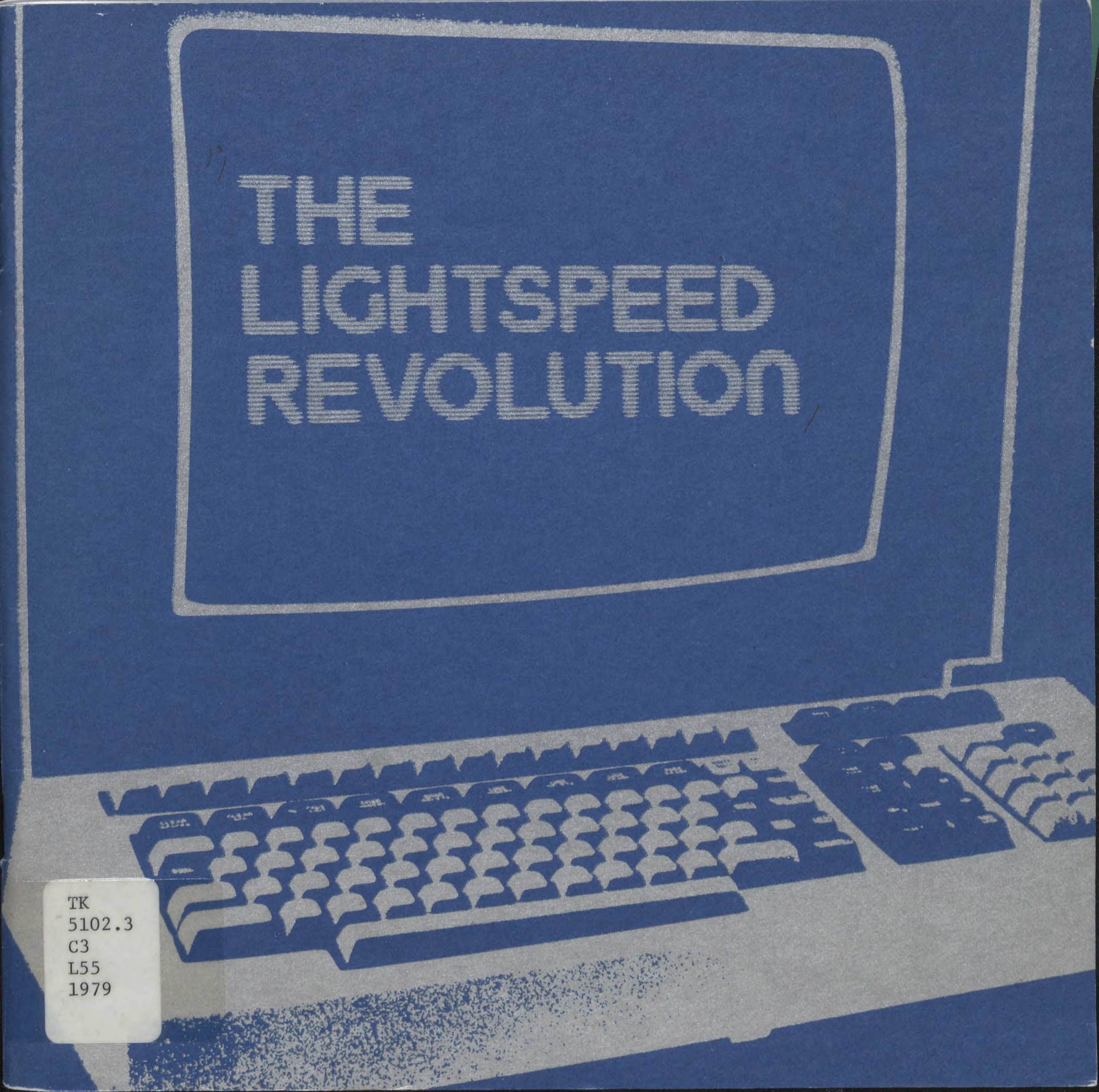
THE LIGHTSPEED REVOLUTION



Government of Canada
Department of Communications

Gouvernement du Canada
Ministère des Communications

You are now entering the lightspeed revolution.

Communications travelling at lightspeed are changing the way you shop, bank, gossip, play, learn and even think. They are also shrinking the world dramatically. The global village is no longer prophecy.

This is your guide to that revolution.

Here you'll learn about new satellite developments which may bring television programs from every country in the world right into your home. You'll come to understand better the invisible airwaves which bring you news and entertainment every day. You'll discover new telecommunications developments which may transform your life.

The 400 scientists and technicians at the Communications Research Centre (CRC) are living the lightspeed revolution. If their research seems futuristic, remember that much of Canada's material wealth comes from our telecommunications industries — telephone, broadcasting, cable and mobile radio.

Much of the research is intended to make sure this Canadian industry remains innovative and able to compete in the burgeoning world telecommunications market.

The work done at CRC is not only bringing tomorrow closer to today. Inventions, developments and findings of CRC researchers are transferred to industry, so that Canadian companies and Canadian workers benefit.

The Department of Communications (DOC) is also trying to respond to the reality of Canada — a country vast in size and divided by formidable geographical barriers, with a people widely scattered and from many different cultures. It is working to ensure that in the future, every Canadian, whether here in the South or the remotest reaches of the Far North, can participate in the national telecommunications network.

With the dramatic new services now emerging, we may soon become active originators of our own electronic entertainment and information services. A whole new dimension of self-expression may redefine the Canadian reality.

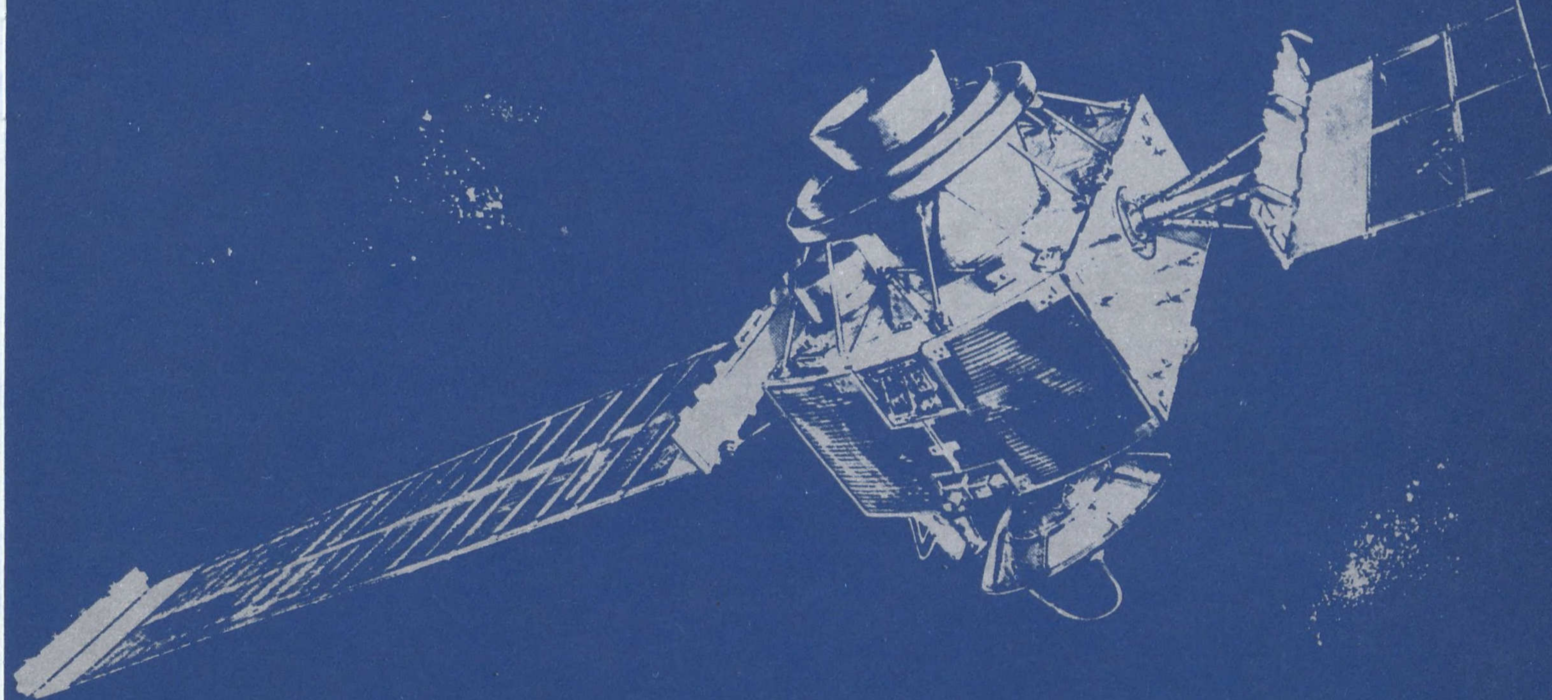
In short, the lightspeed revolution may change us in ways we never expected.

