a desktop marine simulation software program for vessel manoeuvring and ship handling.

# INCREASING FLEXIBILITY AND PERFORMANCE OF A COMMUNICATIONS SATELLITE

Communication satellites, which provide us with data transmission, television, radio, telephone and Internet, to name a few are constantly increasing in complexity to meet the demands of new applications.

Delivering signals of varying power and bandwidth, at any location, according to the user needs is a technologically challenging task. The CSA provided support to COM DEV for the development of the BEAM*LINK™ technology to meet this requirement.



BEAM*LINK™ is a technology that divides transponders into multiple channels that can be independently routed on multi-beam systems. It is a drop-in box that operates on selected transponders to efficiently manage partial transponder traffic. Only those transponders carrying narrowband traffic are subchannelized. The sub-channels can have variable bandwidths on command, so that the payload can be configured optimally for the traffic patterns.

BEAM*LINK™ offers vastly increased traffic management flexibility for multi-beam satellites, increasing service provider revenues up to $40 million per year, and enabling the introduction of new services. This technology will fly on the next generation Anik F2 satellites. COM DEV's recognized leadership in this technology sector has lead to a contract award to build a Ka-band processor for the ASTRA 1K satellite, which will provide two-way Internet via satellite in Europe.

# ERS-1 GROUND STATIONS

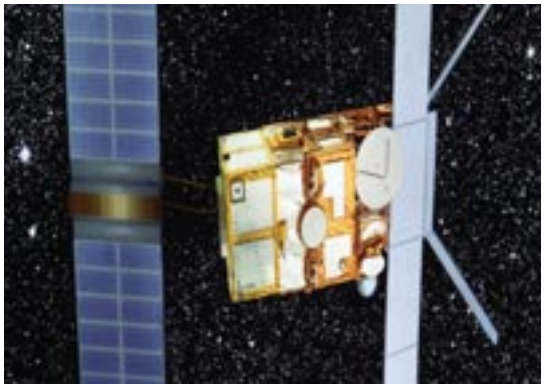
Canada's first Earth Observation satellite, RADARSAT-1 was successful due in part to the experience gained in the reception, processing and use of ERS-1 data. This was the first European Remote Sensing satellite for coastal, sea and ice applications that faithfully provided data from 1991 to 1996, and whose main contractor was the Canadian company, MacDonald Dettwiler (MDA).

MDA was responsible for the management, engineering, design assembly integration and verification, and product assurance of the ground segment which includes the Synthetic Aperture Radar (SAR) fast delivery processing subsystem, the data processing monitoring computer, the data recorder and the reproduction subsystem.

This contract resulted from Canada's financial contribution to the ERS program within the framework of the Cooperation Agreement with the European Space Agency (ESA). The Canada-ESA Agreement opens the doors of the European space program to Canadian companies and offers them the opportunity to market their products and services on international markets.

Information provided by ERS-1 had a profound effect on our understanding of oceans, polar ice caps and climate, as well as many other areas: pollution monitoring, weather forecasting, crop monitoring, deforestation, efficiency of navigation and ship routing, fishery resource management and offshore exploration.

With a $27 million ESA contract for ERS-1, MacDonald Dettwiler was able to win every contract worldwide to upgrade existing ground stations to receive ERS-1 data. This strength translated into sales of radar satellite processing and ground systems to the Japanese government (JERS, ADEOS), and was a key factor in successful bids of major new Earth Observation ground stations. The ERS-1 ground segment contracts have also allowed MacDonald Dettwiler to receive important contracts from the ESA General budget for software upgrades and maintenance (Earthnet).



Additionally, the CSA's investment in the ESA program provided access to ERS data for use by the Canadian Ice Service and resulted in RADARSAT International Inc. (RSI), a wholly owned subsidiary of MDA, being selected to sell the ERS data.

***Daniel E. Friedmann, President and CEO, MacDonald Dettwiler and Associates Ltd.,*** *"The CSA's investment in space technology development has created an environment that both encourages and enables Canadian industry to succeed at home and abroad. In MacDonald Dettwiler's case, CSA's ongoing investment to ensure the participation of Canadian companies in European Space Agency programs has been a major driver in our success. The experience gained in domestic and ESA programs has enabled us to develop world-class technology for Earth Observation markets around the world, to the extent that MacDonald Dettwiler is now the recognized international leader in high-performance operational EO systems."*

# THE NEXT BEST THING TO BEING THERE

To operate the Canadarm-2 and the Special Purpose Dexterous Manipulator (SPDM), the International Space Station (ISS) astronauts must be fully trained and certified on Earth prior to launch. This requires complex high fidelity training tools and techniques that adequately simulate the ISS, Canadarm-2 and MSS (Mobile Servicing System) and provide realistic training scenarios. Traditional approaches to complex work site design, such as for the astronaut robotic workstations for the International Space Station, rely extensively on mock-ups, and through a trial and error process that finally converge to an efficient work site layout. This is a costly and time-consuming process. The challenge is to develop ever better training and support tools while limiting dependence on costly physical mock-ups.

There has been, over the last decade, great interest in Virtual Reality (VR) as a tool for simulation and training, especially with the incredible increase in computer power, the advent of the Internet as a global communication tool and VR is being used more and more in high tech industries.

Developed by Genicom Inc., through support from the CSA, Safework, a virtual reality human model evaluates the functionality of a workstation prior to primary physical mock-ups. The Virtual Reality (VR) module enables astronauts to be represented accurately in a VR environment using the Canadarm and working in the International Space Station. The CSA has integrated part of this technology in its Space Station's Virtual Operations Training Environment (VOTE).

Safework simulation models are well known for their accuracy in representing virtual human beings in various environments. The system has 104 anthropometric variables and 148 degrees of freedom. Equipped with position and orientation sensors, the user is represented within the virtual scene by a mannequin whose physical characteristics and movements identically follow those of the user. The user is also able to observe the scene from the model's point-of-view through a head-mounted display in which models are rapidly created via 3D digitalization.

The primary market targeted by Genicom for VirtualMan, the product name for the human simulation model, is the entertainment/animation software market. Safework, is the human model of choice in leading aerospace, automotive, military, medical and industrial companies. It is now used for training Japanese, American, Russian and Canadian astronauts.

Founded in 1984, SAFEWORK Inc. was acquired by Dassault Systemes in the spring of 2000, becoming the subsidiary known as the "Human Modelling Competency Centre" for Dassault Systemes brands.

# REDUCING SIZE AND MASS THROUGH SUPERCONDUCTIVITY

A communication satellite receives processes, and transmits signals. Multiplexers in a satellite serve the function of dividing and combining the various signals into frequency bands that can be handled by existing amplifiers on satellites. These microwave multiplexers traditionally occupy a large volume in a satellite.

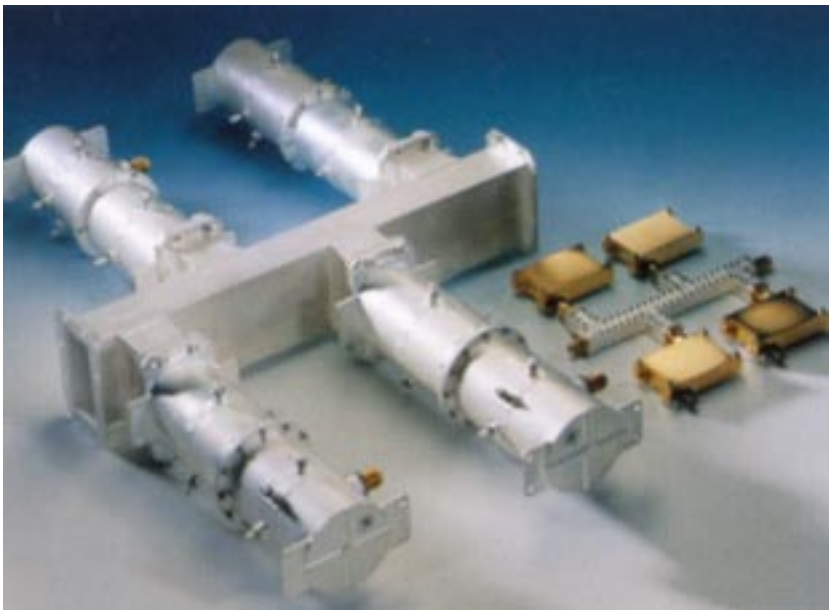
High Temperature Superconductive (HTS) multiplexers are 50% smaller in size and mass in comparison with conventional dielectric resonator technology. An integrated cryogenic HTS front end can also lead to an improvement in noise figure.

COM DEV produces input and output multiplexers operating in frequencies from 200 MHz to 30 GHz, with bandwidths from less than 0.3% to up to 20%. Its input multiplexers, which use dielectric resonators, offer the smallest, lightest filter module currently on the market with a mass of less than 140 grams per channel at Ku-band, a Q factor of over 13,000 and a flat in-band amplitude and group delay performance. Its output multiplexers provide full band (2 GHz) contiguous, non-contiguous or quasi-contiguous multiplexing of multiple channels.

HTS technology is based on a ceramic compound of Yttrium Barium Copper Oxide (YBCO), which has a critical temperature for superconductivity of 120 degrees K. The CSA has supported the development of multiplexers using this COM DEV technology.

In 1999, COM DEV successfully demonstrated a 4-channel high-temperature superconductor (HTS) multiplexer on the Naval Research Laboratory's Advanced Research and Global Observation Satellite (ARGOS). They also demonstrated an integrated cryogenic Ka-band receiver with an improvement in noise figure. This improvement will have a considerable impact on the cost and size of Ka-band ground terminals.

COM DEV's leadership in this market niche is further confirmed with the recent award of a contract valued in excess of $25 million to provide switches and multiplexers for two of the world's largest communications satellites being built by Astrium N.V. for INTELSAT. The two satellites will carry more than 200 COM DEV multiplexer channels and over 950 COM DEV switches. The HTS technology will ensure that it retains this market dominance.



# GROUND TRANSPORTATION: KEEPING THE FLOW ON TIME

The assembly and operation of such a complex endeavour as the International Space Station require a constant flow of goods, materials, parts and products from all around the world in a carefully and precisely planned and monitored manner. Routing, scheduling and dispatching are time-intensive operations that are currently done predominantly via manual means, which rely heavily upon experience. "What-if" analyses are all but impossible. The logistics for this complex chain of linked activities along with the derivation of mitigation plans is a tremendous challenge.

The CSA funded Dynacon, an engineering firm that specializes in robotics and automation, to address this challenge and investigate the technology options.

As a result of its investigations, Dynacon was able to develop and successfully market four commercial routing and scheduling logistics software packages:

- *Dispatcher Assistant* which performs load optimization, consolidation and routing;
- *Carrier Manager* which facilitates carrier selection, freight rating and analysis;
- *Direct Ship* which adds LTL and inter-carrier shipping to Carrier Manager; and
- *Route Manager* which treats multi-modal, multi-node routing and scheduling transport problems.

The packages provides several key attributes such as: Automatic geocoding via postal and zip codes; user-friendly graphical interfaces with onscreen editing, and textual entry via universal files; user-selectable operational modes (number and type of hubs, backhaul capability, route types, carrier types, fleet selections, shipment choices, geographical regions).

The benefits of this suite include the automation of the most complex routing, scheduling and dispatching operations along with the minimization of routing, scheduling and carrier costs. With the growth of e-commerce and in an increasingly competitive marketplace, the extra margin that can be extracted from a more efficient distribution system, as provided by Dynacon's logistic software products, can make the difference between profit and loss.

# FROM DETECTING TOUCH TO DETECTING WHO TOUCHES YOU

Advanced robotic operations will be performed on the International Space Station by the Special Purpose Dexterous Manipulator (SPDM) supplied by the CSA. These operations will require the robot to be able to approach, contact, grasp and manipulate a wide variety of objects such as cables, components, handles, protection blankets, tools, etc. While it may sound simple for a robot to grasp an object, it requires a complex sequence of precise positioning as the robot gripper moves in closer to the object until it makes contact. The most crucial part is the last 1 cm to 1 mm where the robot gripper must be properly aligned with the object in preparation for contact. Therefore, very short range or proximity measurement sensors are required, and ideally these sensors should be integrated within the actual robot "fingers" themselves.

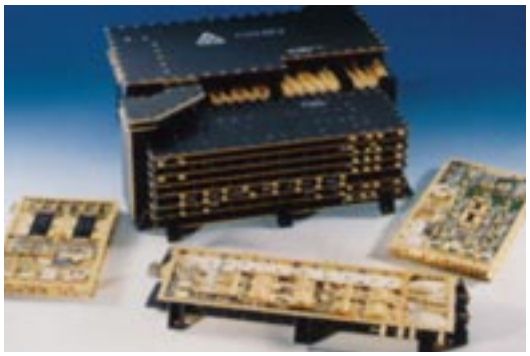
To address this challenge, the CSA funded Kinetic Science Inc. (KSI) to develop a "near touch" proximity sensor which would provide detailed information on the distance and orientation of an object between 1 cm and 1 mm from the fingertips of the robot. Employing silicon micromachined sensor technology with integrated electronics processing, KSI developed a proximity sensor that provides both image features and range data very near to the surface of the sensor. Since it does not require any conventional lenses, it reduces image distortions.

As a spinoff, KSI developed Vision Skin™, a human fingerprint biometric sensor (a fingerprint reader) which permits automated fingerprint reading for computer security and access control applications. Fingerprints are, with DNA, one of the unique feature each of us possesses to differentiate ourselves from one another.

The Vision Skin™ fingerprint reader has enormous market potential in police and security applications. The computer industry is also being targeted as a major market. In 1997, KSI signed a licence agreement covering Asia (excluding Japan) for commercializing fingerprint identification devices.

KSI provides research services and product development in the fields of advanced sensors, actuators, automation and advanced biometric sensors for computer security.

# SURFACE ACOUSTIC WAVE FILTERS



Today's communications are done widely through the use of satellites, therefore satellite communications must be able to reuse frequencies and channel communication signals. Surface Acoustic Wave (SAW) filters are an important element in sub-channel segmentation, but the efficient and cost-effective manufacture of SAW filters requires exceptional modelling capabilities and expertise in controlling the process. COM DEV International Ltd. possesses extensive experience in SAW filter technology, established after 15 years of collaboration with government and university experts. COM DEV is now a world leader in the processing of SAW devices for commercial space programs and has the capacity to address the growing needs of the wireless telecommunications industry.

For INMARSAT 3, a satellite system essential for almost all of the world's major television, broadcast and print news organizations, SAW filters were produced to be spectrally efficient, with transition bandwidths of 200 kHz at an operating frequency of approximately 170 MHz. Similar SAW devices were also designed for ESA's (European Space Agency) EMS (European Land Mobile Services) payload onboard ITALSAT-F2 satellite, which made use of 15 different SAW designs. More recently, work was completed on the ARTEMIS program, which employed 15 different SAW designs, with improved spectral efficiency achieved with 100 kHz transition bandwidths. Current work has seen the development of SAW devices operating at frequencies up to 1.6 GHz, with a reduction in filter loss.

