

THE CANADIAN SPACE AGENCY
REPORT TO THE 38TH COSPAR MEETING (BREMEN, GERMANY)
SPACE SCIENCE RESEARCH IN CANADA



Canadian Space
Agency

Agence spatiale
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Canada



INTRODUCTION

Canada has achieved remarkable success in space exploration, research and development, despite limited resources, modest budgets and a relatively small community of industry and academic players.

Canada was one of the first nations to use satellite imagery to map its territory. Canada built the world's first domestic satellite telecommunication system; helped to design and build advanced radar satellites that track ice formations and ships over wide areas; and developed sensitive space instruments and satellites to monitor atmospheric pollution and assess the health of our ozone layer.

In large part, Canada's success in space is due to the Canadian Space Agency's (CSA) decision to focus on specific areas of space research and development. This has allowed Canada to foster world-class expertise and competitiveness in niche areas. In partnership with Canada's research community, industry, government agencies and international organizations, the CSA has fostered opportunities for Canadian companies to participate in large-scale, multinational projects, thereby enhancing our global competitiveness while generating



results and knowledge that benefit Canadians by improving quality of life and the health of our planet.

The success of this approach is evident in Canada's most recent space research activities, focused in areas from enhancing the health and safety of those who venture into space, to measuring the impact that space activities have on all of us back on Earth.

- In a study being conducted by a York University research team, six astronauts aboard the International Space Station are being tested to see how they determine spatial orientation in a weightless environment. Without gravity, astronauts rely solely on body position and visual cues to tell up from down. Disorientation can have serious consequences, as they might easily flip a switch the wrong way or move in the wrong direction during an emergency.
- During long periods in space, astronauts' bones become weaker, increasing the risk of fractures. The CSA teamed up with industrial and academic partners in Canada to design, build and operate a fully automated mini space laboratory known as

eOSTEO to gain a greater understanding of the processes that lead to bone loss in microgravity.

- In an unusual experiment—in which 24 women spent two months in slightly inverted beds to simulate microgravity—two Canadian research teams achieved dramatic results. Dr. Guy Trudel of the University of Ottawa and his team are investigating treatments to minimize the effects of microgravity on the human body, which may also improve treatment of chronic childhood diseases. By studying changes to the volunteers' cardiovascular systems, Dr. Richard Hughson of the University of Waterloo increased knowledge of how the heart and blood vessels adapt to microgravity.
- In a separate but related experiment called CCISS—Cardiovascular and Cerebrovascular Control on Return from the International Space Station—Dr. Hughson looked at how astronauts' bodies adapt to microgravity over an extended period. His team hopes to determine the long-term effects of weightlessness and what can be done to alleviate them.

- Earth's atmosphere and magnetosphere offer protection from the effects of space radiation; however, astronauts in low Earth orbit run a greater risk of cancer and other health hazards from much higher doses of space radiation. A new research study on space radiation, known as the Radi-N Neutron Field Study, is now underway to measure the neutron radiation levels on the International Space Station in the hopes of gaining more knowledge about this phenomenon.
- Just hours after the Phoenix Mars Lander touched down at the planet's northern polar cap, the Canadian built and designed meteorological (MET) station began recording daily weather conditions on Mars, including wind speed, atmospheric pressure and temperature. The MET investigated many of the mysteries that once surrounded the Red Planet, especially concerning water and precipitation patterns.
- Two instruments aboard the Herschel Space Observatory with Canadian contributions—HIFI (Heterodyne Instrument for the Far Infrared)

and SPIRE (Spectral and Photometric Imaging Receiver)—are helping astronomers to study the formation of stars and galaxies and molecular chemistry in a variety of cosmic environments. HIFI is the prime instrument to analyze the chemistry of our galaxy from space, while SPIRE, using its ability to image and obtain spectra over a large region of the sky simultaneously, has already demonstrated its remarkable abilities through deep observations of extra-galactic fields. SPIRE is also providing clues concerning the origin of the Cosmic Infrared Background radiation.

- Two of the CSA's four atmospheric science missions are focused on changes to the ozone layer over the Arctic. Results from those two missions—OSIRIS and SCISAT—have contributed significantly to international climate modeling, and assessments of ozone layer recovery and climate change. Weather centres around the world now rely on OSIRIS and SCISAT to measure and model the stratosphere and to deliver more accurate and timely weather predictions.