Design

HEWSON • BRIDGE
ASSOCIATES LTD

Ottawa, Canada

Contents



SPACE

Satellites: the world-shrinkers

As satellites drift through the icy vacuum of outer space, they're bringing us all together at lightspeed.

Already many cross-Canada telephone calls and most international telecommunications, including television broadcasts, pass through satellites. In the future, more and more telecommunications services will come to depend upon them. And, with each new satellite application, the world will shrink a little more.

A Canadian space odyssey

When the Canadian Alouette I satellite soared into space in 1962, only the Russians and Americans had been there before us.

Since that time, Canada has maintained its lead in space technology and communications. We now have eight satellites orbiting the earth, with another soon to be launched.

Much of the necessary expertise and laboratory facilities for these endeavors is here at CRC.

The electromagnetic mappers: scientific satellites

The mission of Alouette I, designed and built at CRC, was to map the ionosphere — the region of electrically charged particles beginning about 56 km above the earth.

The ionosphere is controlled by the earth's magnetic field and by solar influence. It is closely related to the shimmeringly beautiful northern lights. It also has both helpful and frustratingly disruptive effects on radio communications.

Only a satellite circling the world at a high altitude can provide an accurate global picture of the different times, places and radio frequencies subject to ionospheric disturbances. This knowledge is important in improving radio communications, especially in northern latitudes.

Thus, in co-operation with the U.S. National Aeronautics and Space Administration (NASA), Canada launched Alouette II in 1965, ISIS I in 1969 and ISIS II in 1972.

All worked perfectly and information is still being received.

The space-talkers: commercial operational satellites

Canada was the first to launch into geostationary orbit a commercial communications satellite for domestic use. The satellite — Anik I — launched November 1972 was later joined by Anik II and Anik III.

The Anik satellites now carry many long-distance telephone calls and television service to the remoter parts of Canada. They are an essential part of our telecommunications network.

They orbit the equator at the same speed and in the same direction as the earth turns. Thus they are, for our purposes, stationary.

Hermes: the communications technology satellite

Canada's experimental communications satellite, Hermes, launched January 1976 in co-operation with the U.S., has the world's most powerful satellite transmitter and uses higher frequencies than conventional satellites.

The transmitter tube of the satellite is powered by solar energy. Two solar wings, 7 m long and 1.2 m wide, absorb energy from the sun and convert it into electricity.

Soon, a new satellite – Anik B – will soar into space and also assume a geostationary orbit. This satellite will use both the Hermes radio frequencies and those used by the earlier Anik satellites.

This new generation of satellites, more powerful and operating at higher frequencies, can now use small, cheap or less elaborate earth terminals to pick up their signals. Therein lies their potential.

Mission control: satellite ground control station

Once a satellite is in orbit, you've got to keep a constant check on it and take action if something goes wrong.

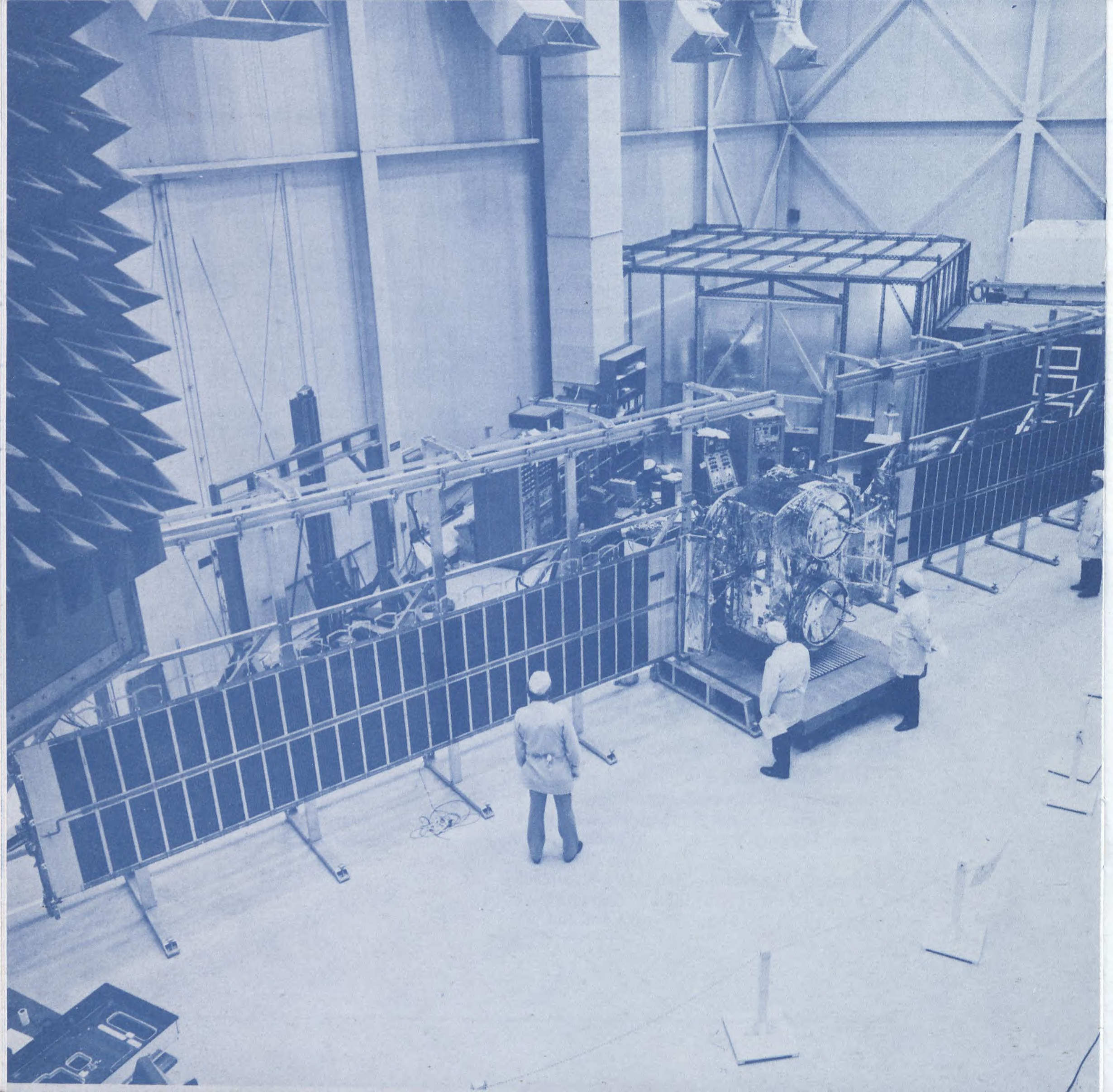
Fortunately, the Hermes satellite keeps track of its own internal workings. It also has sensors which tell about its orbit and the direction it's pointing – by defining its position in relation to the earth and sun. And the satellite is continually sending this information back to earth.