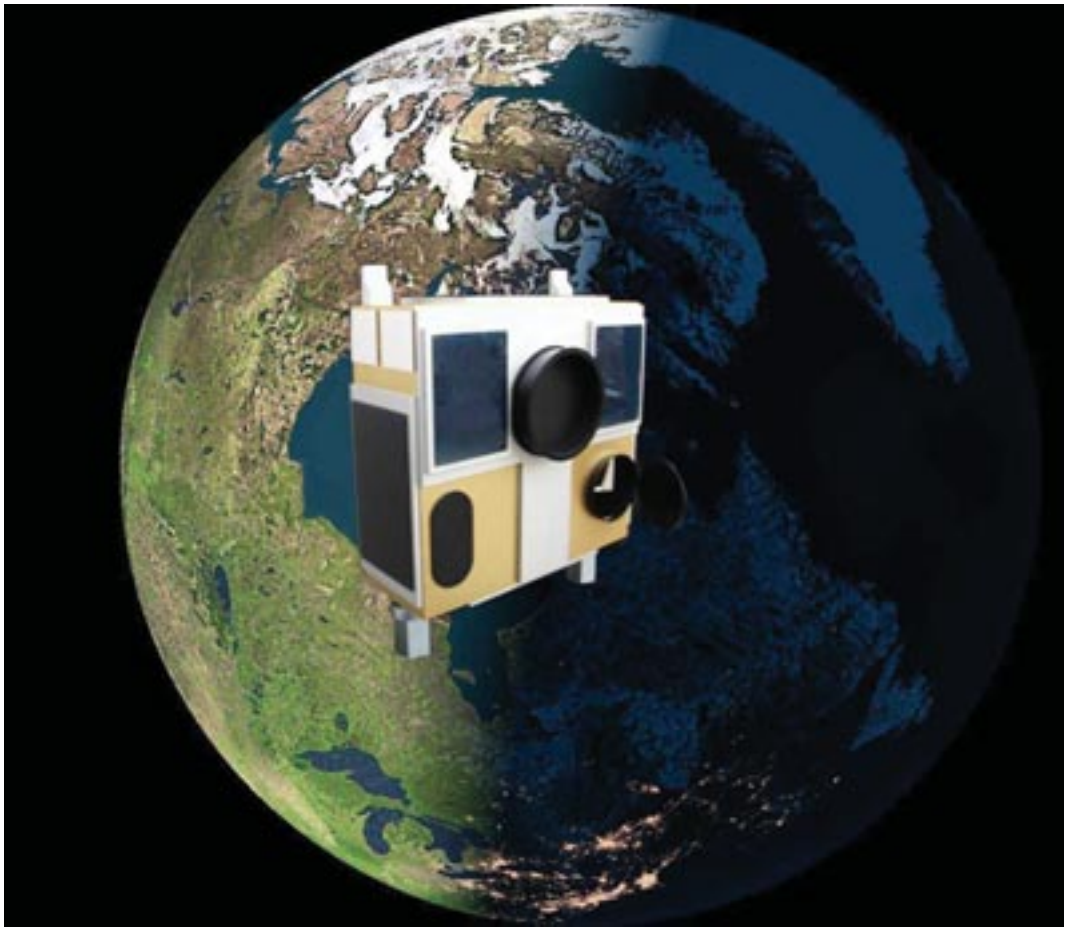

The CSA played an important role in the development of COM DEV SAW technologies through funding and technical leadership encompassing individual products, applications and manufacturing processes. COM DEV International is the largest Canadian-owned designer, manufacturer and distributor of space and ground-based wireless products and subsystems.

# POSITIONING MICROSATELLITES

Microsatellites offer many opportunities for science and commercial missions formerly unavailable due to the prohibitive cost of larger satellites. With a size of 50 to 100 kg, their cost ($5-10M) is much lower than those of previous generations of satellites. Many of these new missions require pointing agility and control performance equal to those of large satellites. Achieving this has required miniaturizing the many sensor, actuator and control computer components needed, as well as drastically reducing their production costs.

Dynacon Ltd. developed, with CSA collaboration and financial support, a complete Satellite Attitude Control System: the High Performance Attitude Control System (HPAC™). HPAC™ is a family of small satellite hardware and software products, very small and low-cost, enabling microsatellites to rival the attitude control capabilities of much larger satellites. This allows microsatellites to carry out more ambitious missions than ever before, bringing new satellite customers into the space market.

HPAC™ products enabled Dynacon to develop the CSA's MOST mission—Canada's first space telescope. Furthermore, HPAC™ has also been chosen to be the attitude control system of Australia's Fedsat satellite and is providing Dynacon entry into the global microsatellite market.




# UNDERSTANDING THE ENVIRONMENT AND CONTRIBUTING TO SUSTAINABLE DEVELOPMENT

# FLOOD MONITORING

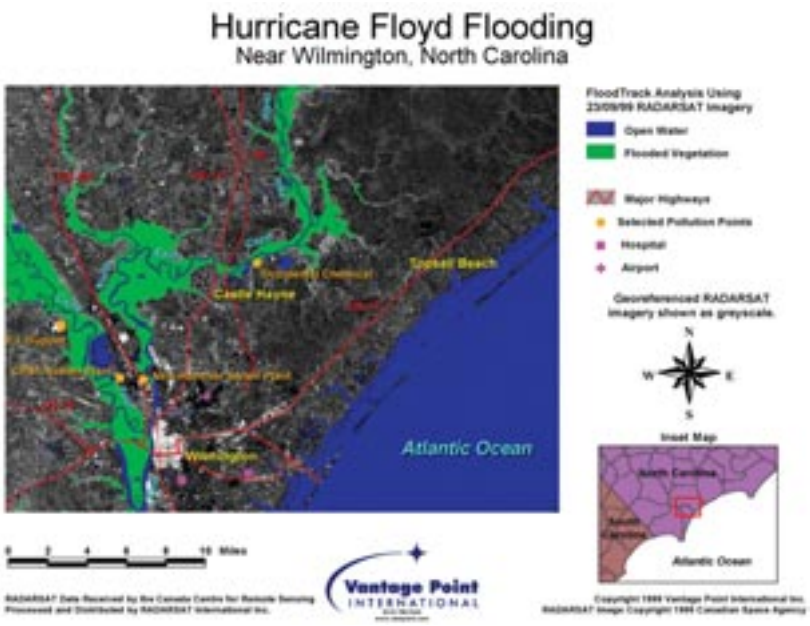
Earth Observation through satellites like RADARSAT-1 can be used in many fields. Perhaps the most spectacular and direct benefit is flood monitoring. The difficulty is to acquire and analyze RADARSAT data and present it to the customer quickly and conveniently for disaster mitigation. Powerful software has been developed with support from the CSA, to meet this challenge.

Vantage Point International Inc.'s (VPI) Flood Monitoring Workstation and FloodTrack Monitoring Service, provides precise information on flood extent quickly, cost-effectively and conveniently. FloodTrack technology distinguishes between open water and flooded vegetation with high precision and provides fully georeferenced flood contour maps that can be delivered via the Internet.

This technology contributed to the development of two new services: FloodTrack/DEM (Digital Elevation Model) integration and FloodTrack shoreline mapping. The Canadian International Development Agency (CIDA) and the World Food Program have used FloodTrack for relief work in the Mozambique floods and the 1997 Red River flood in Canada.

Vantage Point International's core technology areas are Radar, FloodTrack and Digital Signal Processing. This technology development has led to a 200% increase in revenues for VPI and has led to 3 direct alliances with other private sector firms in the US and Canada, enabling them to become a leader in the disaster management and floodplain management markets.

***Ronald Saper, President, Vantage Point International Inc.,*** *"The RUDP (Radarsat User Development Program) made it possible for VPI to create an awareness of FloodTrack throughout Canada and the US, to market our services and to generate sales. Thanks to the CSA, for supporting and fostering Canadian industrial capability."*



# UNDERSTANDING IMAGES

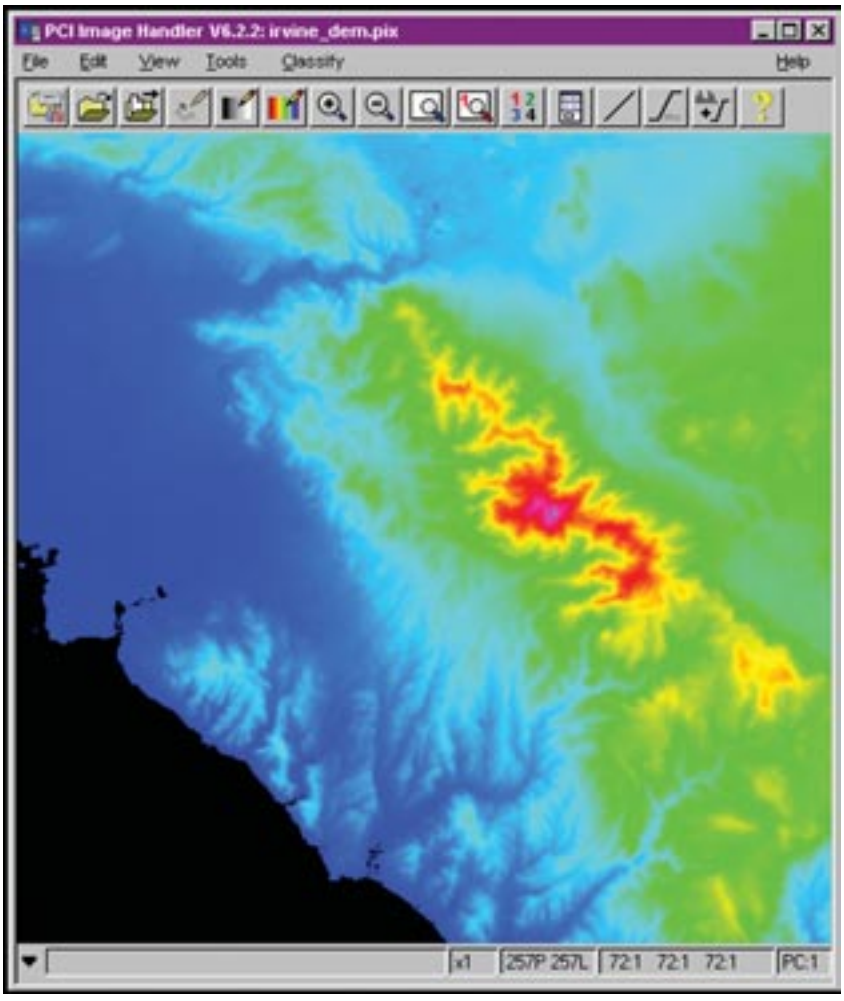
In many parts of the world, persistent cloud cover hinders the collection of remote sensing data from space sensors and cameras operating in the visible and near infrared portions of the electromagnetic spectrum. Although RADARSAT-1 data can effectively replace such sensors for many applications such as cartography, the particular nature of radar data makes it necessary to orthorectify the image, a process which is complex and requires a great deal of data translation and processing, mostly by experts.

It is in response to the great demand for orthorectified imagery that PCI Geomatics, a world leading developer of Geomatics software, created RSAFE, a powerful system that allows users to orthorectify RADARSAT imagery and group such images into a seamless mosaic.

Through the RSAFE project, PCI also created OrthoEngine processing and correction software models for RADARSAT. The targeted market is users with only basic radar background. All complicated math models are internal to OrthoEngine and the most laborious tasks are performed in either automatic or semi-automatic modes, thereby freeing up valuable personnel resources.

The RSAFE technology built into OrthoEngine has fostered new sales in regions where demand for cartographic information is high. Major customers include federal and local governments and oil and gas exploration companies.

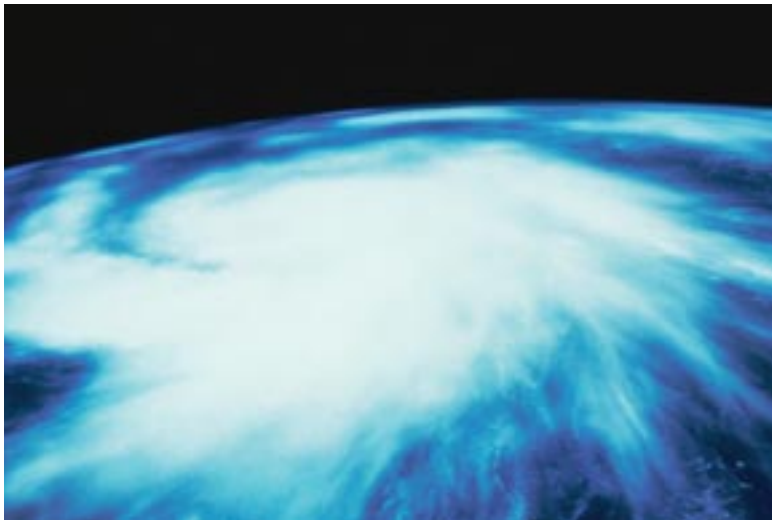
In addition to providing partial funding for the technology development, the CSA sponsored collaboration with product stakeholders and provided guidance for development. It also assisted in the profiling of RSAFE, and in providing PCI with RADARSAT data for development, testing, training and marketing purposes.



# UNDERSTANDING OZONE

The depletion of the ozone layer in the stratosphere is one of the major environmental crises our planet faces today. Currently, there is no reliable data available on global distribution of ozone in the troposphere with high resolution, especially in the Polar Regions.

The only way to measure chemical species (including ozone) globally with good vertical and horizontal resolution is to use Lidar (LIght Detection And Ranging), an active instrument, which can transmit laser pulses from a satellite through the atmosphere. Differential Absorption Lidar is now considered the most suitable sensor for global vertical profiling of ozone from space. Each laser pulse has two wavelengths in the ultraviolet: one within an ozone absorption line, and the other at a nearby wavelength off the ozone absorption line. By measuring the intensity of light backscattered along the pulse path at each wavelength, one can obtain the spatial distribution of ozone concentrations with good vertical and horizontal resolution. This same lidar system can also transmit in the visible range of the spectrum, and measure atmospheric aerosols and clouds as a function of 3D-coordinates.



It is in this context that NASA and the Canadian Space Agency in 1998 undertook a project entitled ORACLE (Ozone Research in the Atmosphere by Co-operative Lidar Experiments) to evaluate this approach. The project successfully demonstrated the possibilities of quantitative measurement of chemical species in the atmosphere using space-based LIDAR technologies, and it gave international recognition to Canadian industrial capabilities in designing, building, integrating, and operating airborne, ground-based and space-based lidar sensors and systems. In addition, it led to the development of unique, space lidar subsystems and potentially marketable components (space-deployable telescopes with secondary-stage correctors, space-based photon-counting detectors, highly efficient all-solid-state Raman lasers, and others). Another offshoot of the ORACLE project is a partnership with the Meteorological Service of Canada, a major potential user of the sensor data atmospheric modelling.

The CSA appointed Optech, a world class Lidar system R&D and manufacturing company, as the Canadian industrial lead. Optech is designing the ORACLE receiver which consists of a telescope, a secondary optics module, and the signal processing electronics. The telescope is designed to travel into space in a compact package and deploy once in orbit.

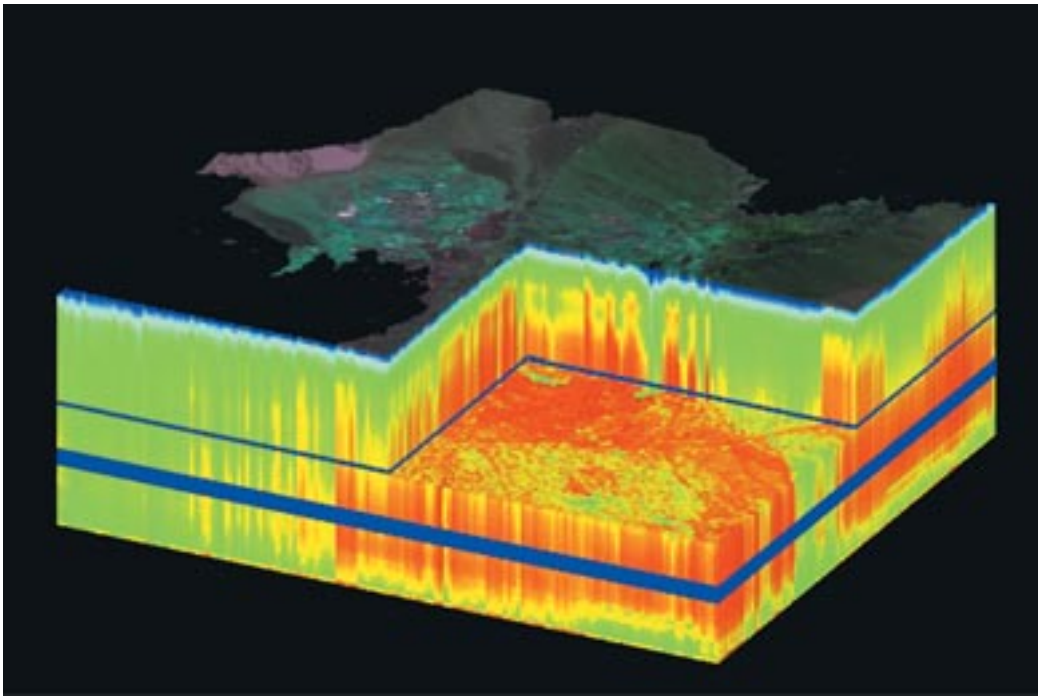
# VIEWING HYPERSPECTRAL DATA

The future generation of Earth Observation optical instruments will use imaging spectrometers, which acquire image data in hundreds of spectral bands. Research has shown that the information-rich hyperspectral image data can be processed to derive dozens of new information products. However, a severe limitation in the operational use of hyperspectral Earth Observation image data is the sheer volume of data produced by airborne and space-based imaging spectrometers.