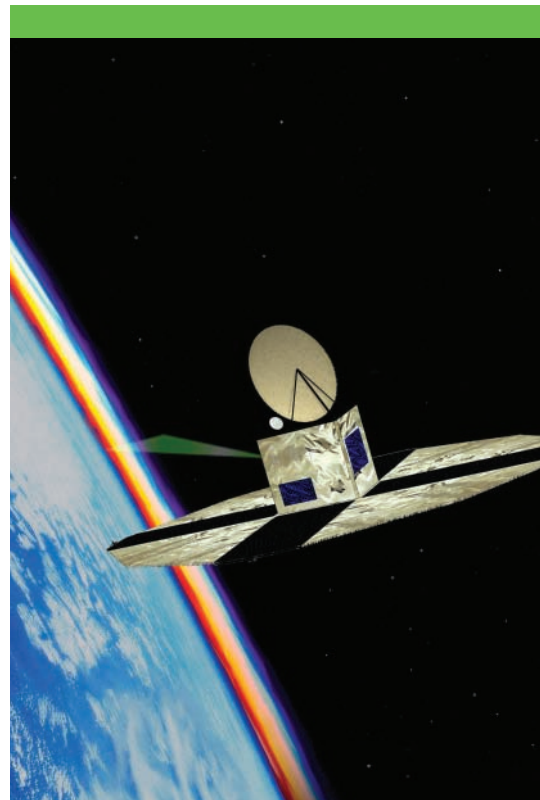


SPACE-BASED ATMOSPHERIC RESEARCH

Given its northern location, naturally has a keen interest in the depletion of the ozone layer occurring over the Arctic. In fact, of the four current Canadian Space Agency atmospheric science missions, two are focused on monitoring changes in the ozone layer.

Canada's interests aside, the results of those two missions—OSIRIS and SCISAT—have contributed significantly to international climate modelling, and assessments of ozone layer recovery and climate change.

Orbiting the Earth aboard the Swedish satellite Odin, which was launched from Siberia in 2001, OSIRIS (Optic Spectrograph and Infrared Imager) enables the international scientific community to observe and measure the ozone layer, as well as the amount of aerosols in the atmosphere, from space. Nearly a decade after it was launched, the instrument continues to capture detailed data on ozone depletion and aerosols that contribute to climate change, especially at high latitudes and over Canada.



OSIRIS on ODIN

The OSIRIS instrument is operated by a team at the Institute of Space and Atmospheric Studies at the University of Saskatchewan. OSIRIS data are used to develop tomographical models that reveal atmospheric structure in new ways. OSIRIS provides crucial data for ozone studies, providing daily, monthly and yearly height profile maps of ozone for specified areas. Using OSIRIS, scientists can observe areas where ozone is changing, as well as mapping concentrations of aerosols and nitrogen dioxide, two major sources of atmospheric pollution.

Launched two years after OSIRIS, SCISAT was expected to function for just two years. Seven years later, the international community continues to reap benefits from the satellite and its prime instrument, known as the Atmospheric Chemistry Experiment (ACE). In fact, SCISAT has been so successful that its development team was awarded the 2009 Alouette Award for outstanding contributions to advancement in Canadian space technology, applications, science and engineering.

SCISAT carries two main instruments, both designed and built in Canada, to carry out its mission of remote sensing of the Earth's atmosphere. Both instruments make measurements in solar occultation, which means

that they stare at the sun as it rises and sets through the atmosphere, 30 times per day (15 orbits per day). Data collected from one of those instruments, the infrared Fourier Transform Spectrometer (ACE-FTS), are widely seen as the standard by which concentrations of constituents are measured in the Earth's middle atmosphere. The instrument routinely measures approximately 35 species of gas as well as various types of aerosols.

The second instrument aboard SCISAT is a spectrophotometer called MAESTRO (Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation). Throughout its mission, MAESTRO has provided high-resolution data on the atmosphere and precise profiles of ozone concentration. It has also measured the amounts of organic and inorganic particles under polar ozone holes and near large tropospheric pollution sources. The troposphere is that portion of the atmosphere between the Earth's surface and an altitude of approximately 15 km.