These vital signals are picked up by large ground terminals and forwarded to the CRC satellite ground control centre. Computers inside the station sort out the data and present it to an operator. Commands are sent to the satellite using the 10 m antenna in front of the control centre.

The information is flashed on display screens inside the station. These screens are attached to two computers — one for control functions and the other for back-up. The computers know what the state of the satellite should be and can measure precisely the degree to which it is deviating from this ideal. A third computer is on stand-by, in case one of its companions fails.

If the satellite has deviated a little from its orbit or its antennas are pointing slightly in the wrong direction, the control computer helps the operator correct the problem, instructing the satellite to fire some combination of its thrusters for an exactly specified period of time.

In a more complex situation, the computers will require human assistance. But the system is designed so that one man can normally monitor and maintain satellite operations.



The CRC satellite ground control station also plans, controls and closely monitors the operations of Canada's two active scientific satellites, ISIS I and ISIS II. ISIS scientific data is acquired by these facilities at CRC and by a CRC-controlled facility at Resolute Bay in Canada's Arctic. ISIS scientific data is also acquired by 18 other facilities in 14 countries scattered around the world.

The spacemakers: building and testing the satellites

At the Communications Research Centre, scientists and technicians have worked on the assembly of five of the eight Canadian satellites now orbiting the earth.

In CRC labs, many of the satellites and their components were subjected to the stress and strain of simulated rocket launches and the extremes of heat and cold in outer space.

The David Florida Laboratory

The David Florida Laboratory, built in 1972, is the most complete aerospace and spacecraft test and assembly facility in Canada.

Soon it will be significantly expanded to ensure Canadian industry has the facilities to become a world leader in space communications.

The cleanest place in town: the high bay area

The laboratory's high bay area is where the experimental Hermes communications satellite was tested and assembled.

Within its clean area, personnel must wear special coats and paper hats to prevent dust and dandruff from floating free. The air pressure is also kept a little higher than outside to keep out dust. The air changes 10 times an hour, while special air filters keep dust levels to a minimum.

These precautions are vital. A dust speck could cause a malfunction in miniaturized spacecraft components, which must be extremely small and light because of the enormous cost of lifting anything into orbit around the earth.

Shake, rattle and roll: vibration tests

When a satellite soars into outer space, it is subjected to the enormous stresses and strains of launch. Rocket engine vibrations and extreme acceleration effectively increase its weight many times.

To test whether satellites or their components are tough enough to withstand this, researchers use "shakers" (they shake it), or vibration tables (they vibrate it). Sensors hooked up to a computer measure exactly how well they're taking the strain.

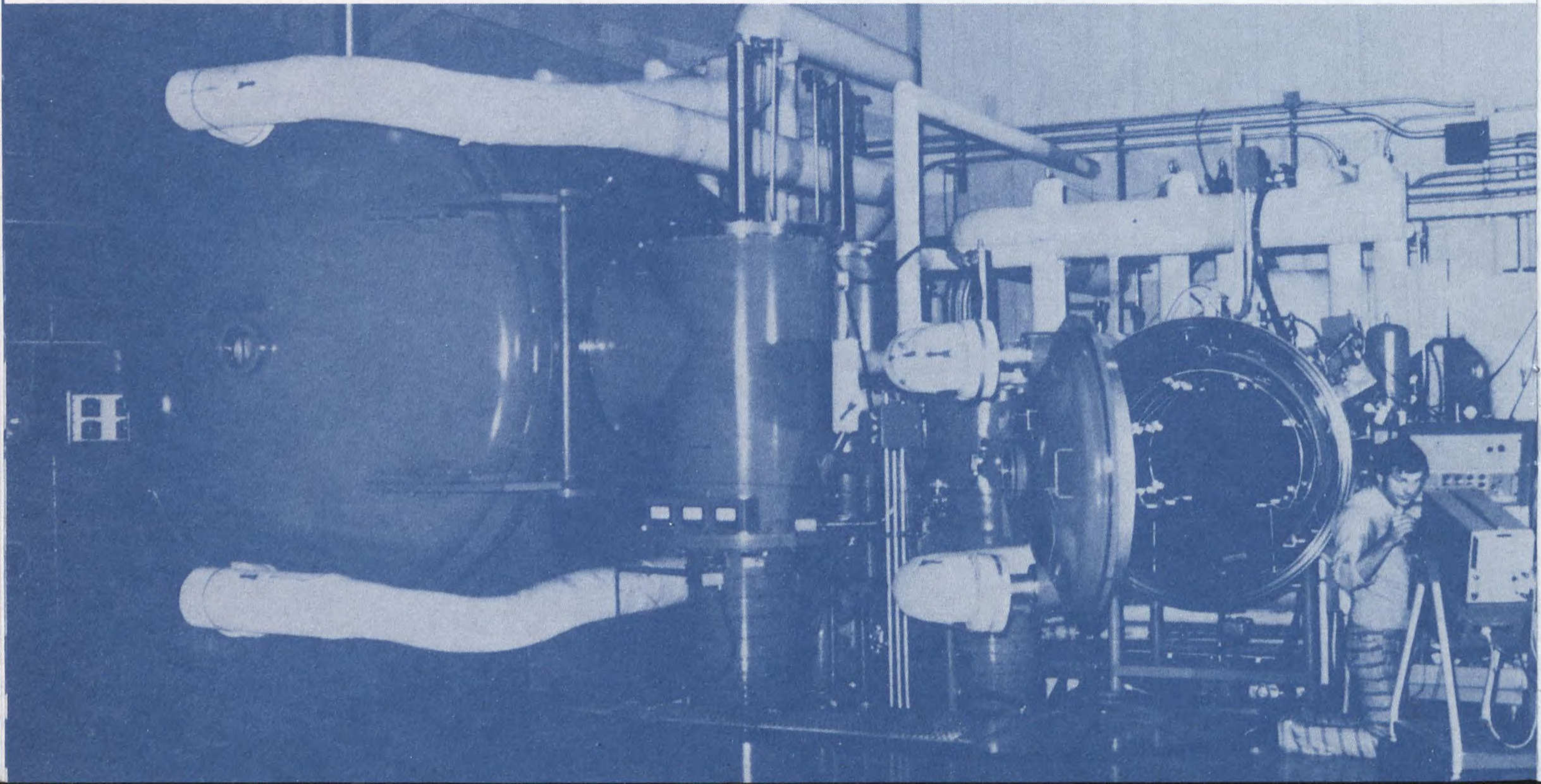
These shakers and vibration tables are driven by electrical force amplifiers, operating a lot like supremely powerful stereo amplifiers. The largest can subject satellites to many times the force of gravity.

These devices are mounted on a 75-ton seismic mass structurally isolated from the laboratory. Otherwise, they might shake the building apart.

Hot, cold and empty: thermal vacuum chambers

Once in orbit, a satellite's tribulations aren't over.

Outer space is a near-perfect vacuum. Its temperature can be as cold as −273°C, a temperature at which most metals become brittle, or the satellite can be exposed to naked sunlight much more intense than the feeble rays filtered through our atmosphere on the hottest summer day.