The Hyperspectral Image Browser (HIBR), devised by MacDonald Dettwiler (MDA), is a tool for remotely browsing (via the Web) highly compressed yet information-rich hyperspectral data sets. HIBR compressed hypercubes are smaller, faster to process and faster to electronically transfer, with minor loss in product accuracy, thus providing operational potential for global applications exploitation.

The HIBR tool uses a CSA patented Vector Quantization technology to compress the acquired image data, and subsequently to apply the information-extraction algorithms to the compressed cubes. These orders-of-magnitude smaller hypercube result in significantly faster processing and orders-of-magnitude faster data transmission. The HIBR tool may therefore be used by those who wish to rapidly browse compressed hypercubes, to select data for later more thorough analysis, or to remotely process compressed hypercubes to acquire end information products.

The CSA has licensed the Vector Quantization technology to MDA, who in turn have developed an HIBR browser for implementation at hyperspectral image data source sites where large catalogues and archives are located, and hyperspectral data source sites from which derived information products are to be generated.



# BATTLING FOREST FIRES

Forest fires destroy valuable resources. In British Columbia (BC) alone, the BC Forest Service responds to an average of over 3000 fires a year in an area of over 1 million square kilometres. Recently, using expertise gained through their work in a number of ESA projects supported by the CSA, MacDonald Dettwiler designed an integrated system for communications and localization services in emergency situations such as forest fire fighting, earthquakes, etc.

Real-time Emergency Management via Satellite (REMSAT) uses satellite technology to improve communication between fire-fighting crews in the field and their control centres to deliver up-to-date position and status information on all resources, aircraft, equipment, and personnel.

The objective is direct communication, providing voice and localization services between on-site staff and a centralized operations control, through the use of pocket size portable or hand held personal terminals which communicate with satellites via large terminals mounted on vehicles. In the case of forest fires, for example, satellite terminals are installed on the fire trucks and the firemen use wireless terminals. Both the truck and the personal terminals provide for localization in adverse conditions (e.g. smoke induced low visibility).

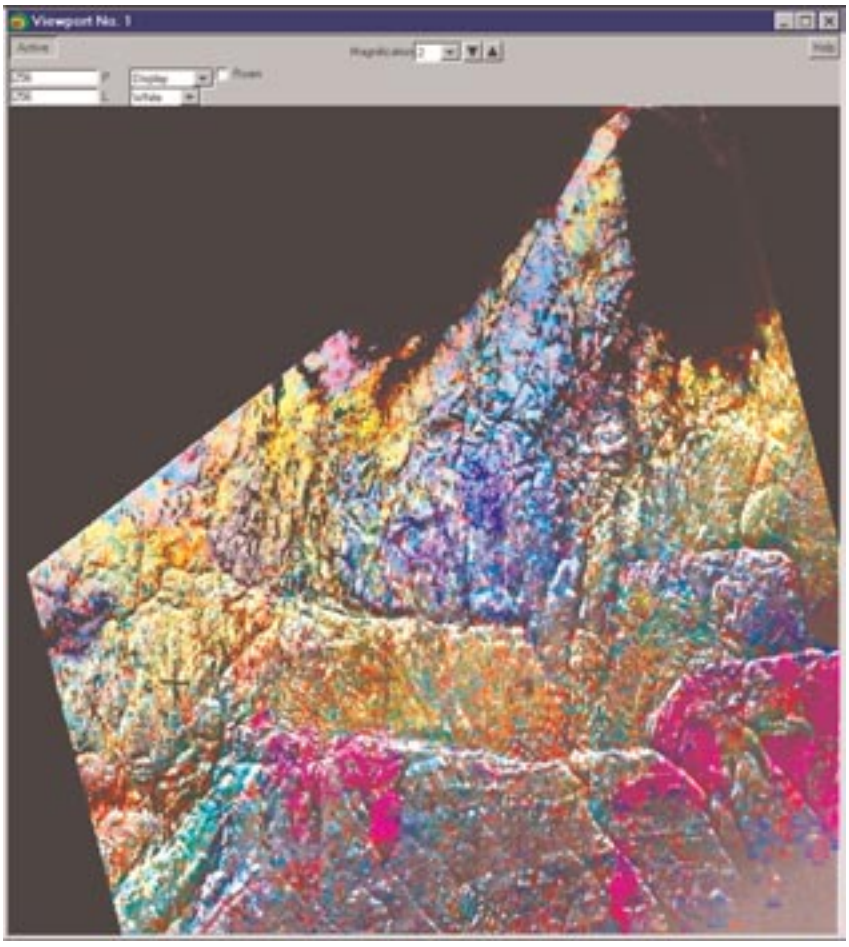
REMSAT provides the BC Forest Service with a transportable Fire Command and Control that can be deployed in any remote location where there is poor communications infrastructure. REMSAT will have a significant impact on the management of emergency situations around the world, including earthquakes, floods, and extreme weather events. This technology will help Canada and the world in managing natural disasters in the future.

# MITIGATING FLOOD DAMAGE

During the 1997 Red River floods, as with several other similar natural disasters, the RADARSAT-1 satellite was put to extensive use providing radar pictures of the waters. However, extracting useful information from these microwave "photographs" requires very special and powerful image processors. These processors must be able to ingest formidable amounts of data and process it quickly and accurately into information that can be easily transmitted and readily used in the field.

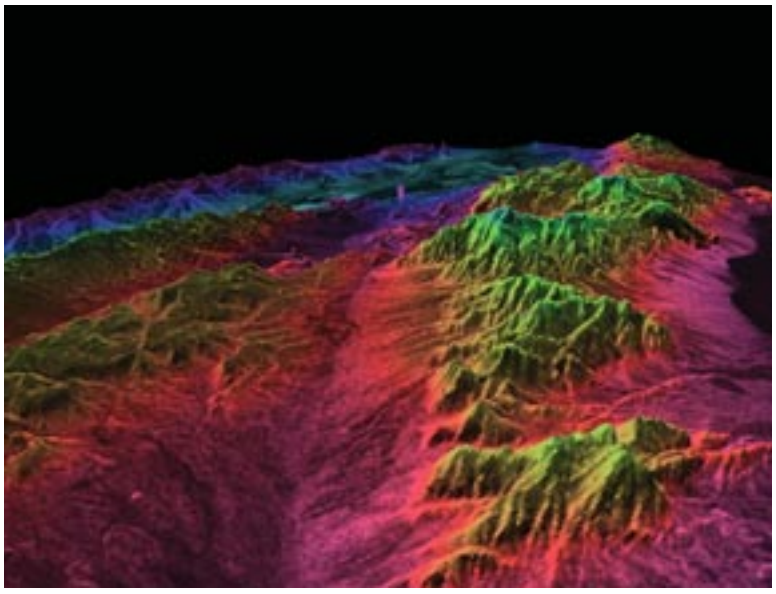
To address these specific requirements, the CSA funded PCI Geomatics to develop the Image Exploitation Workstation (IMEWS), a complete process-oriented image rectification, analysis and mapping workstation designed to provide end users with cost-effective and timely images using space-borne remote sensing data. The work/station supports a host of commercial and military specific remote sensing data, including RADARSAT. Functions include data rectification, enhancement, electronic light table image manipulation, semi-automated and manual feature extraction, measurement and rapid map output. IMEWS is also designed to “plug-in" and enhance military intelligence systems, emergency response information centres, mapping production systems, and other relevant geospatial information systems.

IMEWS has stimulated the use of RADARSAT data in Canada, the US and Europe. Currently the optimum image exploitation tool available in the world, IMEWS is expected to become the premier software tool for leveraging RADARSAT data into the global military market.



# SEEING MOUNTAINS AND VALLEYS

Up-to-date terrain models are needed for such applications as road and telecommunications network planning, natural disaster mitigation, and strategic purposes. However, they are costly and difficult to acquire through conventional airborne methods since access to many regions of the world is impeded either by poor weather conditions or political considerations. RADARSAT data is very suitable to derive Digital Elevation Models (DEMs) of the terrain and to allow for easy and regular update of the information.



***Patrick McConnell, President, Atlantis Scientific Inc.,*** *"The willingness of the CSA to support Atlantis Scientific Inc. in its plans to commercialize interferometric technology was a catalyst that enabled Atlantis to undertake the work. Cost sharing reduced the overall risk and allowed us to move faster. As a result, Atlantis Scientific Inc. today dominates the niche market for interferometric software and has been able to position itself as a world leader in the provision of interferometrically derived value added products."*

The challenge was to develop an affordable commercial software package that would allow end-users to quickly and economically convert RADARSAT imagery into Digital Elevation Models. Atlantis Scientific Inc., with help from the CSA, accepted this challenge and successfully developed and commercialized its EarthView™ InSAR software. This software transforms SAR (Synthetic Aperture Radar) images into Digital Elevation Models using interferometric techniques that produce maps accurate to within 15 meters. Horizontal resolution of 10 meters can be achieved by using RADARSAT's Fine-beam mode.

EarthView™ software and information products are already being used in many sectors such as education, mining, petroleum exploration and production, other geological applications, glaciology, military, oceanography and telecommunications.

In addition to growth due to its software products, Atlantis has also expanded into an image processing services provider for those who wish to benefit from the technology without having to master it. These services include such products as land surface subsidence maps and elevation models. Thanks to commercial products like EarthView™, Atlantis now dominates the commercial off-the-shelf market for SAR and interferometric software and has sold more desktop SAR software than any other company in the world. Up to the end of 1999, these products generated close to $3 million in revenue and are expected to generate a total of $5 to 6 million during their useful life.

# MONITORING THE OCEANS

Earth Observation also means observation of the oceans. Because of the rapidly changing nature of the oceans, information is time critical but difficult to acquire due not only to the weather but also to the vast areas to be covered. Only satellites such as RADARSAT can fulfil the requirements for timely and repeated imagery over large areas. However, satellites generate huge amounts of data, which must be interpreted rapidly. A very powerful and user friendly workstation was therefore required to ingest satellite imagery and turn it into readily useable information products for such users as coast guards, insurance companies, environment services, and navigation authorities.

It is in response to this requirement that SATLANTIC Inc. designed and produced the OMW (Ocean Monitoring Workstation) expert system. This system processes satellite images of the ocean surface to extract real time information for vessel detection, ocean waves data, frontal boundaries in the ocean, as well as atmosphere and oil spill monitoring. The OMW has been configured to process all beam modes of RADARSAT and the SAR (Synthetic Aperture Radar) mode of both ERS-1 and ERS-2 satellites. The OMW software has a user-friendly graphic interface and works independently or interactively, networked or remote, and can transmit strategic information based on SAR images in just five minutes.

The OMW contributes to monitoring and management as well as to search and rescue operations at sea, by analyzing imagery within minutes of data receipt. The intelligent search method provides the most accurate identification of vessels in SAR imagery. Applications include: Shipping traffic and ocean operations (ship monitoring, monitoring of spills, search, recovery and rescue operations); Meteorology (analysis of changes in pressure and wind systems); Sea conditions (analysis of sea winds and currents, analysis of physical parameters); Oil Spill Monitoring (location of areas of ocean that are potentially contaminated).

The CSA supported the development of OMW, and the first OMW expert system was put in operation at the Gatineau Satellite Station in 1995.

# CROP STRESS

Nutrient stress is an important factor in crop growth and disease. Until recently, real-time assessment of plant stress has been based on canopy colour. However, decolourization often indicates stress when it is already too late to do anything about it. Also, reflectance-based (colour) approaches lack the capability to distinguish among the many stresses that may affect a crop at a given time (nutrients, insects, disease...).

The challenge is therefore to find a method that can provide information early in the growing season and can discriminate among the many causes of plant stress in an economical fashion. This is where space technologies offer promising possibilities.

The capabilities of Laser-Induced Fluorescence (LIF) in discriminating among nutrient stresses have been explored using a compact multi-wavelength fluorescent LIDAR (LIght Detection and Ranging). As early as six days after fertilizer

treatments of plants grown under control, distinct effects of nitrogen and sulphur deficiencies have been detected in the ultraviolet-induced fluorescence spectra of the nutritient-deficient plants. This distinction could not be achieved through conventional methods based on leaf reflectance. With the LIDAR, the changes were detected prior or simultaneously to the inhibition of plant growth.

This development can lead to the emergence of a new generation of in-situ analytical sensors supporting satellite remote observations. It demonstrates the possibility of quantitatively assessing stresses on agricultural crops in real-time, in the field and remotely.

This research was conducted by Agriculture and Agri-Food Canada's Horticultural Research and Development Centre and Norsk-Hydro Agricultural Research Centre, together with Laser Diagnostic Instruments Ltd. of Tallinn, Estonia. Norsk-Hydro Agricultural Research Centre is a global player in the agriculture industry. In addition to funding the research, the CSA provided both expertise and R&D resources, and participated in the experiment and system design.


# QUALITY OF LIFE

# CONNECTING IN SPACE

Canada's principal contribution, both to the Space Shuttle Program and to the International Space Station (ISS), consisted of the Canadarm and the Canadarm-2. To be able to operate these efficiently, astronauts must be able to see what they are doing, which is not as easy as it may seem in an environment where there is no "up" or "down" and where distance references are often hard to come by.

The challenge here is to provide astronauts with a 3-dimensional view of a payload while manoeuvring it into a narrow capture envelope. The CSA supported this technology development at Neptec.

Neptec's Space Vision System (SVS) processes signals from conventional video cameras to accurately determine the position and attitude of objects such as satellites or elements of the International Space Station. The measured three dimensional position and orientation of the objects are then synthesized into real-time alphanumeric and graphical displays which an operator of the shuttle's robotic arm uses to manoeuvre the objects into accurate alignment.

Passive cameras are used to image special high-contrast target dots or natural features on an object. Photogrammetric analysis then determines the six degrees of freedom of the object in relation to the camera frame of reference.

The SVS has been employed on the space shuttle and will be part of the standard equipment configuration on the International Space Station. The CSA's early confidence in this innovative idea allowed Neptec to develop the technology and to become a prime contractor to NASA. Neptec has had an annual growth of over 35% with annual revenues approaching $20 million.

# COMMUNICATIONS SATELLITES PROVIDE ACCESS TO THE INTERNET

The convergence of communications services: telephony, television, data, the Internet, etc. imposes new requirements on the global communications infrastructure. It must be able to reach virtually every corner of the globe to meet both the needs of local residents and those of the extended operations of major corporations. Satellite networks can effectively complement if not replace other current communications network technologies, wired and cellular telephone, cable and fibre.

There are solid technological reasons for which the satellite is expected to assume such a strategic role in the future. Once a satellite is deployed, its signals carrying Internet access, television, data, IP caching, multimedia streaming, etc. can immediately reach a huge geographical area. Other technologies would take years to construct infrastructures so as to cover the same areas, at several times the cost. Satellite communications have proven their reliability particularly in the VSAT (Very Small Antenna/Aperture Terminal) market.

The current challenge is to increase the performance and reduce the cost of microwave transmission and reception components for satellite ground stations, especially at Ka-band, and to develop technology to effectively transport broadband content into and out of the Internet backbone in order to create a market for end-user terminals. NORSAT International Inc. has designed such an end-to-end system solution.

The CSA provided funding to NORSAT under the ESA Program which led to the development of some of the basic technology used in both NORSAT's (European Space Agency) terminal and transport products. Potentially, billions of dollars in revenues and tens of thousands of person years of employment will be returned to a successful Canadian terminal/hub industry. Satellite networks are expected to capture 15 to 30% of the broadband market (expected to be worth US$200 billion by the end of the decade).

NORSAT designs, engineers and distributes products for use in satellite wireless communications. They received the world's first two commercial orders for Ka-band SIT (Satellite Interactive Terminal) outdoor units. Over 25 hubs have been installed worldwide.

# CONNECTING THE PLANET THROUGH HIGH-SPEED NETWORKING

To meet the explosive demand for high-speed network applications, broadband communication via satellite will be used more and more.

EMS Technologies provides the Satellite Interactive Terminals, hubs and the on-board digital signal processors (SpaceMux) required to provide broadband services via satellite. The hubs and terminals allow users to access an Internet Service Provider through a small low-cost unit operating in a "star" configuration. SpaceMux will enable individual users to communicate with each other at 2 Mbit/sec data rates without having to pass through a hub. This combination of "star" and "mesh" connectivity will enable a new range of high speed Internet applications, including IP telephony and desktop video using web cameras. The system will use DVB-RCS (Digital Video Broadcast-Return Channel System) user terminals. DVB-RCS is an international standard for multimedia satellite networks.