Since its launch, the SCISAT satellite has detected pollutants in the atmosphere never before identified from space. These measurements are providing a new understanding of the details of our complex, dynamic atmosphere and, most importantly, the changes that are occurring due to both human-induced and natural phenomena.

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SOLAR-TERRESTRIAL SCIENCES IN CANADA

Of the world's northern countries, Canada has perhaps the "best seat in the house" from which to view the aurora borealis. But our favourable location also affords scientists an unrivalled opportunity to study the solar winds that create this fascinating natural phenomenon.

A great deal is already known about the solar wind, an ever-present stream of ions and electrons that blows off the Sun and expands outward. As it hurtles through space at an average speed of 400 km per second, the solar wind interacts with Earth's magnetic field, stretching it to create a long downstream tail. The energy stored in this long tail is released in bursts of accelerated particles and electrical currents called substorms. These substorms occur along the equatorial plane of Earth's night side, then propagate along magnetic field lines to the polar regions. It is here that they create the spectacular night sky displays that we know as the northern lights.

What scientists have yet to determine, despite numerous studies of Earth's magnetosphere and its space weather, is where and at what point the energy from these substorms transforms into auroras. The THEMIS program, a collaborative research mission



involving a number of Canadian and U.S. organizations, is now taking advantage of Canada's unique location and talented space researchers to answer that question and others about the substorms.

THEMIS employs five identical satellites whose apogees—the point at which they are furthest from Earth—align every four days with a network of ground-based observatories, of which there are 16 located in Canada and four in Alaska.

Dr. Eric Donovan, an associate professor of physics and astronomy at the University of Calgary, led the Canadian team of engineers and scientists that helped their American counterparts develop the network of observatories. Today, as the Canadian head of the THEMIS program, Dr. Donovan is responsible for overseeing the 16 Canadian observatories and for retrieving the massive amounts of data generated by all 20 observatories.

This data is being used to answer longstanding questions about the nature of substorms and the abrupt and explosive release of solar wind energy stored within Earth's magnetotail. The primary objectives of THEMIS are to:

- establish when and where substorms begin

- determine how individual components of a substorm interact
- determine how substorms power the aurora borealis

Another innovative Canadian program is shining as brightly as the light of the aurora borealis. The Canadian GeoSpace Monitoring Program (CGSM) is a coordinated observation, data assimilation and modelling program that, like THEMIS, is taking advantage of the fact that Canada has the largest accessible landmass under the auroral and polar regions. This ideal location is complemented by Canada's history as a leader in the solar-terrestrial sciences.

Through CGSM, Canadian scientists are leading international efforts to answer fundamental questions and address issues at the very forefront of space physics research. The program's overarching goal is to increase our understanding of how mass and energy are transported across the entire solar-terrestrial system. Its primary scientific objective is to elucidate the fundamental processes that cause and control convection, magnetotail instabilities (which THEMIS researchers are also studying), auroral particle

acceleration, and the energization, transport and loss of magnetospheric particles.

A lot is riding on the success of CGSM. If the program's goals are achieved, the result will be significant advances in space weather prediction and the development of empirical space environment models. CGSM research will also be central to understanding how weather in space influences weather and climate on Earth, particularly now, as the magnetic environments of both the Sun and the Earth undergo rapid changes.

The THEMIS science team is led by the University of California at Berkeley on behalf of NASA, and brings together scientists from the US, Canada and Europe. The Canadian THEMIS team is funded by the CSA and includes the universities of Calgary, Alberta, New Brunswick, Saskatchewan and Athabasca University; and Natural Resources Canada.

The Canadian Geospace Monitoring program includes nearly three-dozen researchers from five Canadian universities (the University of Alberta, the University of Calgary, the University of Saskatchewan, the University of Waterloo and the University of New Brunswick) as well as three government agencies (Natural Resources Canada, the National Research Council's Dominion Radio Astrophysical Observatory and the Canadian Space Agency.)

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WOMEN INTERNATIONAL SPACE SIMULATION FOR EXPLORATION (WISE)

Most people would tend to believe that you must actually go into space to conduct or advance space research. But as an unusual experiment has shown, you don't even have to get out of bed.