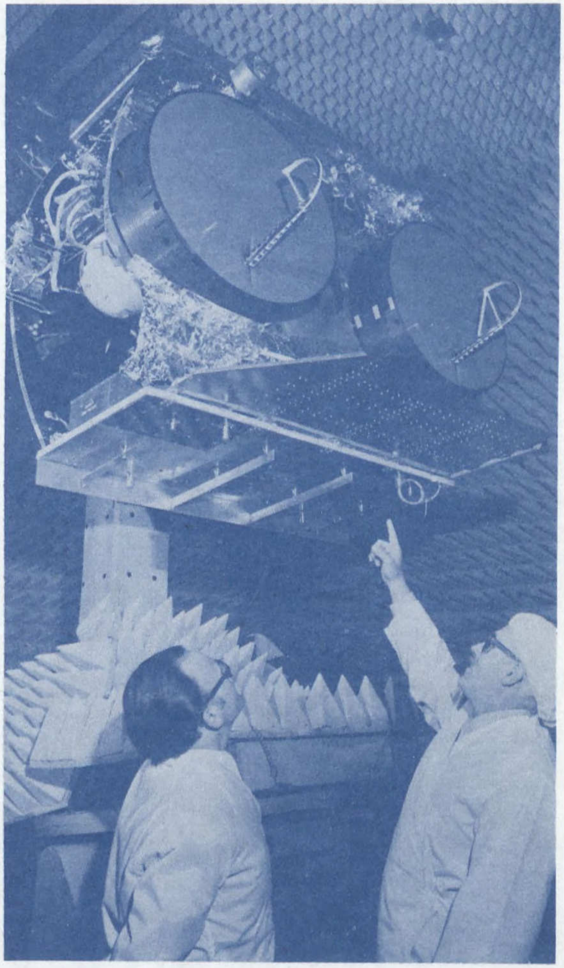


The three thermal vacuum chambers of the lab can simulate the blazing heat, severe cold and utter airlessness of outer space. During tests, satellites and their components are tied into a computer in order to measure precisely how well they endure these temperature extremes in vacuum conditions. The vacuum created inside the chambers, though not as perfect as in outer space, is still considerable. For example, the air inside an operating chamber can be roughly 10 billion times as thin as outside.

A place of perfect radio silence: the anechoic chamber

A communications satellite not only has to survive the rigors of launch and outer space. Its antennas and structure must be perfectly adjusted so that it can send and receive signals of the proper frequency and power.

The radio frequency test facility at the David Florida Laboratory accurately simulates radio properties of the outer space environment in a sealed "anechoic chamber" with interior walls which absorb all radio waves. This simulates the absence of radio reflections in outer space.



The grounded spacefarer: Hermes engineering model

In the high bay area stands an engineering model of the Hermes satellite. Its twin now rotates with the earth at a height of 36,000 km. The model is almost identical in every way to the operating satellite except that it doesn't have any solar wings. It is the development model of the satellite now in orbit. And, if something goes wrong with the orbiting twin, an examination of its earth-bound brother may reveal the problem.

The long arm of the shuttle: remote manipulator arm

A Canadian industrial team is currently using the environmental facilities to test in a simulated space environment the remote manipulator arm to be used in the American space shuttle.

The re-usable space shuttle, scheduled for launch in 1980, will be a kind of ferry for carrying satellites and other space vehicles back and forth between earth and orbit.

The shuttle crew uses the remote manipulator to unload space vehicles from the shuttle and to retrieve them for repair if necessary.

The people's terminals: Hermes earth stations

Earth terminals are shrinking at a rapid rate.

The Department of Communications, in conjunction with Canadian industry, has developed a series of tiny, transportable and inexpensive earth terminals as part of the Hermes program.

The Hermes satellite and its small earth terminals have already been used in a number of social and technical experiments.

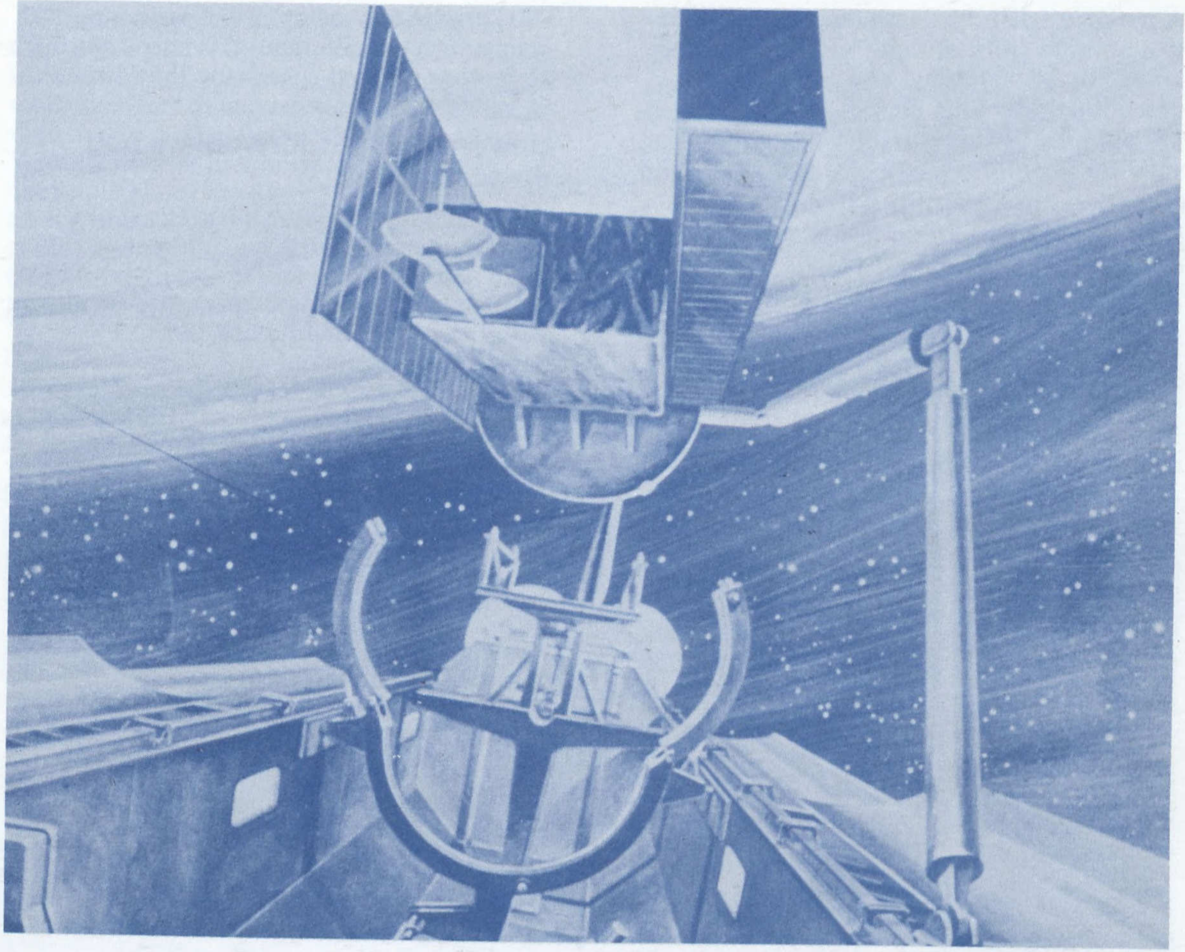
One social experiment involved instantaneous televised consultations between doctors in an isolated hospital on James Bay and specialists in a hospital in London, Ontario. Another terminal permitted nurses a few hundred kilometres from the James Bay hospital to consult by telephone with its doctors.

In other experiments, the satellite and terminals have permitted native-produced programs to reach remote native communities in Alberta, educational programming to reach inaccessible B.C. lumber camps and cultural exchanges between a Prairie community and one in Quebec.

Already, these new, portable terminals are changing the way we communicate. In the future, such terminals, costing no more than a color TV, may pick up direct satellite transmissions of television from around the world.

Live . . . from Hermes . . . somewhere over the equator

How can these small terminals pick up signals from a satellite 36,000 km above the equator?



A parabolic dish focusses incoming signals to a point in front of them where the signals are collected, amplified and passed on to detection units. This kind of antenna is required for the high frequencies used in satellite communications.

Catching the signal: a little to the left, please

Earth terminals won't pick up much unless they're pointed right at the satellite and the satellite antennas are pointed at them. Think of a flashlight beam. When the terminal faces even a little away from the satellite, the signal decays into noise and static.