The basis of all of EMS' DVB-RCS activity was the CSA Advanced Satcom program. ESA activities (under the Canada-ESA Partnership Program of the CSA) have also contributed to the development of this technology. EMS was also awarded a contract from the CSA for the demonstration of digital-mesh-connectivity system on the Anik F2 satellite, and is active in next generation DVB-RCS technology development within the ESA ARTES 3 program.

EMS is the key technology supplier for the first commercial deployment of DVB-RCS (Digital Video Broadcasting - Return Channel System) standard on the SES/ASTRA satellite system. EMS is supplying a satellite hub and prototype terminal units to SES. In addition to a $9.5 million contract from the CSA, EMS was granted an Authorization to Proceed from Telesat and Hughes Space & Communications worth an additional $9 million on the flight unit, a DVB-RCS compatible on-board processor.

# HELP IN RESCUE

Imagine this: you are a helicopter pilot on a rescue mission, maintaining low altitude in mountainous terrain. The weather couldn't be worse: sleet, winds, absolutely no light to guide you. Then you see them straight in front of you: powerlines! You know you can't pull up as fast as you should.

As a means for the rotorcraft industry to significantly reduce accidents due to collisions with objects especially during poor weather operations, thus increasing operating flexibility, EMS Technologies has designed a low-cost, high-performance 35 GHz airborne thin-spherical dielectric lens antenna for an obstacle avoidance RADAR.

The system will permit helicopter pilots flying at low altitude to see obstacles as small as power transmission lines and towers from distances of up to two kilometres in the most difficult day and night weather conditions, thus increasing flight safety, particularly for helicopters used in emergency medical services, search and rescue, law enforcement, fire fighting, etc.

The dielectric lens antenna is of the zoned thin-spherical type. This robust mechanisms allow for rapid scans of the flight window while maintaining excellent stability of the system. The spatial distribution to the lens is much more efficient than the signal distribution networks required for phased arrays. Compared to phased arrays, this dielectric lens can also be fabricated at a lower cost. The dielectric material chosen for the lens allows for the elimination of the radome, resulting in optimal RF (Radio Frequency) performance and minimum cost.

The CSA provided funding for technology development, which produced a thin spherical lens analysis and synthesis software package that has been used for the design of the OASys (Obstacle Awareness System) antenna and also resulted in the refinement of the manufacturing techniques for this type of antenna.

EMS signed a Memorandum of Agreement with Amphitech International Inc. for the design, manufacture and test of a Ka-band radar antenna and gyro-stabilized platform sub-system for a new helicopter Obstacle Awareness System (OASys RADAR). EMS has provided cost-effective products and solutions for spacecraft, aeronautical and ground-based systems for over thirty years. Using the latest technologies and tools available, EMS continues to provide world-class products to a worldwide customer base.

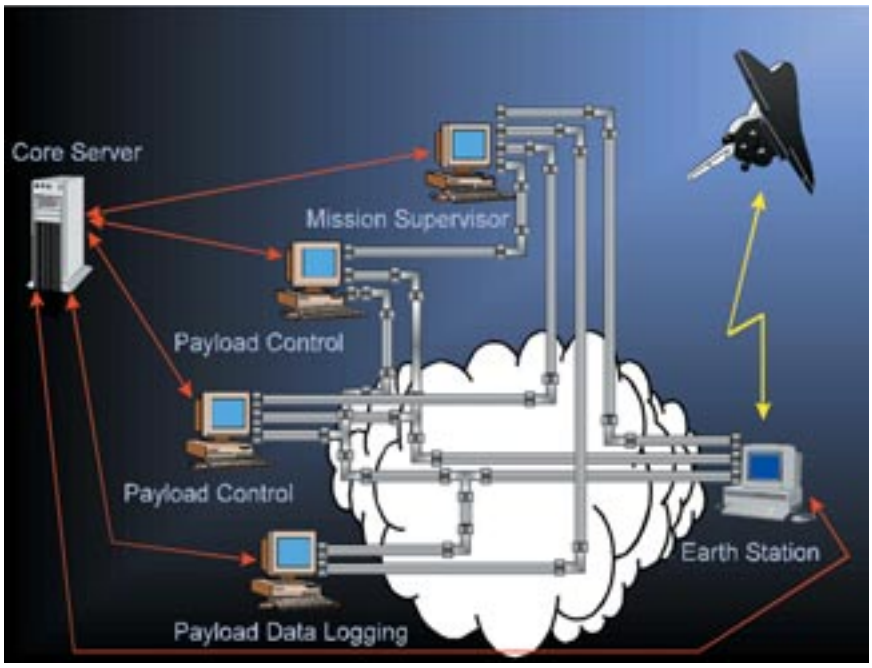
# MORE THAN SIMPLY GETTING CONNECTED

With recent developments in technology, there is an ever increasing need for highly reliable, efficient transmission of data. Whether it be for telemedicine, tele-education or remote operation of satellites, reliable communication is indispensable. One way to enhance communications capabilities is to build on top of already existing, easily accessible infrastructures such as the Internet.

Xiphos Technologies Inc. (XTI) has successfully coupled the development of low-cost embedded control engines with advanced Internet and space-based real-time virtual private networks. Their XTCommunicator (XTC) software provides robust, high-performance network communications. The goal is to provide a complete communications service, incorporating the very best network features available while ensuring efficient use of complex networks, especially those with satellite and wireless segments.

XTC already provides secure transmission of medical data, by satellite, from Northern Canada, thus increasing the standard of health care for many people, such as diabetics, at reduced cost.

XTC was created to let scientists share access to experiments in space and to simplify the implementation of sophisticated robot teleoperation systems. It is a form of Virtual Private Network (VPN), a method of providing private communication using shared or public networks. XTC is added to existing software applications to turn them into high-end network applications. It seamlessly adds authentication, encryption, protection from failed links, data sharing, firewall transit, and special management for high-bandwidth satellite environments. Access to the VPN can be controlled and monitored by a central Core Server.




The development and commercialization of XTC was supported by the CSA. XTC will use the Internet to provide ground-segment data communications during the H-Reflex space science experiments, which are scheduled for shuttle missions STS-102 and STS-105.

# COMMUNICATION THROUGH LIGHT

Given its intrinsic properties: small size and weight, high bandwidth, and Electro-Magnetic Interference (EMI) immunity, fibre optics will increasingly be used in robotic applications, including vision systems, tele-operation and remote sensing. For example, underwater remotely operated vehicles use fibre optic rotary joints to provide continuous fibre optic telemetry and control links.

One of the major challenges facing this technology is the integration of fibre optics into mechanical joints, permitting a variety of movements in various environments, without affecting the fibres themselves. Another is to implement practical opto-mechanical designs which are sufficiently optically efficient to permit passive or unrepeated operation.

For certain applications, a Fibre Optic Rotary Joint (FORJ), the development of which was funded by the CSA, may be an enabling component. The demands of the space environment, such as atomic oxygen, radiation, temperature and temperature cycling, have to be met with new materials and design choices. Hollow-bore versions are desirable over existing designs based on "coaxial" schemes wherein the optical and mechanical axes are the same. For the Space Station Mobile Servicing System (MSS), this could provide the possibility of a retrofitable rotary coupling, as vision and sensor systems grow to demand fibre optic telemetry over its thirty-year life.

Focal Technologies has recently introduced a range of video/data multiplexers, which allow the combination of multiple electrical and/or fibre optic signals into a single high-speed optical fibre. These joints are designed to work under all sorts of extreme environments, from continuous rotation at 60 rpm, to vacuums with no outgassing and low particle generation, to adverse weather conditions.

Terrestrial applications include offshore oil and gas, oceanographic, remotely operated vehicles, and a wide range of industrial requirements. Other examples include cable reelers used in bomb disposal robots and materials handling systems, as well as cranes, turrets, turbines and remote I/O in industrial machinery and surveillance systems.

# MEDICAL TESTING BENEFITS FROM SPACE-AGE ROBOTICS

Culture preparation for microbiology is a labour intensive, tedious process done, for the most part, manually. Specimen streaking lacks precision and repeatability and varies considerably between lab personnel. Moreover, lab personnel are exposed to biohazards and themselves represent potential sources of contamination for specimens.

As a terrestrial spinoff of technology developed with CSA support for space robotics, Dynacon Inc. has produced a technology to simplify the process and make it both more reliable and more efficient. The technology is called **InocuLAB**™; it is an automated workcell that performs culture preparation in microbiology labs. **InocuLAB**™ is the first product of its kind to successfully meet the needs of microbiology labs. Robotic control and vision system technology are used to automate the preparation procedure. **InocuLAB**™ performs


the following functions: specimen containers are identified via bar codes, uncapped and recapped; medium plates are dispensed, uncapped, recapped, bar-coded and stacked; exposed agar media are inoculated and streaked in pre-programmed user-specified patterns.

**InocuLAB**™ processes large numbers of specimens in a time and cost effective manner with little human intervention, which improves precision and repeatability during specimen preparation. Moreover, potential contamination from manual handling is eliminated and exposure of lab personnel to biohazards decreased. The improved quality control includes a detailed "paper-trail" of specimen preparation.

Models are available to handle urine or swab specimens or both simultaneously, with the slowest model up to three times faster than its human counterparts.



Canadian Space Agency | Agence spatiale canadienne

# GUIDING CANADIAN MINE RESCUE TEAMS THROUGH FIRE

In the harsh space environment, conventional cameras and vision systems must be handled with great care in order not to aim them at the sun. These systems require sophisticated controls to deal with the very broad range of lighting conditions and they rely on visual targets (special unique patterns) painted or applied on structures for precise measurements.

To overcome these drawbacks, a novel radar-based vision technology was developed under CSA funding by COMLAB Inc. which specializes in RF (Radio Frequency), microwave and telecommunications systems. While radars are normally used for long range detection (10 to 100s of kilometres), the challenge here was to develop a very short range radar (from a few meters to 25 meters) which could resolve decimetre scale features and provide images of the scene in real-time.

Such a technology finds immediate application in assisting rescue teams in Canadian mines. Among the many dangers that come with working in mines, fire is one of the most feared. Due to the very thick smoke and dust cloud, visibility is nearly zero and no conventional camera or laser-based vision systems can be used to assist rescue teams. To get to trapped miners, rescuers must slowly drive their rescue vehicle while probing a pole through the side windows to "feel" their way through the mine galleries, with the constant danger of running over somebody unconscious.

Tests performed at Noranda Mining provided initial justification of the technology in mining applications, and showed that radar was clearly superior to other technologies. This technology could have an important impact on the security of workers in underground mines.

The key technology is a Phased Array Antenna (PAA) which has no moving parts. It replaces the mechanically rotated antenna, thus considerably improving reliability and operating speed. The radar operating frequency and pulse width are adjusted to enable the system to work at close distances with great positional accuracy. Operation at such short ranges has never been used in any angle-scanning pulsed radar before.

This technology enabled COMLAB Inc. to increase its market share in educational radars with a complete new line of phased array antenna products as well as opening new opportunities for COMLAB in RF multi-point communications.

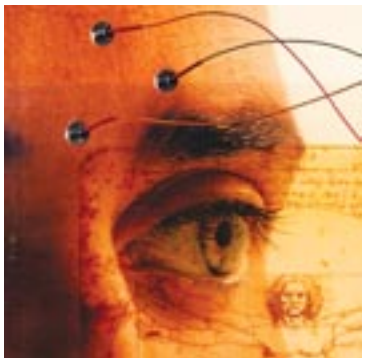
# ICE CHALLENGE

The effects of ice accumulation on various structures can be devastating. In December 1997, Air Canada Flight 646 crashed during its final approach to the Fredericton airport in New Brunswick. Fortunately, none of the 42 passengers and crew were killed, but many were seriously injured. Ice build-up on the wings may have been a critical factor in the accident. One month later the worst ice storm in living memory hit Quebec, crippling the power grid and cutting the electrical supply of nearly half of the population. For thousands, power would not come back for weeks.

Experts concluded that such events could be prevented if it were possible to detect accumulation of ice on structures and to initiate ice-removal measures in a timely fashion. Efficient ice-removing techniques already exist, but adequate ice detection devices remained a challenge until Instrumar Limited of Newfoundland developed systems, such as the IM 101 Ice Detector and the C/FIMS aircraft-mounted sensor, commercialized by Honeywell. The system relies on a novel approach for the detection of material substances. It detects a material's response to the electromagnetic field generated by the detector. Its prime application is for the detection of ice, fluids and contaminants on aircraft wings.

The IM101 ice-monitoring sensor is a fully commercial product. Its fundamental component is a thin ceramic probe with embedded electrodes used to establish an electromagnetic field. The fact that the sensor has no moving parts and is robustly designed, providing virtually maintenance free operation is also a critical commercial advantage.

INSTRUMAR is actively pursuing other applications of this core technology. One promising potential application is for non-intrusive, multiphase flow measurement (air/water/oil) for the oil industry. Technology development support was provided by the CSA.



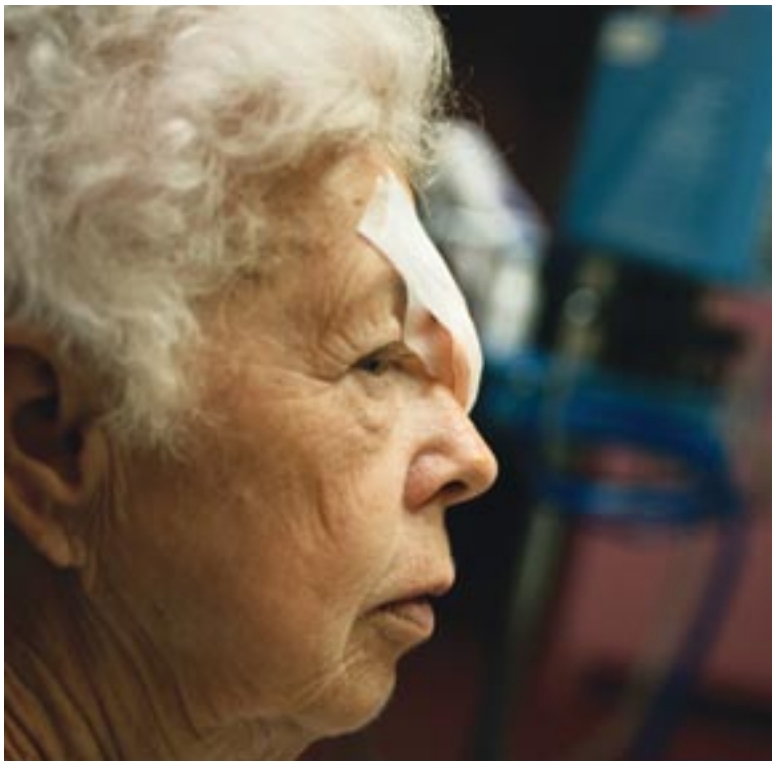
# WHEN SEEING A DOCTOR IS NOT THAT SIMPLE

How will astronauts consult a doctor halfway to Mars? Either they'll have to return to Earth for an appointment about a year later, or use technologies that enable remote medical consultation, diagnostics and treatment. Such remote medical services are grouped under the terminology of "Telemedicine". Without such enabling technologies human presence other than within earth's immediate vicinity is not conceivable.

These same technologies will soon see terrestrial application for the benefit of Canadians. Canada is the second largest country in the world and many of its smaller communities are isolated when it comes to accessing specialized medical treatment.

To address some of these challenges, the CSA joined a team led by MacDonald Dettwiler (MDA) to develop the Intelligent Screening of Imagery for Teleophthalmology (I-SITE) system. Diabetic retinopathy is the leading cause of blindness in North America and I-SITE is an intelligent telemedicine system for the detection and diagnosis of diabetic retinopathy. It utilizes space technologies in image data management and communications to improve both access and quality of health care to Canadians in remote northern aboriginal communities, who are 3 to 5 times more susceptible to diabetic retinopathy than any other segment of the Canadian population.