In the experiment, called WISE (Women International Space Simulation for Exploration), 24 female volunteers spent two months lying in bed with their heads six degrees below horizontal. This was carried out in two phases, with 12 women participating in each phase.

The slight inversion was designed to simulate the effects of weightlessness on the human body, and the physical impact of remaining in that position for a prolonged period of time. The findings confirmed the effects scientists had observed among astronauts returning from space: muscles atrophy due to a lack of physical activity; the heart rate increases; blood pressure control is impaired; and there is a loss of coordination. WISE also studied the psychological effects of isolation, monotony and low mobility—again, conditions similar to those faced by astronauts who spend long periods aboard the International Space Station.

Throughout the study, some of the candidates carried out all of their daily activities in bed, remaining in



the head-down position for meals and washing, even for entertainment. One group of participants took part in daily activities (running on a treadmill designed specially to be used in a horizontal position, or performing leg contractions on a resistive exercise device) to determine the benefits of physical exercise countermeasures. Many used their free time to watch TV, study a new language or pursue a subject of interest. Women volunteers were selected because little data exists on the adaptation of the female body to weightlessness and on how to reduce the effects of microgravity on women. In 2001, a similar study was done on male subjects.

One of two Canadian scientists on the WISE team, Dr. Guy Trudel of the University of Ottawa's Department of Medicine, was among those studying how the body reacts to long periods of inactivity, such as an accumulation of fat in the bone marrow and its effect on blood-forming cells, tendon changes as well as adipose changes in the muscles.

Dr. Trudel, a medical rehabilitation specialist, is especially qualified to contribute to the WISE experiment. At The Ottawa Hospital Rehabilitation Centre, he treats people who require extended periods

of bed rest. His patients experience many of the same physical problems as astronauts returning from space, including muscle atrophy and loss of bone mass.

Based on the WISE findings, Dr. Trudel's team is in the process of identifying treatments that would minimize the effects of microgravity on the human body. In practical terms, the team believes the results of the WISE experiment will lead to improved treatment not only of long periods of bed rest but also of chronic diseases reducing mobility.

The other Canadian on the WISE team, Dr. Richard Hughson of the Department of Kinesiology at the University of Waterloo, is looking at how the structure and function of the volunteers' cardiovascular systems changed during their time in bed in order to learn more about how the heart and blood vessels adapt to microgravity environments. Those findings are then compared to what researchers have seen in astronauts after they complete their space missions.

The body, says Dr. Hughson, compensates for zero gravity by reducing blood volume, while the reflexes that control the heart and blood vessels become less efficient. This increases the possibility of fainting and

dizziness upon return to Earth. In our everyday lives on Earth, transitions between lying down and an upright posture challenge the cardiovascular system. The WISE experiment has helped researchers to understand why people who are susceptible to dizziness or fainting, such as the elderly, are likely to lose consciousness and fall, and what might be done to prevent these problems.

While existing countermeasures to microgravity are safe for astronauts serving aboard the International Space Station, additional or more rigorous and specific countermeasures will likely be required for longer missions. A mission to Mars, for example, would expose astronauts to weightlessness and reduced gravity on Mars for up to three years. Developing more effective countermeasures is essential to ensure the health of the astronauts and the success of longer space missions.

WISE is an international effort sponsored by the European Space Agency with the participation of two Canadian scientists, Dr. Richard Hughson from the University of Waterloo and Dr. Guy Trudel from the University of Ottawa. Their participation was made possible through the CSA's contribution to the study.

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BODIES IN THE SPACE ENVIRONMENT (BISE)

Humans rely on three factors for spatial orientation: gravity, vision and other body sensors. But what if one of those factors is removed? For example, what happens to astronauts when they're in space—an environment without gravity—and are forced to rely only on visual and body cues to help them tell up from down?

A team of researchers at York University, supported by the Canadian Space Agency and led by Dr. Laurence Harris, is trying to determine how astronauts distinguish up from down in a near-weightless environment. In the experiment—entitled Bodies in the Space Environment (BISE)—scientists are analyzing data collected before, during and after flight. Six astronauts, including Canadian Space Agency astronaut Bob Thirsk, have volunteered to participate in the BISE study, which is being carried out during a research mission aboard the International Space Station (ISS).