Signal absorption and deflection

If a tree, building or mountain blocks the line-of-sight path between satellite and terminal, no signal at all will get through. Even your hand can absorb a satellite signal.

When lightspeed seems slow: signal delay

Radio waves travel at the speed of light, but even lightspeed seems slow when one has to cover some 110,000 km. It takes less than half a second for a signal to go up to a satellite and return. The tiny delay in receiving a satellite's return signal can be a problem.

For example, during long-distance telephone calls via satellite, you may sometimes hear the echo of your own voice. This effect arises from the delay and the fact telephone receivers let you hear your own voice so the line won't seem dead. Special switching mechanisms prevent this echo effect from being so serious that you couldn't finish a sentence.

CRC is working on improved switching mechanisms to eliminate this space stutter altogether without sacrificing the resonance of your telephone receiver.

Unwanted ears: scramblers and de-scramblers

A satellite beam covers a large part of the earth and anyone with enough money can build a terminal to pick up the signal. The problem of privacy will become more severe with increased satellite use.

One solution is a device on the satellite to scramble the signal, rendering it meaningless to unwanted ears. In the earth terminal, a decoder would unscramble the message. Such a device must be effective, but not so complex that too much time, money or hardware is required to scramble and de-scramble the signal.

The hybrid computer

The hybrid computer combines digital and analog computing methods. It's one of the biggest facilities of its kind in Canada.

At the Communications Research Centre, this computer is used in the design and simulation of attitude control systems for spacecraft. It is critical to the success of space programs. Computer simulation is the only practical means of analysing attitude control performance before launch.

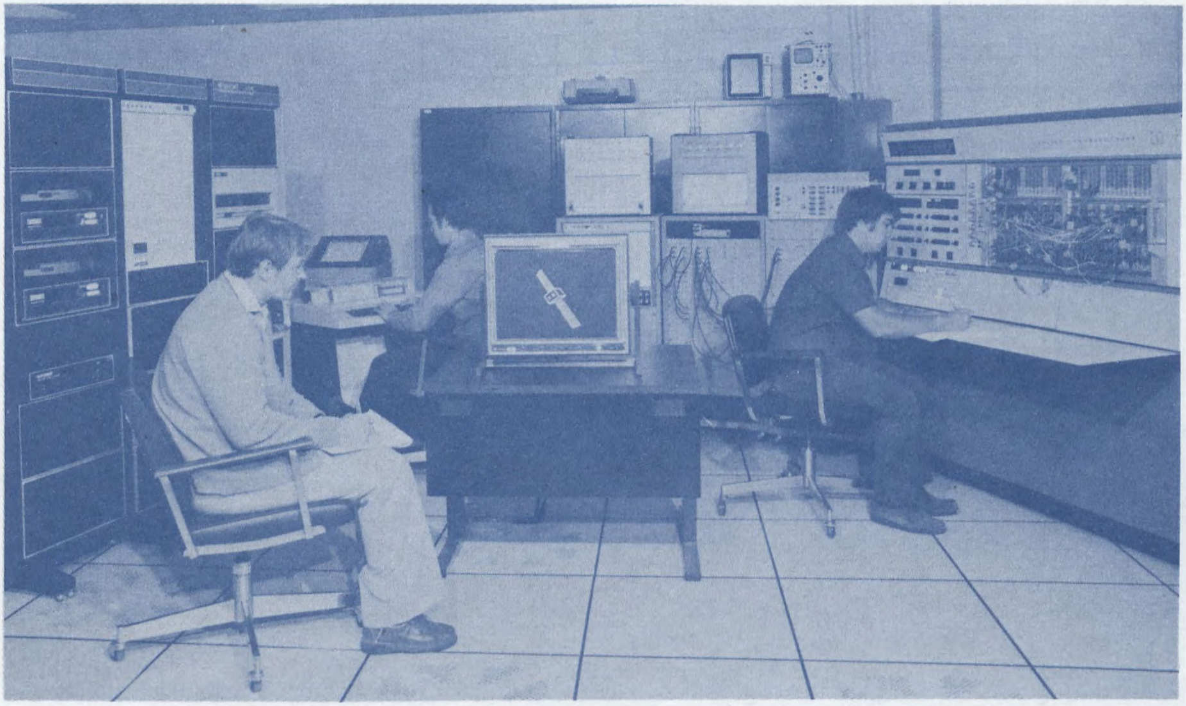
The two computer elements complement each other perfectly. When a fast calculation is needed, the analog computer is used. The more accurate digital computer refines and remembers perfectly the resulting figures. With its greater flexibility, it also makes decisions about the kinds of problems the analog should handle. The digital computer is also used to set up, check out and store data generated by the analog computer.

Orbiting rescuers: SARSAT

Soon satellites will be locating downed aircraft more quickly and effectively than now possible using planes and ships in Canada's air and sea rescue fleet.

The first SARSAT (Search and Rescue Satellite) package will be launched in 1981 or 1982. As it circles the globe at a speed of seven kilometres a second at a height of 850 km, its antennas will be able to cover all of Canada every 12 hours.

These antennas will pick up signals from an Emergency Locator Transmitter (ELT) in a downed aircraft. The jolt of the crash landing will already have activated the ELT, a small transmitter which looks like a walkie-talkie.



As the satellite picks up the emergency signal, its own transmitter will send the signal back down to a well-equipped earth terminal.

This signal will contain enough information to reveal, within 10 to 15 km, where the downed aircraft is located. Improved ELTs will reduce the possibility of error from two to five kilometres.

It can now take several hours after a crash for search and rescue authorities to become aware that an aircraft is missing and it can take days or weeks to search the flight path of the downed plane.

With one SARSAT in orbit, it would take no longer than 12 hours — the time required for the satellite to cover all of Canada — for the plane to be located. With two satellites, the longest time would be six hours. With four, it would take at most only three hours. The difference could be a matter of life or death.

Plugging-in in the wilderness: electricity sources for communications at remote sites

All communications equipment requires a power source. But in remote areas far from power lines, it is no easy task to assure reliable power.

The Defence Research Establishment (Ottawa) is assessing the usefulness of windmills attached to batteries for keeping radio repeater stations operating in remote areas.

To power remote sensors, it is now investigating solar converters and storage devices. It is also developing nickel-cadmium batteries for Hermes terminals and lithium batteries for sonobuoys and Emergency Locator Transmitters carried by aircraft.

The Department of National Defence already employs ultra-quiet motor generators to charge field radar batteries, while its research establishment is now assessing the usefulness of thermal electric generators for a similar purpose.

SPECTRUM

The radio spectrum: electronic highway

The radio spectrum is invisible, inaudible, odorless, tasteless and untouchable. It's more ethereal than air, but we wouldn't have any radio or television without it.

The spectrum is a range of frequencies used for radio-communications at lightspeed through the air. And, because so many want to communicate, it is a valuable public resource which is in short supply. The Department of Communications is therefore seeking ways to use it more effectively.

The frequency is simply the number of radio waves propagated in a second. If a lot of waves are propagated in a second, each wave will be quite short. Thus, the higher the frequency, the shorter the length of each wave.

Radio antennas are built so that their dimensions relate to the wavelength of the radio frequency they're supposed to send or receive. When a wave of the proper length hits an antenna, it induces a signal in the metal which then goes to your radio or TV set.

Whatever frequency you use, you can get interference. This happens when an unwanted signal affects the receiver. The source of the interference could be natural, such as a thunderstorm, or man-made such as an electric motor, or another radio transmitter.

As part of its efforts to improve communications in Canada, the department investigates and analyses interference so that its effects can be reduced or eliminated.

DOC: the spectrum's decongestant

The Department of Communications is the spectrum's decongestant.

Its district offices license users of the spectrum, carefully allocate them radio frequencies, set precise limits on the power of transmitters, check to make sure that users stay within these frequencies and limits, and search out and eliminate sources of interference. With the increasing use of radio, it's a big job, especially in large cities where thousands of taxis, police forces, CBers and others crowd the airwaves.