MDA developed the prototype unit including the image processing software of I-SITE, and the University of Alberta Dept. of Ophthalmology set the functional design specifications and performed the clinical research and field evaluation. I-SITE was funded by PRECARN and with contributions by the team members. It is opening a new world of opportunities for the application of Earth Observation, going from a satellite image processing technology to images of the human eye captured by a new generation of high-resolution digital cameras. Among other contributions, the CSA provided satellite communications to transmit very high-resolution images of screened patients from remote communities to specialists located in Edmonton during the field evaluation of the system.



# COPING WITH HARSH ENVIRONMENTS

Of all the environments humankind faces, space is probably the least hospitable. A host of technologies has been developed by the Canadian Space Agency and the European Space Agency (ESA) for the protection of astronauts and hardware, and for operation in this harsh environment. Some of these technologies, such as smart robots and sensors, advanced materials, satellite-based remote sensing, advanced communications, and control and power systems, are expected to be highly applicable to harsh terrestrial environments.

However, adapting space technologies to specific harsh terrestrial environments requires in-depth knowledge of the application domain, of its performance and safety standards, and of user requirements. In addition, it requires funding which can only be obtained from end users if they are persuaded that the expected benefits will materialize. The challenge is to find and implement cost-effective technologies that enhance safety while reducing adverse impact on the environment.

The Harsh Environment Initiative (HEI) was launched at C-CORE, an applied R&D corporation focusing on resource industries, to conduct value-added development of space technologies that benefit industries operating in harsh terrestrial environments such as the oil and gas pipeline and mining industries in Canada, Europe and abroad. The HEI approach, made possible through the Canada-ESA Partnership Program, is to first determine the commercial technical challenges facing resource industries through extensive consultation with key industrial members. Following this, HEI seeks innovative space technology solutions that can be integrated or adapted as part of a larger commercially driven product or service solution for industry.

The HEI has generated an international network, which consists of twenty-five technical team members and seventy partners in Canada and Europe. Different benefits are engendered by this research: for primary industries (increased production at lower cost and diminished risk); for receptor SMEs (new expertise, niche markets, collaborative ventures); for sponsors of space technology and development (increased return on investment).

# ASTRONAUT RADIATION

Astronauts and critical spacecraft electronic components are subjected to the detrimental effects of high radiation levels in the space environment. Until recently, the industry was ill-equipped to effectively deal with this hazardous element, as traditional technologies that monitored levels of radiation proved cumbersome and unreliable in providing critical information on dangerous radiation build-up. This is why Thomson & Nielsen Electronics Inc. (TN) has devised a system for onboard astronaut radiation dosimetry.

The TN sensors, which are based on semiconductor radiation sensors, are low-cost, small, lightweight, accurate and capable of being integrated with electronic information systems. Their main advantage is an ability to provide the user with immediate and direct read-outs of radiation levels. The device has been successfully tested onboard the Russian Space Station Mir, with a more advanced model scheduled for testing by a Canadian Astronaut on a NASA space shuttle mission. This technology could eventually be used on Earth, especially in nuclear waste disposal and close-range monitoring of nuclear disaster areas.

Thomson & Nielsen Electronics' proposal for an experiment to measure astronaut EVA (extravehicular activity, or "space walk") doses on ISS was accepted after international scientific peer review, giving TN valuable space qualification experience as well as international exposure.

Thomson & Nielsen has built a solid international reputation for radiation detection technologies. Business and government clients in Canada, the US and Europe rely on TN for a wide range of products and services. The CSA provided funding, technical expertise and networking within the international space industry.

Future revenue and job growth is expected once commercial alliances result in orders for space radiation monitors. TN has benefited from alliances with other agencies such as DREO (Defence Research Establishment Ottawa), ESA (European Space Agency), NASA and the Russian Institute for Biomedical Problems, and has begun to form alliances with commercial satellite manufacturers.

***Ian Thomson, President, Thomson & Nielsen Electronics Ltd.,*** *"The CSA has contributed through funding, technical expertise (e.g. space qualification), and networking within the international space industry. Revenue and job growth is expected once the commercial alliances result in orders for space radiation monitors."*

# UNCOOLED DETECTORS

It is sometimes surprising how small pieces of technology, conceived for satellites and other space hardware, find their way into many aspects of our lives. And they often go unnoticed by all but a small number of technicians and engineers. One such instance is the uncooled infrared detector.

Its primary use was in space-related sensing systems, Earth imaging, space surveillance and flight control equipment (for small satellites). But now it has potential for use in a variety of commercial applications: transportation, security/law enforcement, industrial machine and process control, waste and pollution detection and medical imaging. Even the military finds applications: night vision equipment, mine detection systems; missile seeker sensors; precision guided munitions; intrusion alarms; reconnaissance and fire control systems.

Compared to cooled detectors, which require high-cost, high-performance sub-systems, uncooled detectors are capable of operating at room temperature and thus offer considerable advantages in cost and operational convenience. The low-cost ambient temperature infrared detector has performance figures approaching those of cooled detectors.

The CSA provided support for the development of this enabling technology by the National Optics Institute (INO). The INO is engaged in the commercialization of the products of research and development in close partnership with the private sector. It has expertise in optical systems and components; photonics materials and processes; photonics and guided optics; laser systems technology; and information processing. Custom bolometric arrays are under development for use in future space missions, primarily for satellite-based thermal imaging of the earth.

Sales and contracts related to bolometric infrared detector array technology are expected to provide revenue of $1 million in fiscal year 2001/2002. Contracts have come from the European Space Agency, Matra Marconi Space, Officine Galileo, and other players in the global aerospace industry.


# TECHNOLOGY DEVELOPMENT AND DIFFUSION

# STEERING BY THE LIGHT OF STARS

For centuries, the sextant was the indispensable navigation instrument for mariners all over the globe, enabling a navigator to compute his latitude from the position of fixed stars. Satellites too, can use the stars to guide themselves. However, up to now, it has generally been necessary for spacecraft to carry an entire suite of sensors: earth sensors, sun sensors, star sensors and gyroscopes. Now with CALTRAC, a single device, can replace many of these.

EMS Technologies' CALTRAC™ Star Tracker is a computerized sextant combining the precise attitude determination capability of a traditional star tracker with the rapid response normally associated with gyros, scanning earth sensors and sun sensors. It provides accurate high-speed attitude information for a wide range of satellite applications. This innovative product for attitude determination of spacecraft is fully autonomous, lighter and uses less power than conventional devices and can even be used for spinning spacecraft.

The CSA provided EMS Technologies with in-house R&D expertise and capabilities and supported the development of CALTRAC™.

***Gerald S. Bush, President, EMS Technologies Inc.,*** *"The successful partnership in technology development with the CSA has been a key ingredient in the pre-eminent position that EMS Technologies has achieved in supplying global space markets."*

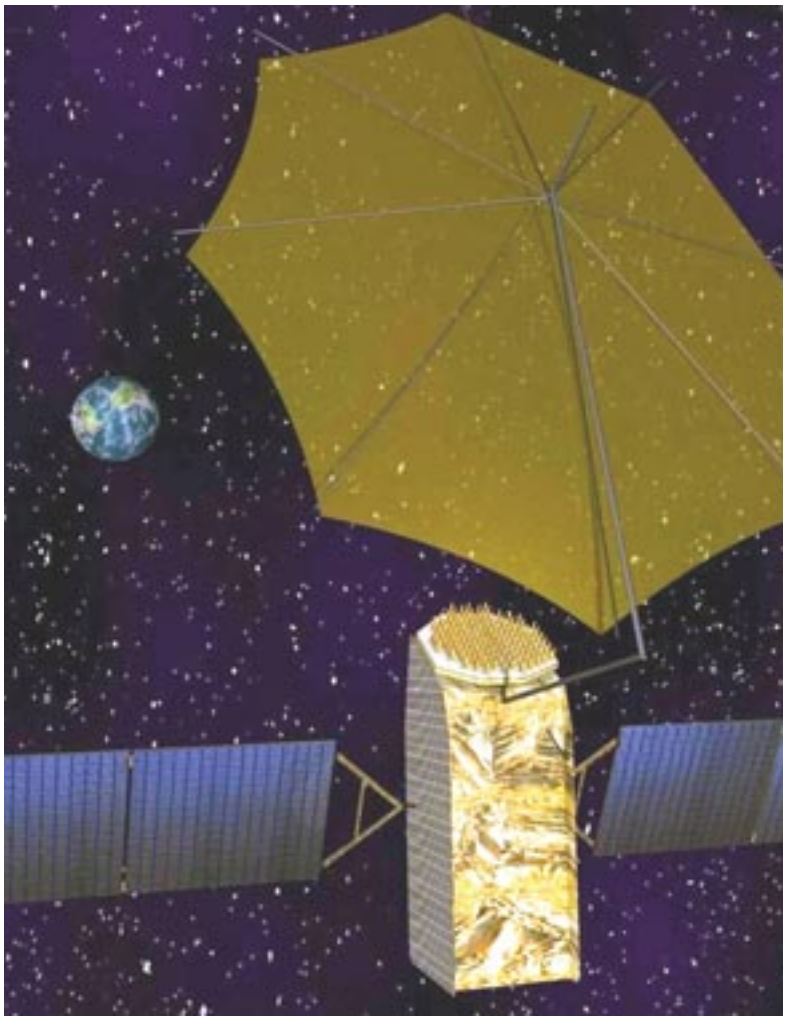
# LONG DISTANCE CALLS TO ROBOTS

Maintaining the International Space Station (ISS) will require frequent, complex inspection, repair and construction activities in free space. To limit space walks, which are the riskiest of astronaut tasks, specialized robots such as the Canadian supplied Space Station Remote Manipulator System (SSRMS or Canadarm-2) and the Special Purpose Dextrous Manipulator (SPDM) will be used. Controlling these robots, however, requires constant human supervision. The ability to control both the Canadarm-2 and the SPDM directly from earth would free precious astronaut time to accomplish important science experiments. The challenge then, is to conduct such remote robotic operations, also called tele-operation, while maintaining or enhancing crew safety.

To address this challenge, the CSA joined a collaborative team led by MacDonald Dettwiler Robotics (MDR) to develop the Interactive Intelligent Remote Operations (IIRO) Ground Control System. IIRO enables human operation of remotely located robotic systems over the Internet or via satellite links. The key technical components of the IIRO system includes: worksite modelling, integration of 3D vision sensor data, augmented reality task planning environment, complex motion script generation, rehearsal and editing with local autonomy capability plus playback and analysis of actual operation sequences. The IIRO system has been successfully demonstrated by an operator at the CSA's John H. Chapman Centre in Saint-Hubert operating, in real-time, a remotely controlled excavator at the Syncrude mine site (Alberta). This technology has become an important element of the growing terrestrial remote machinery market.

# MANUFACTURING LIGHTWEIGHT ANTENNAS

Devising a technology to manufacture large, lightweight satellite antenna structures in response to customer demands for lower mass, shorter delivery times, reduced technical risk and higher power handling capabilities, was the challenge that EMS Technologies, with CSA support was asked to overcome.



EMS Technologies, under its Mobile Mechanical Technology Development Program (MMTDP) developed new manufacturing techniques allowing for reduced manufacturing times while minimizing production risk. These innovations reduced the number of structural elements in the manufacture of large panels. By so doing, mass and manufacturing cost decreased at the same time. This new method also reduces the amount of post-processing of machined components, enabling faster turn around and improved relative cost of manufactured components.

These new manufacturing techniques were key to EMS being awarded a $25 million contract by ASTRIUM to supply antennas for INMARSAT 4, a satellite system that provides worldwide portable communication tools. They also played a major role in EMS winning a contract on AceS-2 mobile communications satellite, the follow-on program to AceS-1. Moreover, these new techniques are playing a major role in the implementation and execution of EMS's portion of the RADARSAT-2 program.

# SWITCHES FOR SATELLITES

Redundancy is required onboard satellites to overcome the inevitable failure of satellite components. Switches allow defective components to be replaced by functioning components. The CSA provided support for the development of switches for space applications at COM DEV.

COM DEV space of Cambridge Ontario, offers the largest range of space qualified coaxial and waveguide switches in the world, operating from UHF up to Ka-Band. These switches provide a lightweight, low loss and highly reliable means to perform redundancy or cross-connect functions. Waveguide switches have been designed to handle in excess of 200 watts of power, in a compact 130-gram package. The versatile T-Switch, weighing only 110 grams, is the most commonly used coaxial switch on communications satellites today.

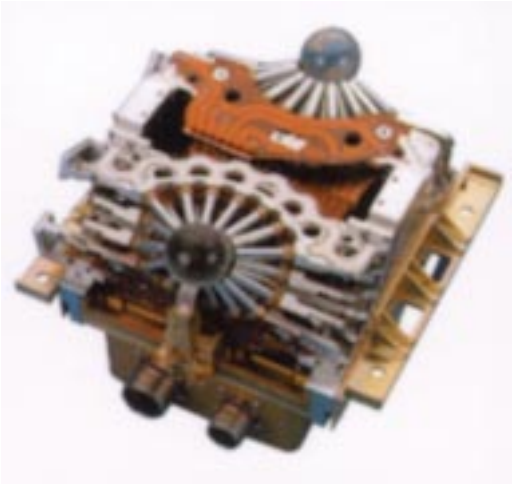
COM DEV was awarded a contract valued in excess of $25 million to provide switches and multiplexers for two of the world's largest communications satellites, being built by Astrium N.V. for INTELSAT. The two satellites will carry more than 200 COM DEV multiplexer channels and over 950 COM DEV switches. COM DEV has also provided space hardware for each of the previous 21 INTELSAT satellites.

COM DEV is an industry leader in switches, holding 60 to70 percent of the global market and several key patents for waveguide and coaxial switches. They have shipped more than 15 000 units with no in-orbit failure.

***Richard Kolacz, COM DEV Space,*** *"Funding from the Strategic Technologies Development Program is critical to ensure that Canadian Industry can develop the technologies required to compete in the global market place with countries that provide significant support to their space industries."*

# MOBILE ANTENNA

The continual demand for higher performance by customers has led to a new requirement for a combined (Tx/Rx) Transmission/Reception diplexed feed, whose performance hinges on the development of high power passive inter-modular (PIM) free diplexer and radiating elements.



The new diplexed feed technology replaces the separate feed approach of the previous generation of L-Band Antenna feeds. Wide-band radiating elements (helices and cup-patch) replaced the narrow-band predecessor (dipole), the diplexers replaced the bandpass filter (BPFs) and separate Tx and Rx feeds were replaced by a single feed approach. The resulting advantages for a spacecraft system is the use of one feed rather than two, hence requiring only one reflector instead of two. This solution offers performance gains while providing cost, mass and schedule savings for the satellite prime contractor. It also allows the flexibility of adding other payloads to the spacecraft.

The CSA provided support for mobile mechanical technology development under the Space Technology Development Program and for the development of a two-way satellite antenna system and new power-efficient technologies for mobile users under the International Mobile Satellite Communications Program.

EMS received a contract worth US$ 25 million from ASTRIUM to supply three combined transmit/receive antenna feeds for the INMARSAT Broadband Global Area Network program, with an option for two additional feeds. EMS' multi-element cup-helix L-band antenna feeds are considered to be one of the most challenging systems of the INMARSAT B-GAN Program. EMS is bidding with ASTRIUM on other potential mobile programs like Anik-F3.

# INTERSATELLITE LINKS

High data rate intersatellite communications will be needed in applications such as short range links between clusters of satellites in one or adjacent orbital slots, medium range links forming a network in LEO (Low Earth Orbit) and MEO (Medium Earth Orbit) constellations, and longer links between GEO (Geostationary Orbit) satellites. This requires optical intersatellite link or satellite to ground communications links with digital data transfer at 10 Gbps at ranges of 10 000 kilometres.

COM DEV and Ball Aerospace have formed a joint venture company: Laser Communications International, to cooperatively develop a family of OISL (Optical intersatellite links) terminals for commercial space applications. Early stages of the development were supported by the CSA.

Optical intersatellite links offer higher data rates than microwave alternatives. There is no requirement for spectrum approval and interference threats are minimal with laser communications. The OISL terminal consists of an optical head containing the optics; the pointing, acquisition and tracking subsystems, the transceiver and control electronics. A key element of the OISL development strategy was to use the BELCOR wavelength standard to take advantage of the rapid technological advances and economies of scale created by the terrestrial fibre optics industry.

Radiation testing and space qualifications of all the key components in the OISL have been successfully completed.

An OISL test bed was constructed and a test terminal built and successfully demonstrated acquisition, tracking and communications of four, fully duplexed channels operating at up to 2.48 Gbps, under simulated vibration conditions.