In the study, the six astronauts view a computer screen through a cylinder that blocks all other visual information. Background images then appear on screen—orientated up, down, sideways or diagonally in relation to the astronauts—and a letter is then superimposed on top



of each image. The letter could be seen as a “p” or a “d” depending on its orientation, and the astronauts are asked to indicate which they think it is.

The York team will measure the transition points where the letter changes from a p to a d and back again. The angle between those two points becomes the “perceptual upright.” The team can then alter that perceptual upright by changing the astronaut’s body orientation or visual orientation.

The study is particularly important for the safety of astronauts. When their brains no longer have gravity to help them determine up and down, astronauts must rely solely on the two remaining cues—the position of their bodies, and what they see around them—to tell the difference. If they get disoriented, they are more likely to make errors like flipping the wrong switches or moving in the wrong direction during an emergency. Dr. Harris is confident that the team’s findings will help create a safer work environment in space.

Disorientation could have serious consequences aboard the ISS, says Harris. For example, in an emergency evacuation, it’s critical to guide people quickly to the

safest exit. “But to do that,” he says, “you have to know what cues they’re using and how effective they are.”

With that in mind, BISE researchers are hoping to determine the relative importance of visual and body cues to the subjects’ spatial perception. One question they’re eager to answer is how the brain combines multiple pieces of information about orientation to come up with the right answer. They do have some clues. In previous studies—carried out in special aircraft that produce brief periods of microgravity—scientists discovered that without gravity to guide them, people rely more on body cues than on vision to tell them which way is up.

The BISE experiment is also relevant to astronauts on spacewalks, because when they are outside the spacecraft, they have to adjust their position by relying upon whatever visual cues are available. The study even has long-term implications for people who will never venture into space, says Harris: “The tools we develop through the BISE experiment can also help people who experience balancing problems or are prone to falling, including seniors and people with conditions like Parkinson’s disease.”

BISE is a CSA-sponsored International Space Station experiment led by York University’s Principal Investigators Laurence Harris and Michael Jenkin. The Co-Investigators include Heather Jenkin, Richard Dyde and James Zacher (all of York University), and from MIT, Andrew M. Liu and Charles M. Oman. International operational and hardware support was provided by ESA and CNES. NASA’s integration team (headed by Lisa Gall and Marshall’s POIC staff) offered integration and operational support before and during the experiment.

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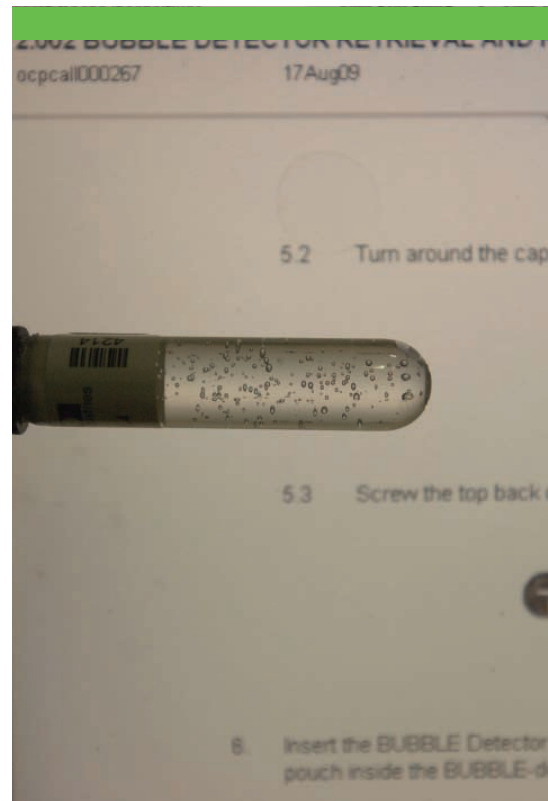
Radi-N: STUDYING SPACE RADIATION

Living and working in space, particularly for extended periods of time, can adversely affect the health and safety of astronauts. Among the most serious threats they face is space radiation, consisting mainly of high-energy charged particles streaking across space. The particles originate from three main sources:

- galactic cosmic rays from outside the solar system
- solar particles emitted by the Sun during solar flares
- radiation trapped by Earth's magnetic field

The Earth's atmosphere and magnetosphere protect people on its surface from the effects of space radiation, and also provide some protection to astronauts in low orbit, such as those aboard the International Space Station (ISS). However, that isn't enough to overcome the increased risk of cancer and other health hazards from much higher doses of space radiation.