Spectrum observation on wheels

With the aid of a computer and special equipment it is possible to survey spectrum use — almost instantly on thousands of channels. The department has three special vans which gather information on the use of mobile frequencies. Inside the van is a minicomputer which automatically tells the van's radio receiver and antenna what frequencies to check and for how long and then records the survey results.

With this information, the department can ensure that we use the crowded radio spectrum more effectively.


GMC
FDB 093

The spectrum whodunit: types of interference sources

It is no easy task locating an interference source. There are just too many potential culprits.

Interference could be from a malfunctioning transmitter, or a power line, a car generator, electric drill, electric razor, home thermostat or other appliance.

The frequency keepers: tracking down interference

Technicians in inspection cars track down interference sources such as those which may disrupt your favorite TV program.

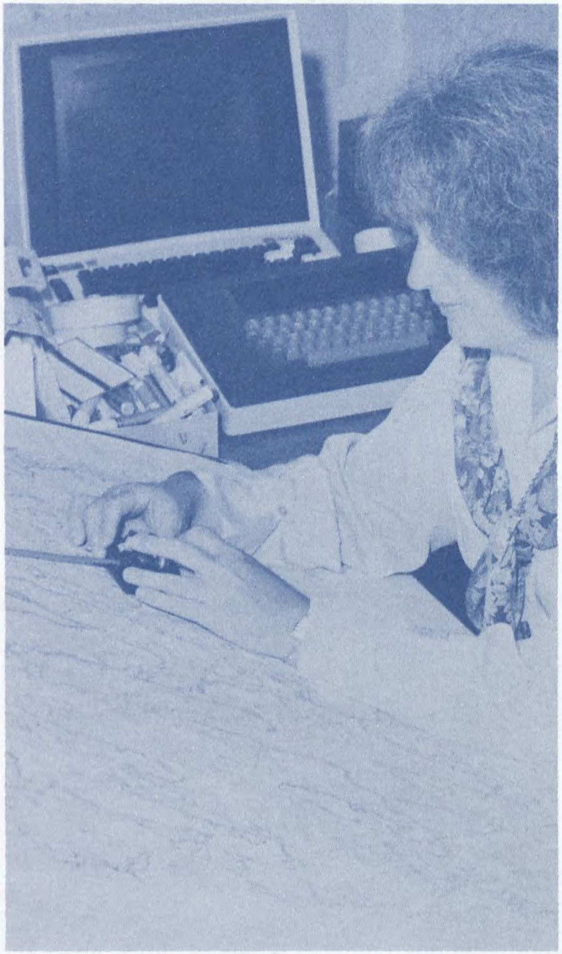
Receivers in the car can pick up a wide range of frequencies. The inspector, by adjusting controls and antennas, can home in on interference sources. As the strength increases, he knows he's getting close or that his antenna is pointing toward the source of interference.

Then it's only a matter of identifying what is causing the problem.

Predicting the performance of radio waves

Hills, mountains, trees and buildings block or deflect radio waves.

That's why the Department of Communications takes into account irregularities in the terrain when allocating radio frequencies and setting limits on transmitter power. But there are many irregularities, and it's a massive job keeping track of them for every radio use.



The Communications Research Centre has a computer which should soon know every hill and dale in southeastern and central Ontario.

The computer will be able to tell you in an instant how big an antenna you'll need to pick up a local TV station, and how well you'll receive it.

AM re-radiation

Power lines and high-rise buildings can deflect the path of radio waves.

The metal in power lines and towers, and the steel girders and wiring in high rises distort the designed pattern of radio signals. And unfortunately, the number of distorting structures is growing all the time.

Sometimes, the dimensions of these structures correspond to the wavelength of the frequencies used by radio broadcasters. In effect, these structures begin to act like transmission antennas which can send radio broadcasts off in all sorts of directions.

They can re-radiate a radio broadcast into a region where it interferes with another previously clear broadcast on the same frequency.

The Communications Research Centre is looking for ways to reduce the effects of this frustrating and expensive problem.

With tiny models of power lines, towers and high rises, CRC scientists are attempting to discover the how these problems arise. They hope, eventually, to make a computer model which will predict the interference to be expected from the sizes and types of power lines, towers and high rises causing re-radiation. Knowing what will happen before a new high-rise building or power line is built could save a lot of grief. They're also working on ways to deal with existing structures so they won't be quite so disruptive.

Opening up new frequencies: probing the unused spectrum

As part of their efforts to solve the problem of congested airwaves, Communications Research Centre scientists are also working on opening up new, higher radio frequencies for use by the public.

These frequencies have some strange yet useful properties.

Take, for example, the 37 Gigahertz frequency which is thousands of times higher than those used for radio and TV broadcasting. Consequently its wavelength is correspondingly smaller.

Each wave is about as long as a pane of glass is thick. When one of these waves strikes a window perpendicularly, it'll pass right through. But, if the pane is tilted, the radio beam will be refracted. In fact, if the angle of the pane is great enough, no radio waves will get through at all.

The vastly longer waves of radio and TV broadcast signals will march right through the windowpane, whatever its angle, without even knowing it existed.

Water can also scatter or absorb these short, extremely high frequency waves.

You wouldn't want to use these extremely high frequencies in rain, fog, snow or other heavy weather. You also wouldn't want to have any obstacles between your transmitter and receiver.

But they do have their advantages. For instance you can transmit much more information a lot more quickly on this higher frequency. You can also use a much smaller antenna, which would be both cheaper and more transportable than the larger antennas needed to send or receive lower frequencies.

It's also economically and technically possible to focus these extremely high frequency waves into a beam so narrow that it's only a few centimetres wide, kilometres away from the transmitter. Such narrow beams are not only difficult to tap, but also less likely to receive or create interference.

Because of these advantages, extremely high frequencies may in the future be used for short-hop communications.

The portable telephone: look ma, no wires

In the future, we may all have portable telephones and be able to dial the world directly without the need for wires or telephone operators.

With an experimental system at CRC, you can now dial your own home directly on a cordless telephone.

When you punch the proper access code and dial, an antenna facility at Camp Fortune picks up your signal and sends it down to a second receiver at the Communications Research Centre. There, the telephone number you've punched is patched into the telephone system which will complete your call.

Weather radar

Radar can foretell the weather — but up until now, an expensive radar system has been required. At the Communications Research Centre, researchers are demonstrating and evaluating a low-cost system which can do the job just as well.

But how can a radar system see a rainstorm kilometres away? The radio waves used by this radar system are short enough to interact with and be bounced back by the water droplets in rainclouds. The radar antenna then picks up the reflected radio waves; it can be determined, by the time it takes for the reflected radio waves to return, exactly how far away the rainstorm is.

Lifesaver in the Far North: remote camp and trail radio system

There are no pay phones on the Arctic tundra.

But Inuit hunters and fishermen must spend long weeks on the trail and in camps far from home if they are to feed their families. During these periods, they are completely out of touch with home — an unhappy and potentially disastrous situation in an emergency.

The Inuit of Koartac, Quebec — a small community on Ungava Bay — is now using an experimental remote camp and trail radio system designed by the Communications Research Centre.