COM DEV is a leading global designer, manufacturer and distributor of wireless infrastructure and the largest Canadian-owned designer and manufacturer of space satellite hardware.

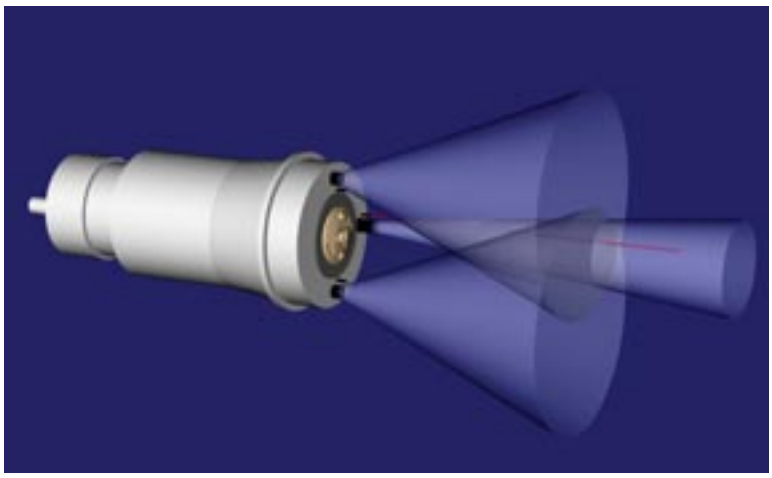
# OBJECT RECOGNITION AND POSE ESTIMATION

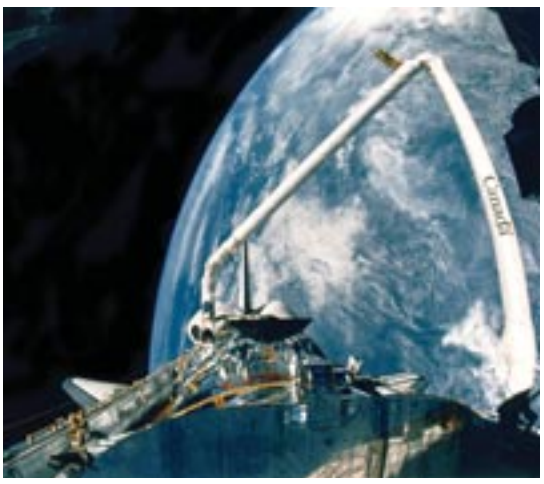
To perform tasks such as assembly, inspection and maintenance, space robots such as those that might be used to refurbish otherwise dead satellites, require real-time vision systems capable of acquiring and reliably processing three dimensional target data under extremely severe conditions of illumination.

In the vacuum of space, sunlit portions of an object are extremely bright, while shadowed portions are very dark. In addition, there is no softening of this contrast by light scattered by the atmosphere. As a result distance judgement and depth perception are difficult. The Object Recognition and Pose Estimation (ORPE) software toolkit, developed by MacDonald Dettwiler Robotics (MDR) in collaboration with the CSA, permits identification of an object, its position and its orientation, using 3D natural features and geometrical models.

The ORPE Toolkit processes stereo camera images to compute 3D data and includes stereo vision systems, contains no moving parts, is of low power and survives well in the space environment. Pose (position and orientation) is estimated in near real-time from full resolution images on a PC system. The ORPE software toolkit can also integrate data from other 3D imaging systems such as range finders.

The ORPE software system will be used in satellite docking operations and is ideal for autonomous robotic tasks, such as satellite servicing.







Canadian Space Agency | Agence spatiale canadienne

# STEERABLE ANTENNAS

IRIDIUM® intersatellite link antennas are to connect 66 low-earth-orbit satellites in a communications network. They will essentially "hand off" signals from one satellite to another, much like equipment in a ground-based cellular phone system.

COM DEV has developed a new design for the IRIDIUM® intersatellite antennas. This design provides two-axis beam steering in a small motion envelope at low price and, due to its unusual design that requires only one rotary joint, has low ohmic loss in the feed, and high gain for its size. This design is being scaled to a suitable aperture for wide bandwidth multimedia and data downlink applications. Larger size space qualified designs will be available in early 2001.

For the IRIDIUM® satellite system, COM DEV shipped more than 1,000 Ka-band antenna systems, which is a feat previously unheard of in the satellite industry. They have built more space-qualified antennas and commercial subsystem antennas than any other company.

The CSA enabled COM DEV to develop and build prototypes of the geared and direct-drive actuators required for the new antennas. CSA support has continued through the ESA (European Space Agency) ARTES-3 program, and COM DEV is now building an Engineering Model of a two-axis gimballed system that will be space qualified in 2001.

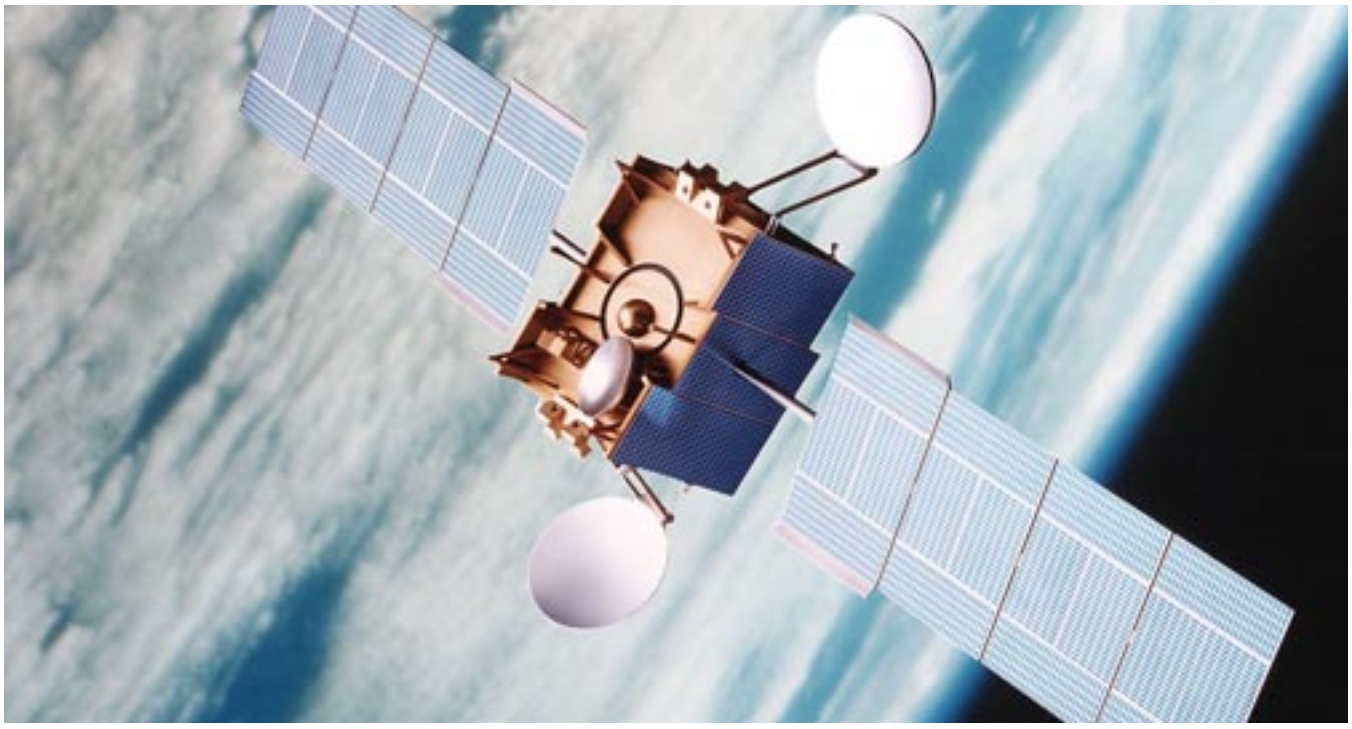
COM DEV has a strong capability in the field of antenna design largely focused on higher frequency, often gimballed antennas from C through V-band. The key COM DEV antenna capabilities are focused on: smaller mechanically steerable antennas for up/down/crosslink applications particularly at Ka band ; intersatellite links, both RF (Radio Frequency) and optical, and TT&C (Telemetry, Tracking and Command) antennas for telemetry data.

# NOT TO LOSE YOUR BEARINGS

Communications satellites must be accurately pointed at their receiving stations on earth or they become completely useless. In 1994, a severe solar storm produced very high levels of radiation which disabled both the primary and backup pointing systems of the Anik E2 telecommunication satellite. Without some sort of remedy, this failure would have represented a cost of hundreds of millions of dollars to the Canadian telecommunications industry.

The solution to this problem was an attitude (pointing) control system operated from earth using radio signals to operate thruster rockets to replace the original autonomous on-board system which used gyroscopic wheels to control attitude. This innovative technology, named the Ground Loop Attitude Control System (GLACS), was developed by Telesat Canada with CSA support. Within six months of the initial failure, GLACS brought Anik E2 back on-line, operating nearly normally, with 90% of its original life expectancy.

Telesat Canada now offers GLACS as a commercial product for the international satellite market. It provides redundancy or backup in the event of a partial failure, thus permitting otherwise crippled satellites to continue to function.



# ALL-OPTICAL INTERSATELLITE LINKS

One of the greatest challenges faced by communication satellite manufacturers is intersatellite communication. This requires a sharp and extremely quick "eye" as the satellites cross each other at high velocity. The current generation of space communications satellites use mechanically steered systems.

Recently, CSA researchers proposed the concept of combining dynamic holography and phase-conjugation elements in one system. With the collaboration of Passat Ltd, they demonstrated the feasibility of an all-optical intersatellite communications system that doesn't require sophisticated, expensive mechanical sub-systems. The system provides fully automated continuous direct and return beam tracking between communicating satellites.

The solid-state laser technology developed by Passat Ltd. has many industrial applications such as laser micromachining, microlithography, marking, engraving, cutting and drilling, and biomedical applications such as those requiring ultraviolet lasers.

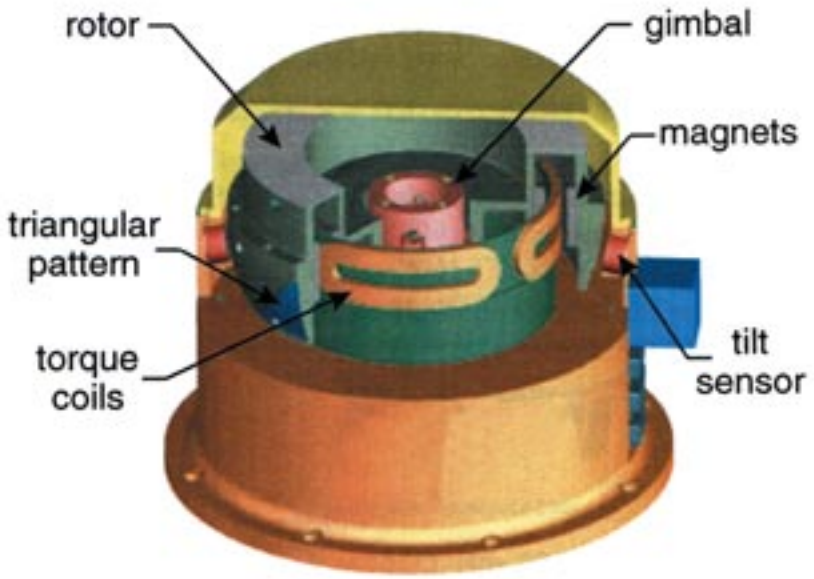
The technology development has increased know-how and led to new spinoff products. Passat has delivered laser systems to leading laser laboratories, such as the Idaho National Engineering Laboratory (USA), Defence Research and Evaluation Agency (UK), Commissariat d'énergie atomique (France) and the Japan Atomic Energy Research Institute. Spin-off applications include self-adjustable signal feeding for fibre optic communication networks and advanced air-to-ground, air-to-air communications.

# KEEPING SATELLITES ON THEIR TOES

With constellations of small cheap satellites entering the communications market, a technology essential to their success is the system to control their attitude pointing. This subsystem must precisely target a ground receiving station while correcting for effects in orbit which would perturb this accuracy, and must do so cheaply, reliably, and ideally consume little power and be lightweight.

Bristol Aerospace Ltd., with CSA support, developed GyroWheel™, an innovative multi-functional device that provides 3-axis attitude control and precise measurement of spacecraft angular motion, allowing for fine pointing attitude control.

GyroWheel™ provides significant reduction in mass, power and cost over conventional fine pointing attitude control systems. One GyroWheel™ can do the work of 3 or 4 conventional momentum wheel actuators and separate gyros, and is about the same size, mass and power as a single momentum wheel. The rate sensing ability allows for 3-axis pointing using relatively inexpensive and small earth horizon sensors. In addition, it can provide high bandwidth attitude data during spacecraft manoeuvres.



# HIGH PERFORMANCE BATTERIES FOR SPACE

A significant result of the trend towards larger capacity communications satellites is the need for the spacecraft themselves to be able to generate more power. These new satellites will generate power in the region of 20 kilowatts as compared to current systems in the 5 kilowatt range. The CSA is supporting a scale-up of technology from the 100-watt class to kilowatts, which addresses the physical packaging design of a large battery module.

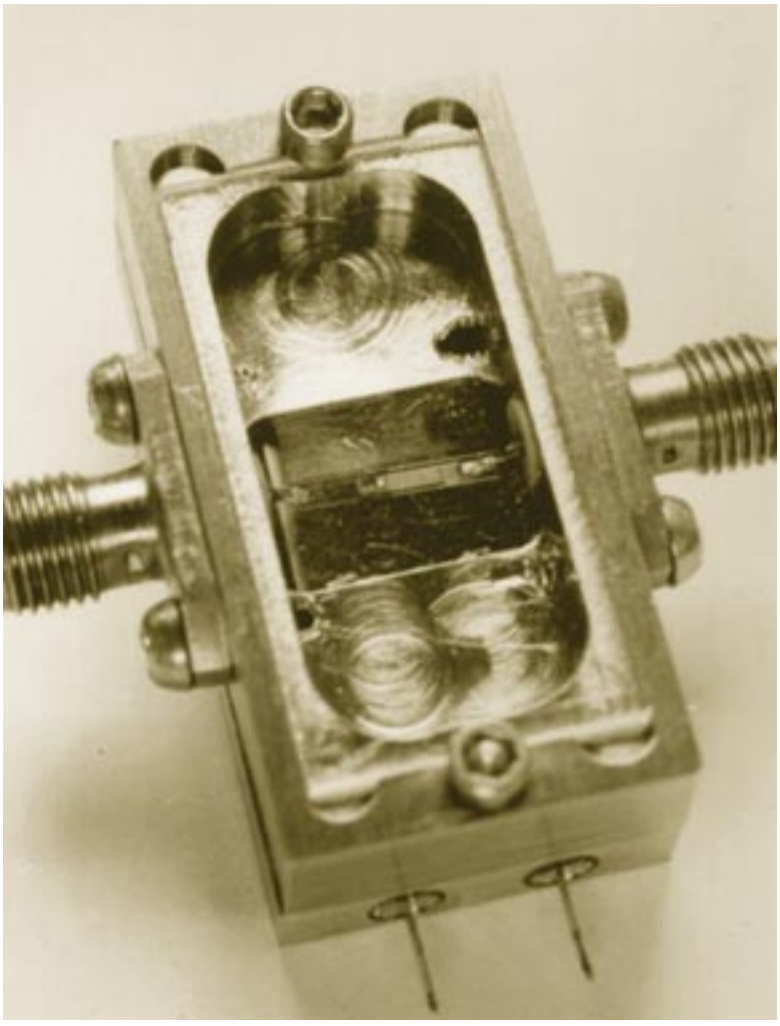
These large battery modules are required to provide electrical power to satellites during periods when the demand for power onboard the satellite exceeds the ability of the solar arrays to generate sufficient electrical power. For example; during launch, ascent and early orbital operations, before the arrays are deployed, during eclipse periods and during periods of peak payload power demand.

To meet this demand, COM DEV is developing a Lithium-ion battery for satellites. The Lithium-ion battery system provides large mass savings per satellite, resulting in substantial cost benefits. The battery uses uniform, reliable cells that require no cell-level power management electronics, thus providing a further mass saving over competing systems. Lithium-ion batteries are smaller, lighter and can provide more power than the batteries currently in use, giving satellite operators the option of building smaller less costly satellites, or increasing the satellite payload. On a large satellite savings can be in excess of 100 kg.