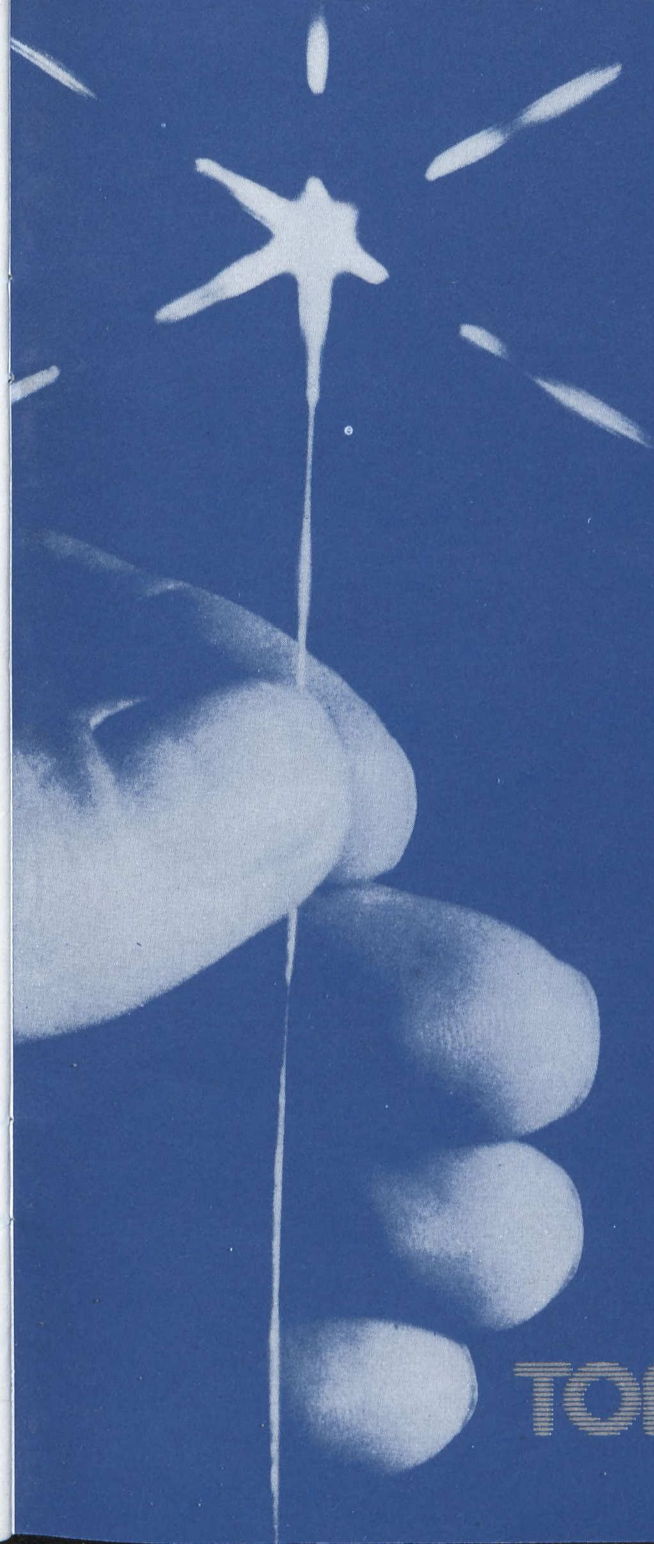
At a high point near the community is a receiving and transmitting antenna which picks up very high frequency (VHF) radio signals.

Anywhere within about 100 km, a hunter using a battery-powered walkie-talkie can send signals to and receive them from the high antenna near the community. The high antenna and a repeater automatically relay signals to or from him or all the VHF radio sets in the community.

The system operates like a party line. Sets located in every home in the community are turned on all the time and someone will always answer in an emergency.

If the hunter is going more than 100 km away from the community, he takes with him a second, portable radio which operates at a high frequency (HF). Its range is up to 300 or 400 km because its signals, in contrast to VHF signals, can be bounced off the ionosphere.

The community HF transceiver station then automatically transforms his signals into VHF and beams them down to the VHF radio sets in the community.



TOMORROW

The lightspeed future

This is the lightspeed future, but the future will soon be upon us.

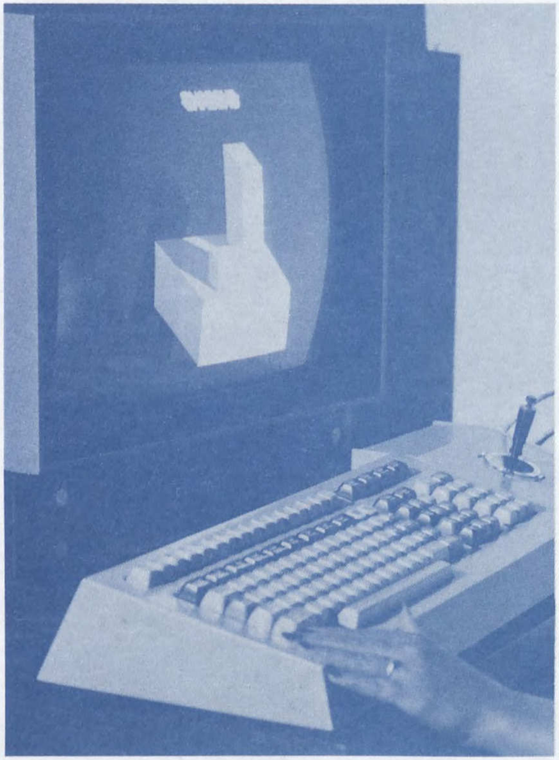
Videotex — a new two-way TV system — will bring you teleshopping, electronic banking, electronic newspapers and electronic mail. Soon it will be linked to data banks all over the world. It will answer questions at lightspeed, and may change your life. An electronic associate of Videotex is already helping non-speaking, physically handicapped children in a quite ingenious way.

At CRC, a future in which telephone wires are turned to glass and carry pulses of brilliant light instead of electricity is already here.

You will be introduced to an electronic circuit smaller than your finger-nail, and shown how it was made and how it may bring a computer into your living room sometime in the 1980s.

Videotex

I am Videotex and was designed at CRC. I look like an ordinary TV set which has been attached to a telephone button-pad or a typewriter keyboard. But looks aren't everything.



If you want information from me, just push a button on my telephone pad, and an index of information will appear on your TV screen. Each item will have a number, and all you have to do is push the right button to get that information on your TV screen. And, if the information includes maps or drawings, I can handle these with ease — in brilliantly defined color. My information will come from libraries and data banks all over the world.

If you'd like some teleshopping, just ask me to produce a catalogue for the store of your choice. Then, when you've made up your mind, just type in the catalogue number of your purchase, its price and your own credit number. The store will deliver the goods, and you won't even have left your home.

With my typewriter keyboard, you can type information into your own data bank for your own use or retrieval by others for a fee. You can draw pictures or graphics on the TV screen with a light pen or joy stick (a lever controlling a marker on the TV screen), and it'll be recorded in the computer data bank. In short, I can make you into an electronic writer, artist and publisher.

If you want to let somebody see what you're doing, you only have to dial their screen and, with a few manipulations, your words, numbers or drawings will be flashed on their TV screen. In fact, your TV screen's will become an electronic blackboard upon which you both can work — or play games — even though you may be thousands of kilometres apart.

My heart is a micro-processor — a tiny computer. Designed in Canada, I have many advantages over similar systems developed elsewhere in the world. I can offer a much clearer, cleaner image on my TV screen. I'm also more flexible and more compatible with data bases which use different terminals. And I'm more adaptable to new telecommunications technology.

Electronic help for non-speaking children

The life of a small child who cannot talk because of some physical or psychological problem is fraught with frustrations.

How can he express feelings and thoughts? How will he learn to read?

One experimental answer has been provided by an electronic device which uses pictograms — or Blissymbols — to convey the meaning of words.

With the help of computer graphics, these pictograms can be displayed on a TV screen along with the words they represent.

It's much easier for a child to recognize these pictograms than equivalent words bearing no resemblance to what they're supposed to represent. The juxtaposition of the two helps him learn to read.

The system is equipped with a joy stick which the child uses to move a marker on the screen to the symbols and words he wants to use. A light pen lets him draw his own symbols and words on the screen.

Equally important, someone else such as a teacher, kilometres away, can see on a TV screen what the child is doing at home and make corrections.