As a result, COM DEV has received a great deal of interest in this product from major satellite contractors around the world. The first flight for such a battery manufactured by COM DEV will be in the Canadian SciSat program.

# MICRO SWITCHES

With the high cost of sending a spacecraft into orbit due to its weight, small and lightweight technologies are being developed in every field of satellite construction. And what is more common in these state-of-the-art machines than switches?



Indeed, many spacecraft applications specifically call for microwave switches of very high reliability at a substantial reduction in mass and volume. CIS Scientific Inc.'s micro-electromechanical microwave (MEM) switches offer the low insertion loss and high power handling capability of conventional electromechanical switches at the reduced size, mass and power requirements typical of solid-state switches. MEM switches can also be easily integrated into surface mounted microstrip Microwave Integrated Circuits (MIC), Miniature Hybrid Microwave Integrated Circuits (MHMIC) and coplanar waveguide structures. Two US patents have been awarded to the company on MEM technology.

CIS Scientific Inc., a young and dynamic company whose main Research and Development activities include the development of MEM devices and devices for photonic applications, was supported in these activities by the CSA. Under its partnership with CSA, CIS scientific has developed an association with the National Research Council (NRC) and with COM DEV, a major manufacturer and distributor of switches for satellite applications. The switch developed by CIS scientific has the potential to replace mechanical and pin diode switches, which are presently used on satellites.

# SATELLITE POWER CONDITIONERS

One of the greatest challenges of spacecraft component design is improving size, mass and efficiency, and reducing costs without compromising the quality and reliability of the products. It is a challenge taken up by corporations like EMS Technologies Inc., a leading provider of wireless and satellite communications solutions, with a growing emphasis on broadband applications. EMS focuses its unique range of technologies on the needs of broadband and mobile-information users.

One of their products is a state-of-the-art family of DC/DC (Direct current to direct current) electronic power conditioners for space applications, which incorporates the latest advancements in design techniques, components and packaging.

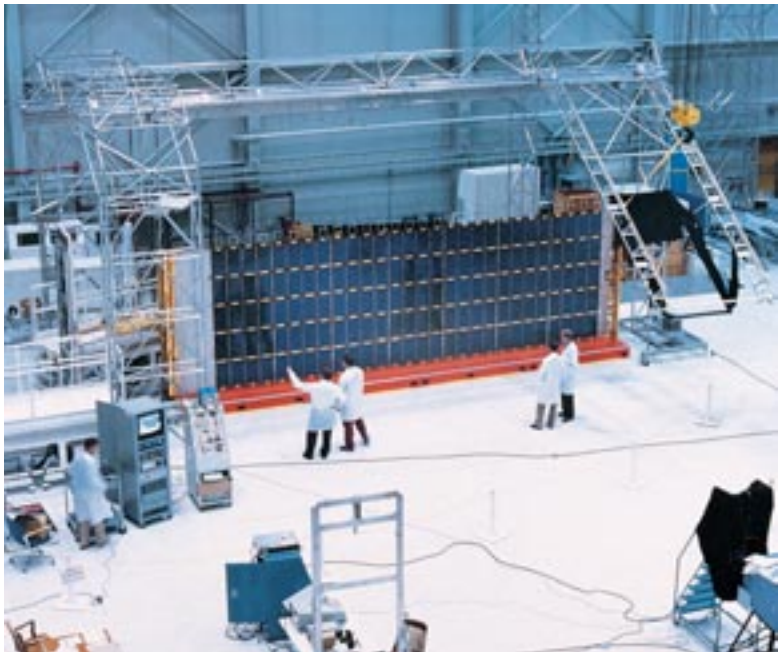
EMS has designed and developed space-qualified power conversion and motor drive units. These include low power EPCs (Electronic Power Conditioners) for Receivers, Up and Down converters, Modulators, Local Oscillators and High power EPCs for SSPAs (Solid State Power Amplifiers) and Digital units. Designed to minimize electromagnetic interference and to provide good audio rejection as well as sequencing (when required), EMS power conditioners provide efficiencies among the highest available in the industry.

EMS has partnerships in place with many customers across the world to supply power conditioners. Their power conditioner designs are the result of many years of research and development, indirectly funded in part by the Canadian Government and the CSA through a number of programs from Anik-E to Advanced Satcom.

# SEEING THE LIGHT

In space, with no cloud or atmosphere to shield them from the rays of the sun, materials must be especially designed not only to last, but also if possible, to use these rays to advantage (as with solar arrays). Surfaces are often so tricky that we need highly complex tools to better understand the behaviour of light as it impinges on these. Stellar Optics Research International Corp.'s (SORIC) took up the challenge and developed SOLEXIS.

SOLEXIS™ is a data resource and selection tool for black, white, reflective and transmissive surfaces and materials used in ground and space-based applications, giving fast access to data for materials used in stray light control, thermal control, calibration and visual target cues.



SORIC gathered data from all significant sources of optical scatter data in North America and now has the world's largest collection of scatter data in the world (about 60 000 data curves). This is the first time that optical, scatter, thermal, and other data have been available in an expert, versatile, comprehensive and user friendly database.

Application areas include targets, visual cues and display systems; radiometers, radiators, reflectance standards; thermal blankets and cold shields; room and instrument enclosures and curtains; as well as mirrors, lenses, prisms and crystals. Materials covered by this project are paints and primers, laquers and varnishes, bulk materials: metals and alloys, glasses, polymers, ceramics, glass composites and more; films, foils, tapes, meshes; fibres, papers, textiles, fabrics, dyes, inks, marking materials; surfaces and films created by processes such as: anodization, electrodeposition, plasma spray, chemical vapour deposition, vacuum, and many more.

The CSA provided funding for a feasibility study and for data acquisition. SORIC specializes in products and services related to black, white, reflective and transmissive surfaces and materials employed and viewed by ground and space-based instrumentation. Founded in 1993, it offers advanced technology and expertise and solves complex problems for its customers in the aerospace, space, defence, astronomical and scientific markets worldwide.

***Sue McCall, Vice President, Stellar Optics Research International Corp.,*** *"The SOLEXIS project would not have been possible without CSA support."*

# TRANSPONDERS: LINKING SPACECRAFTS TO THE WORLD

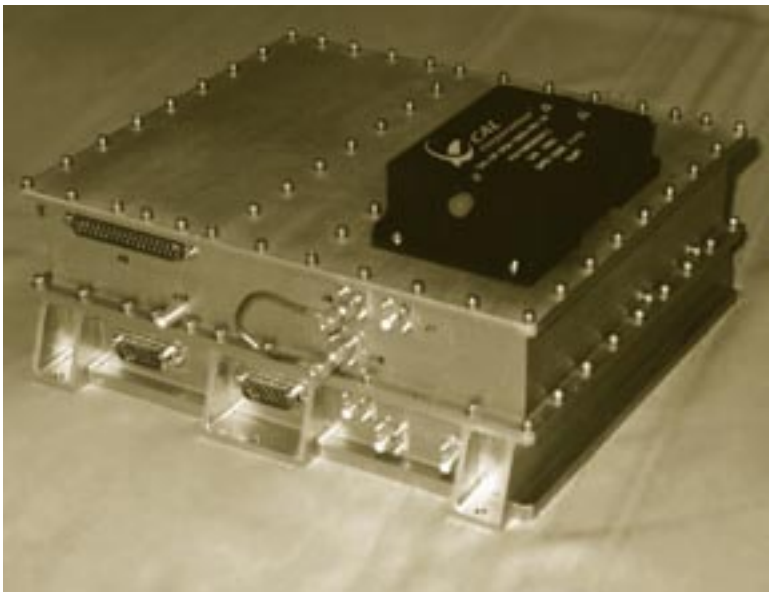
Communications with spacecraft support the downlink of telemetry, tracking and control and safe operation during launch. A basic hardware element of such a communications system is a transponder, such as the state-of-the-art S-band transponder, developed by EMS Technologies.

The Small User Transponder was developed originally under the Canada-ESA (European Space Agency) Partnership Program of the CSA to be readily adaptable for a variety of users. It provides both direct communications with ground systems and with NASA satellite communication networks TDRSS/DRS (Tracking and Data Relay Satellite System / Data Relay System) and DRTS. Direct to ground operation is compatible both with STDN (Spaceflight Tracking and Data Network) and ESOC (European Space Operation Centre) networks. FEC (Forward Error Correction) is also provided, using convolutional encoding.

EMS S-band transponders are the heart of NASDA's H-II Transfer Vehicle (HTV) communications system, and will be part of the avionics suite supplied by Mitsubishi Electric to support vehicle control and telemetry. A pair of transponders will be installed on the Japanese Experiment Module element of Space Station to provide communications to the HTV as it comes into proximity of the Station. The second transponder pair, installed on the HTV, will provide the other half of the Space Station link. The third transponder pair, also installed on the HTV, will provide the communications link between the HTV and ground control through the Tracking and Data Relay Satellite System, which will provide the coverage necessary to ensure safe operation of the HTV during launch and Space Station docking manoeuvres.

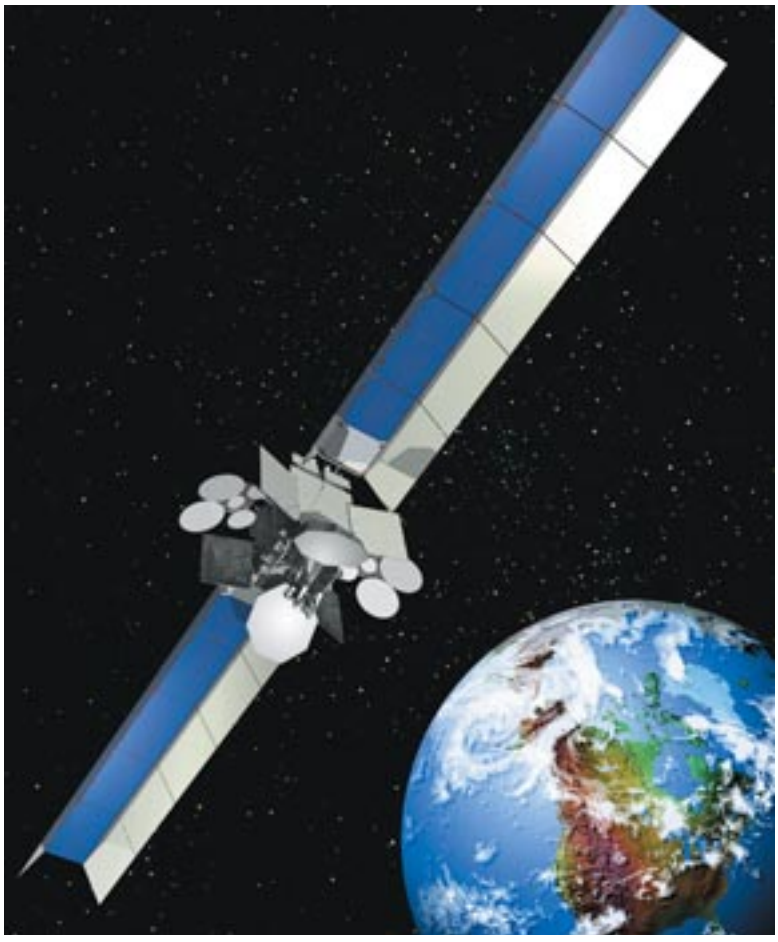
Nine S-band Transponders will be delivered to Mitsubishi Electric Company for supporting the International Space Station for a total value of $9.5 million with potential follow-on orders for up to 40 more units. Production of the transponders will add up to 10 new engineering and support jobs to the company's workforce.

EMS Technologies provides state-of-the-art global telephony, direct broadcast television, and data communications antenna products and systems for private and commercial aircraft. EMS Satcom also offers a wide range of terminal products and system solutions for data communications and specialized applications for current and future communication satellite users.



# Ka-BAND MULTIBEAM ANTENNA TECHNOLOGY

Today's communications satellites must service several customers simultaneously in very different geographical locations. One way to do this is to use multibeam antennas. The performance of such antennas is limited by the inability to efficiently illuminate the aperture with relatively small, closely spaced, feed elements, thus producing a relatively broad primary pattern.



To overcome the performance limitations of multiple beam antennas using a single element per beam, EMS Technologies devised high-directivity efficiency feed elements for high-frequency multibeam reflector antennas. The innovative feed element technology developed, with funding from the CSA, allows for significant RF (Radio Frequency) performance improvement, notably on gain and sidelobe isolation.

EMS has developed high efficiency feed elements that achieve the directivity of physically larger conventional feed elements, and thus significantly increase antenna performance. Feed performance can also be tailored for a specific application. A broad range of alternate feed elements has been developed and fully qualified to address different sets of requirements. The parameters to be optimised include: directivity efficiency, cross-polar performance, return loss, bandwidth, etc. Combined Tx/Rx operation can also be supported. The directivity efficiency ranges from 75% to 100% in the array environment, depending on several factors. Typical secondary pattern improvements are in the order of 0.5 dB for edge-of-coverage gain and an impressive 4 dB for sidelobe isolation.

Ka-band multibeam antenna technology was the key to EMS winning the Anik F2 Ka-band antenna contract. The performance improvements obtained with these feeds, combined with other enabling technologies acquired on the Koreasat-3 and Astra-1K Ka-band antenna programs, has solidified EMS' leading position in Ka-band antennas.

# UNDERSTANDING AND DESIGNING FOR THE SPACE THERMAL ENVIRONMENT

An efficient thermal design in terms of mass and electrical power is essential for every space mission. This requires the capability to perform accurate thermal analysis of space mission and space hardware.

CSA supported MAYA Inc. of Montreal for the development of some special features of a thermal analysis software package called TMG. This is a comprehensive thermal analysis package, which makes it easy to very accurately model the heat transfer of complex mechanical structures.

In order to compete effectively with thermal analysis codes sponsored by NASA and ESA (European Space Agency), MAYA had to deliver exceptional modelling capabilities and leading-edge numerical technology. The CSA's support in co-funding the riskier and more ambitious elements of MAYA's Research and Development program enabled the company to significantly accelerate the pace of its development efforts and thereby achieve technological superiority versus its main competitors in the space industry.

TMG is now the world's best, most efficient and most accurate software for thermal analysis and design and has become the standard tool for thermal analysis within the Canadian space industry. It has also been adopted by industry leaders: Boeing, Lockheed Martin, Matra-Marconi, and Aerospatiale, and is used on a wide range of programs (including RADARSAT, MSAT, GPS, SOHO, Space Station, NGST). Many spin-off opportunities exist in other markets, including automotive, electronics, and medical. The company has grown in size from only a few persons to 60 over the past 4 years.

# CONTACTLESS MEASUREMENT OF VIBRATION

Space structures, particularly large antennas and spacecraft are lightly built and prone to vibration caused by environmental effects, potentially causing degradation of performance. To control or reduce these vibrations it is necessary first to measure them in such a way as to not interfere with them. One approach to do this is to use lasers to measure displacements of a structure without actually touching it.

With conventional technology, simultaneous multi-point measurements of vibration require the use of bulky and complex systems made up of numerous laser vibrometers. These are limited to directing measurement beams at specific single points on structures. They also require considerable set-up time for different targets.

MPB Technologies Inc.'s MCFVIB is a Multi-Channel Fibre Optic Laser Vibrometer for measuring the displacement and velocity of vibrations using non-contact optical interferometry. It can make remote, non-contact measurements of structures under analysis, thereby eliminating any alteration of vibration by the weight of the device. This system uses advanced fibre optic switching technologies to provide multi-point, high-speed beam distribution from a single channel commercially available vibrometer. A special fibre optic signal distribution simplifies system reconfiguration for different target requirements. MCFVIB provides structural specialists with an effective and economical system that eliminates the restrictions of conventional systems and provides new measurement possibilities.

Technology development was initiated and supported by the CSA. MCFVIB will enable the Agency to develop world-class expertise in the dynamics characterization and design of large space structures, thereby giving Canadian satellite manufacturers a substantial competitive edge in international markets.