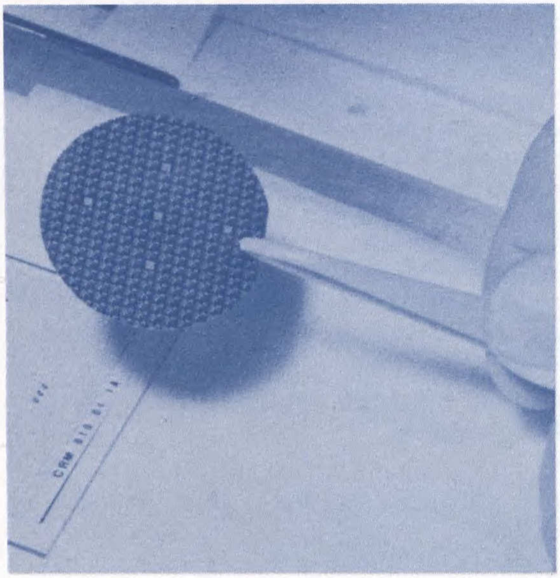
Nerves of glass, thoughts of light: fibre optics

The telecommunications systems of tomorrow will have nerves of glass and thoughts of light.

Instead of existing wires and cables in our telephone and cable systems, we'll be using hair-thin optical fibres made of the purest glass. These won't be carrying electricity, but tiny pulses of light.

Already, these fibres are as cheap as ordinary cable, and their costs will decline as production increases.

They are made of a glass so pure that you could see as well through one kilometre of optical fibre as through a windowpane. They also carry light more efficiently than ordinary cable conducts electricity. Because light has a much higher frequency than the electromagnetic waves moving through cable, an optical fibre may eventually carry a hundred times more telephone or television channels than a cable.



And fibres are not subject to disruption because of a short circuit or the electromagnetic fields of other cables.

The incredible shrinking circuit: integrated circuits

In 1955, a computer of fairly simple capabilities would have filled a fair-sized room. Now a single microprocessor able to perform the same functions can fit onto a tiny chip of silicon about 6 mm square.

It's also much cheaper. You can buy one for the price of a transistor radio. These developments are possible because of progress made on integrated circuits beginning in the early 1960s. At CRC, new experimental integrated circuits are designed and fabricated which, with their lightness, small size and lower power consumption, can be employed in spacecraft.

What is an integrated circuit? Although it is similar to a conventional electrical circuit and does exactly the same things, its components are squeezed together. It relies less on wires and tubes than on the creation of insulating and conducting areas in the chip itself. These are created by soaking different chemicals into the chip, while other chemical treatments create areas and layers of relative non-conductivity.

The use of chemical reactions is one reason why integrated circuits can be so much smaller than conventional circuits. Such reactions require only a few interacting molecules or atoms, and thus can be made to take place in an extremely small area.

The design of such tiny circuits is an extremely demanding task, performed with an electric pen on a draft board containing an electrified grid which transmits the coordinates of every line drawn into a computer. The computer continually checks whether the designer has, in fact, created a working circuit.

The pattern of each layer of chemical treatment shown on the large drawing is then, with the help of a computer, transposed onto a piece of dark red plastic about 500 times bigger than a chip. Only the areas to receive chemical treatment are left dark red. The rest are stripped transparent.

After exhaustive checking of the plastic, the image is photographically reduced and repeated hundreds of times on a glass slide a few inches in size. Each image on the slide is the same size as a silicon chip, while the slide — a few inches wide and long — is the same size as the silicon wafer from which the chips will be cut. The surface of this wafer is covered by an insulating and relatively impermeable layer of silicon dioxide.

Photo-resist, a chemical which becomes insoluble when exposed to ultraviolet light, is applied over the surface of the wafer. Upon exposure through the transparent areas of the slide, those areas on the silicon to be left untreated become covered by a tough film of photo-resist.

The areas to be treated are not exposed to light. They are shielded by the darkened parts of the slide. The unexposed photoresist is removed from the areas by a chemical developer. Thus, when the wafer is placed later in a powerful acid, the impermeable layer of silicon dioxide is dissolved from the surface of the areas to be chemically treated.

Shortly thereafter, a chemical substance which creates a differently charged area is applied to the wafer. When heated in an oven, this chemical diffuses or soaks into the silicon in those areas where the silicon dioxide has been dissolved.

This photographic and chemical process is repeated for each layer of chemical necessary to the proper functioning of a given integrated circuit. When all the layers have been diffused into the wafer, it will contain hundreds of circuits.

Each circuit is then checked under high magnification with tiny electric probes. If a circuit doesn't work, the probe marks it with green ink so that it can be thrown away.

Finally, the silicon wafer is cut into chips, each of which will constitute a tiny functioning integrated circuit.

The electron expander: high-reliability laboratory

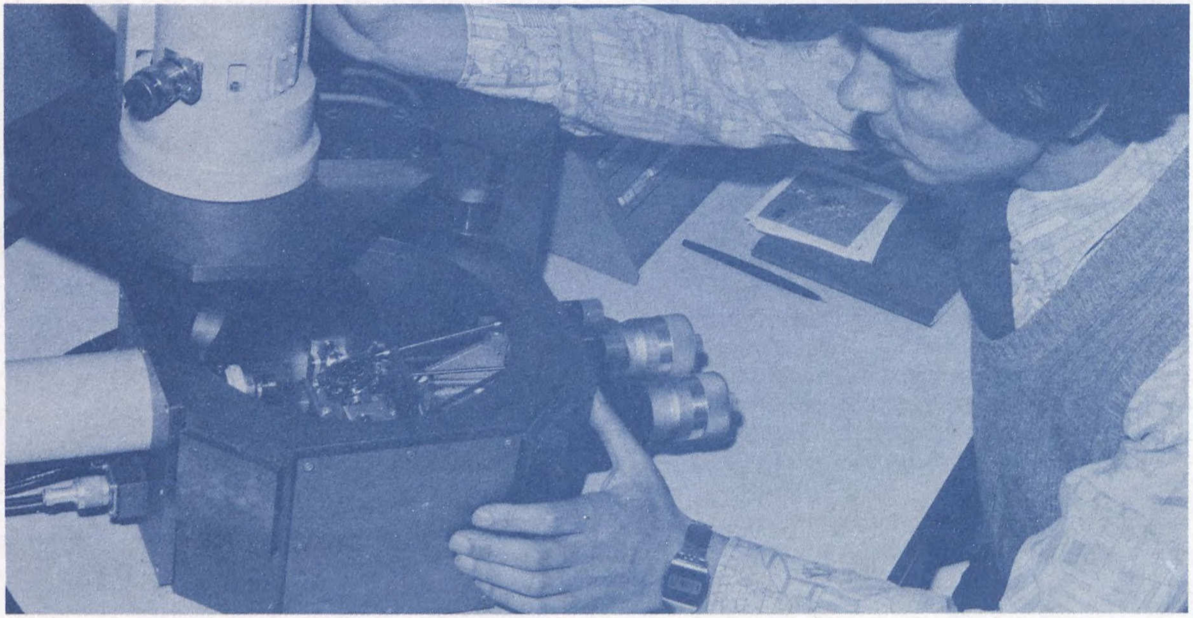
Satellites and their electronic microcircuitry require rigid quality control. The cost of in-orbit failure of a tiny component could be the death of a satellite worth millions of dollars.

Electron microscopy examinations of space electronics components are conducted in the high-reliability laboratory at CRC.

Satellite microcircuits are so small — potential flaws so minute — that it is necessary to use the scanning electron microscope (SEM), which has resolution about 100 times finer than the most sophisticated optical instruments available.

With the SEM, it's possible to get more than just a good picture of a microcircuit. Its infra-red and X-ray emissions under electron bombardment can also be seen.

Proposed new spacecraft microcircuits are tested to ensure they meet the necessary specifications and will last up to eight years in the trying conditions of outer space.



THE LIGHTSPEED REVOLUTION

DATE DUE