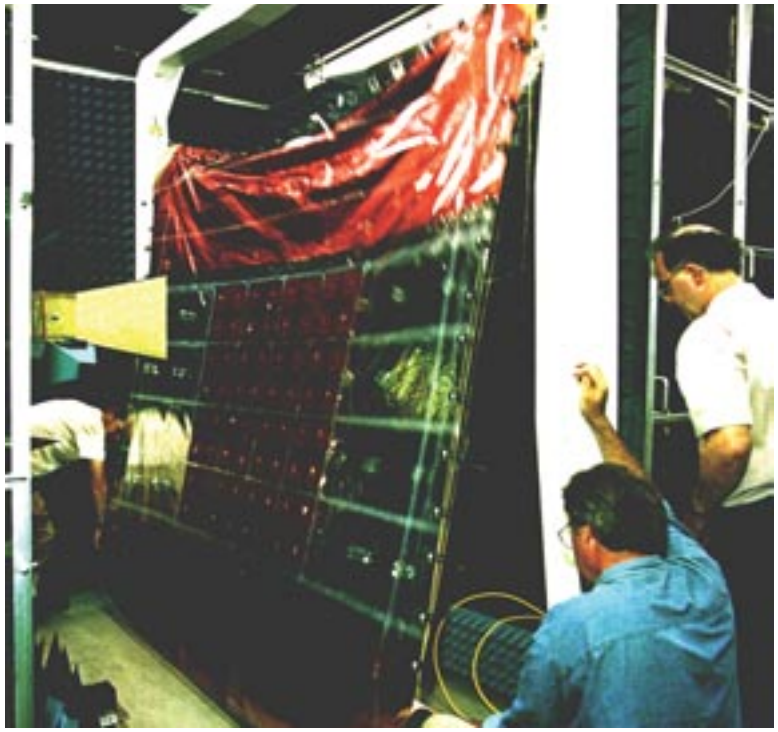
# DEPLOYABLE DOUBLE MEMBRANE ANTENNA

Synthetic Aperture Radar (SAR) Satellites such as RADARSAT-1 and 2 carry a SAR antenna, which has a mass of almost 800 kg and occupies a stowed envelope close to 7 cubic meters. This is an important driver in the choice of the size of the spacecraft, as well as in the choice of a launcher. The cost associated with a satellite of this mass makes it difficult to self-finance the SAR operation. A SAR membrane antenna offers the possibility of constructing extremely lightweight, large aperture spacecraft antennas, having a very small stowed volume (perhaps, less than 100 kg mass and 1 cubic meter stowed volume). This type of antenna could be implemented on a small satellite, with a total mass of less than 1000 kg, at much lower cost.

To answer this challenge, EMS Technologies Inc. has designed a deployable double membrane (DDM) antenna which can be stowed folded within a small canister, and deployed when in orbit by cords attached at the membrane edges.

EMS has developed two different types of membrane antenna; colan the lens type, and the direct radiating type. For the lens design there is a separate feed or feed array which illuminates the input membrane surface. Individual membranes realize the input and output faces of the lens. These membranes are populated by a special variant of a microstrip patch. Bootlace line circuits interconnect adjacent patches on the input and output membranes, and provide the phase adjustments to focus the lens. To simplify assembly, there are no soldered joints, and the bootlace circuits snap into place with a capacitive connection.

This new technology, which has been sponsored by the Canadian Space Agency, provides a leading edge to EMS in the field of array antennas. As a result EMS is well positioned to provide SAR antennas and large array antennas for future missions, making use of small platforms. Several customers, including the United Kingdom and Argentina, have approached EMS to make use of this technology. Japan has also expressed an interest in the concept for a follow-on mission to their Advanced Land Observing Satellite (ALOS).




# WORLD-CLASS RESEARCH

# UNDERSTANDING THE ATMOSPHERE

Whether atmosphere used for weather forecast or for ozone monitoring, satellites are invaluable for observing the atmosphere and to perform these activities, they require special viewing instruments.

The Canadian Space Agency supported the development of a Michelson interferometer based instrument for the ESA ENVISAT satellite as part of the first Polar Orbit Earth Observation Mission Program (POEM-1). This device will provide a better understanding of the Tropo-, Strato- and Mesospheres. The instrument can measure up to 20 trace gases as well as the distribution of aerosol particles in the atmosphere.

This project enabled ABB Bomem to be a major player in a large space program by applying its expertise in Fourier transform spectrometers. ABB Bomem also developed the optical ground support equipment, the ground segment software and the instrument simulator software for this project.

On the weather side, ABB Bomem is also developing the Cross Track Infrared Sounder™ (CrIS) which will measure temperature and humidity profiles in the atmosphere for accurate long-range weather forecasting. As a result of this work, in early 1999 ABB Bomem completed a $1.75 million contract with ITT Aerospace & Communications of Fort Wayne, Indiana for the preliminary design of the main subsystem of the new generation of infrared sensors for weather satellites. In the fall of 1999, the ITT team, including ABB Bomem, won the competition for the follow–on contract for the production of several units. For ABB Bomem, this represents an opportunity of about $15 million.

# SMART STRUCTURES

One of the challenges in space is to reduce the weight of space structures while maintaining their shape and resisting vibration. To address this challenge, a smart structure uses sensors, actuators and intelligent control mechanisms to sense and respond to stimuli in a predetermined manner. The structural materials can be light and flimsy and thus vulnerable to deformation and vibration, but these effects are mitigated by active control. Smart structure technology also has applications in many terrestrial systems including active vibration suppression in automobile suspensions, noise cancellation systems, intelligent bridges and buildings and smart skis.

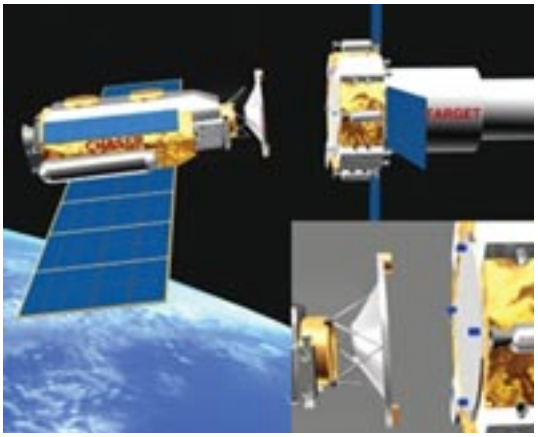
Through a CSA program, SensorTech has developed piezoelectric-based smart structures, a technology that allows lightweight structures to meet the challenge of maintaining their shape and resisting vibration.

Three smart structure components, the Active Strut Member (ASM), the Active Structural Panel (ASP) and the Smart Control System (SCS) were developed under this program. This technology has been successfully demonstrated in the laboratory to maintain the shape of a large parabolic reflector in spite of distorting influences. These developments will make it possible to have, in the future, extremely large structures in space for applications in the areas of high-speed communications, solar power and solar sails.

# DYNAMIC CONTACT

A great proportion of the tasks a robot is expected to perform require that it seize an object or in some way makes contact with its environment. Precisely controlling this interaction is difficult at the best of times, and much more so in space where human supervision is difficult and sometimes impossible.

To address this problem, the Contact Dynamics Toolkit (CDT) was created. This software library is used for the modelling and simulation of intermittent contact/constrained dynamics of mechanical bodies, particularly robots. This technology was developed by MD Robotics in collaboration with the CSA and is incorporated to the International Space Station (ISS).



The CDT models the dynamics of contact as slightly resilient points of contact including friction, kinematic constraints and contact forces. It also includes precise geometry of the contacting surfaces.

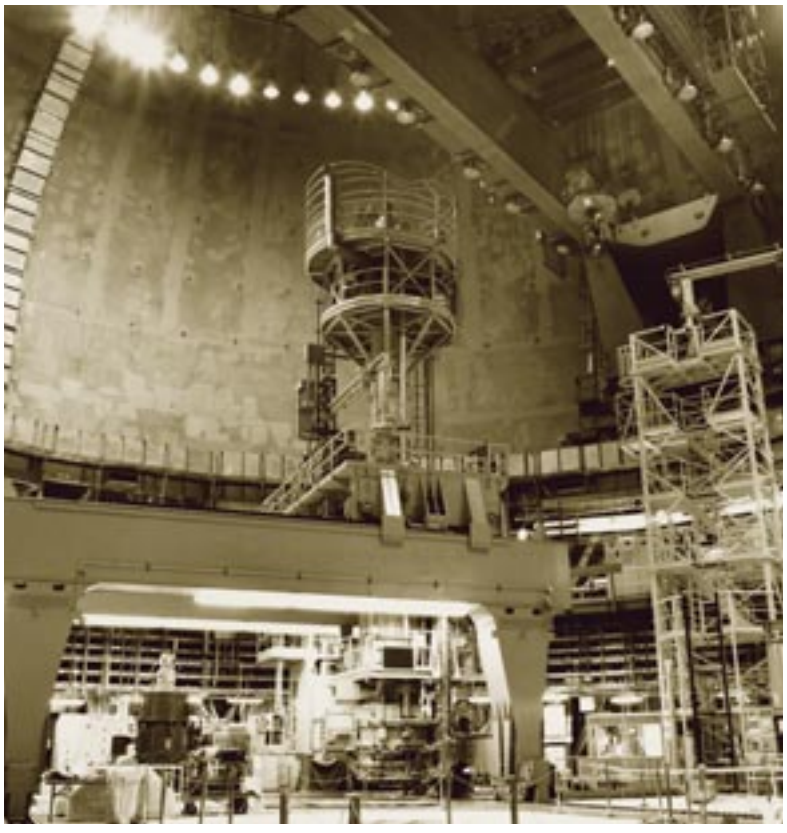
The CDT was instrumental in the development of the Canadian robotics program for the Space Station and resulted in a contract with NASA for its incorporation into the Canadarm simulator for the space shuttle. It will play a major role in the selection of technologies for satellite docking and capture systems for the ISS.

# IMPROVING ON ISAAC ASIMOV'S FIRST LAW OF ROBOTICS

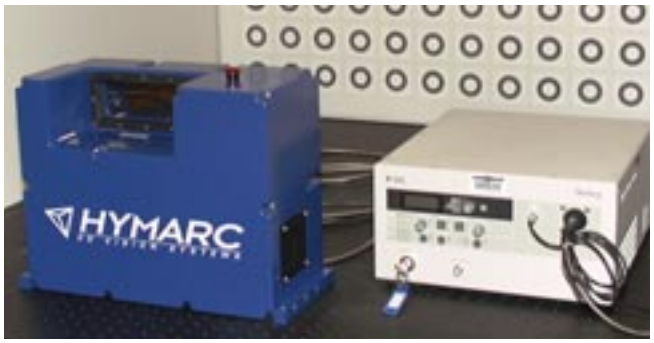
"Robots will not harm humans either through their actions or allow humans to come to harm through inaction". Asimov's statement surprisingly captures a crucial element of robotics: safety. However, in the context of space robotic operations this statement alone does not suffice, and one should add "or through malfunction". The quest for safe robotics systems imposes stringent requirements on every design and operation level. Of fundamental importance are questions such as: what if this component fails? The challenge then is not only to design a robotic system safe under normal operation, but also to build in fail-safe features for unpredictable malfunctions/events in sophisticated robotics systems operating in harsh environments.

The CSA funded Atlantic Nuclear Services Ltd., which specialises in nuclear reactor safety, to develop remote monitoring and diagnostic technologies as well as formal design methods to address this challenge.

Atlantic Nuclear Services Ltd. has developed two specific products for this application. The first, IRMAD, is a remote monitoring and diagnostic system that integrates sophisticated signal processing techniques, analytical models and machine intelligence for monitoring and diagnostics in support of remote command and control of systems and equipment. The second product, AVAT, is a tool for software development using a tabular methodology for the software requirements and specifications which ensures that the developer establishes a software architecture that can be easily verified and validated.



# AVOIDING COLLISIONS




As humans, we rely on our eyes to guide us as we move around, unconsciously avoiding obstacles and selecting a path to our destination. This comes so naturally to us that we do not think of all the complicated steps in the process. Only when one tries to teach this simple skill to a machine does he or she grasp the complexity of the task.

In space, with the Canadarm or the Canadarm-2, and even on earth, complex robots must be capable of sometimes acting without supervision, and must certainly not crash into obstacles. One aspect of the challenge here is the imitation of certain human perceptions, particularly that of sight.

RapidScan™, an automated laser digitizing system which includes a vision component, real-time path planning and collision avoidance, addresses this challenge.

RapidScan™ provides a selection of automated digitizing strategies to handle the complexity of real-world digitizing tasks. Using a surface model constructed from coarse scans of the object, RapidScan™ automatically tracks object contours to deliver high quality surface data in record time.

Developed by Hymarc Ltd. with support from the CSA, RapidScan™ has applications for space vision systems and robotic controls as well as terrestrial scanning of objects to create digital models. As it is automated, the digitizing process does not require continuous operator attention.

As a terrestrial application of this technology, Karmann, the German automotive designer, uses a version of RapidScan™ to automate the digitizing of full-scale car models.

# DEEP SPACE COMMUNICATIONS

The CSA's Canada-ESA (European Space Agency) Partnership Program supports Canadian corporations in their international endeavours. One such example is SED Systems, a division of CALIAN Ltd., which designed and built a 35 meter antenna system to be installed at ESA's facilities near Perth, Australia, in late 2001 for ESA's Rosetta program. This is an antenna system capable of communicating with the spacecraft at a distance of 900 million kilometres, more than six times the distance from the earth to the Sun. It will send commands and receive status and scientific data transmitted by the Rosetta spacecraft as it undertakes its exciting mission to encounter a comet in deep space.

This 35 meter diameter antenna will be one of the largest in the world used for deep-space telemetry, tracking and command applications. A powerful 20 kilowatt transmitter will be used to send signals to the distant spacecraft, and receiving amplifiers will operate at 15 degrees above absolute zero (-273 degrees C) to pick out the weak signals being sent back from deep space. Because of the distance, communications from the earth to the spacecraft and back again could take as long as 100 minutes, even though the signals will be travelling at the speed of light. The entire mission lifetime is 10.5 years.

SED provides systems and services for testing, operating and managing satellite systems. This $23 million contract from the European Space Agency is the largest contract ever awarded to a Canadian company under the General Budget of ESA.

# WEIGHTLESS CONTAINMENT


One of the difficulties in the development of new materials is that the processing container itself can affect the material by contamination or uneven temperature. In addition, gravity affects crystal formation. Without gravity, materials could be developed vastly different from those we know today. If the processing could be done under weightless conditions somehow containing the material, the potential for advanced material development would be tremendous. This is precisely what Guigné International Ltd. has done with Space-DRUMS™(dynamically responding ultrasonic matrix system) a technology which provides the international community with a containerless processing facility for materials such as glasses and ceramics, significantly larger than its predecessors.

With CSA support, Guigné has experienced substantial and increasing scientific and economic growth, from its base in Paradise, NF, and has expanded to include offices and laboratories in St. John's, California, Alabama and Germany.

The Colorado School of Mines selected Guigné, who joined forces with companies such as SPACEHAB, Teledyne Brown Engineering and Astrium-Space Infrastructure, to fly a Space–DRUMS™ payload on the International Space Station (ISS) as a Commercial Payload.

The advanced materials developed on the Space Station will have limitless applications from aircraft parts to computer chips and fibre-optic cables for telecommunications.

***Dr. Jacques Yves Guigné, President and CEO, Guigné International Ltd.,*** *"Our company has received from the CSA immediate benefits which far surpass any financial return. What was significant to our company was the substantial and accelerated scientific growth felt by our team. The expansion of our hardware and software engineering capability, the recognition received by our international peers and the rapid placement of our small science-based company into a very diverse marketplace are some of the benefits felt."*


# LOOKING FORWARD

*It is a cliché to talk of the future as being upon us. But many of the technologies presented here are indeed soon to be available to us.*

*For example, imagine this: a farmer sits in his office, analyzes what his crops needs, gets a long term weather forecast, then uses robotic technology operated from his office to apply fertilizer and water as needed. Or a technician accesses a dangerous waste management system, identifying himself with his fingerprint, from the comfort of his own home. The system is fully automated, from waste manipulation to the detection of leaks, to the analysis of the best container configuration.*

*All these scenarios are within our grasp, the changes taking place in our society, bring space technologies and their benefits ever closer to Canadians. Robotic technologies, telecommunications, medical instrumentation and environmental monitoring are among the many ways that space is playing a role in improving the quality of life here on Earth. The Space Technologies Sector is ensuring that this trend continues, by investing in our Future.*


# CONTACTS

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