A new research study on space radiation is now underway aboard the ISS. In collaboration with Russian space organizations—the State Scientific Center of the



Russian Federation Institute of Biomedical Problems of the Russian Academy of Sciences (IBMP) and the Rocket Space Corporation (RSC-Energia)—the Canadian Space Agency is striving to learn more about space radiation and its effects. The study uses bubble detectors produced by the Canadian company Bubble Technology Industries to serve as neutron monitors. Used in space since 1989, the bubble detectors have been designed to detect neutrons and ignore most other radiation. Neutron radiation is estimated to make up 10 to 30 percent of all radiation exposure that astronauts encounter in space.

In space, neutrons are produced when primary radiation particles collide with physical matter, like the ISS itself. Because neutrons do not carry an electric charge, they have the ability to penetrate deeply into body tissue. With this invasion comes the potential to damage or mutate DNA, which can cause cataracts or even cancer.

Through the Radi-N Neutron Field Study, Canadian Space Agency Astronaut Bob Thirsk was asked to measure the neutron radiation levels on the ISS during Expedition 20/21. He placed six of the finger-sized neutron detectors—each with a different energy

threshold—in various modules on the ISS. Each detector was filled with microscopic liquid droplets suspended in clear polymer gel. When a neutron struck the detector, a single droplet was vaporized, creating a visible gas bubble in the polymer. The bubbles were counted by an automatic reader to create a neutron count for that detector. Finally, the incidence and energy range of neutron radiation throughout the ISS was measured.

The Radi-N study follows the Matroshka-R experiment, also done in collaboration with the IBMP, in which a spherical dummy known as a “phantom” was used to simulate the human body. Bubble detectors were placed in and around the phantom to record the neutron exposure that tissues and organs receive in low orbit. When the experiment showed that the internal areas had absorbed more neutron radiation than anticipated, scientist hypothesized that cosmic rays were interacting with the phantom itself, creating a secondary source of neutrons.

The Radi-N study findings will provide an invaluable resource for accurate risk assessment of neutron radiation in space. The team believes their work will eventually help to protect astronauts against radiation during future space missions.

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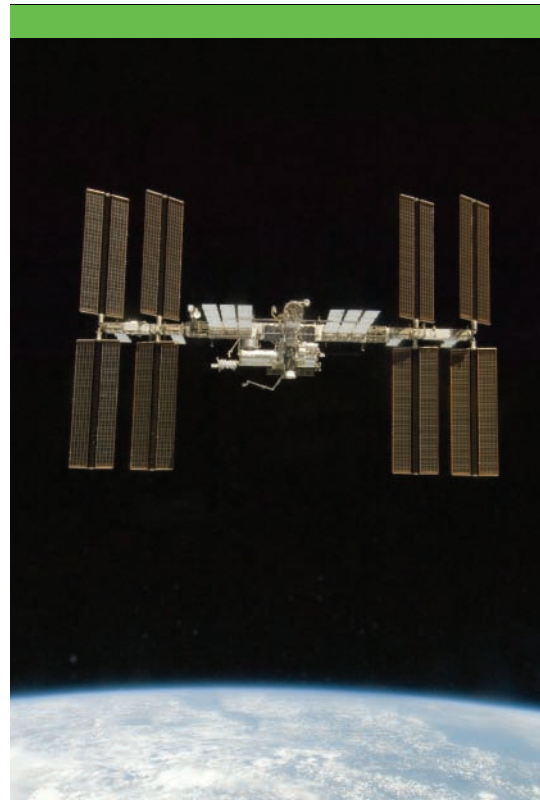


CCISS EXPERIMENT: SPACE TRAVEL, NOT FOR THE FAINT OF HEART!

Astronauts have very busy days

involved in construction, maintenance and research while aboard the International Space Station (ISS), yet their bodies—and even large objects they have to move—float effortlessly in zero gravity. Removing the normal work against gravity that we all must do in our daily lives on Earth can have a weakening effect on muscles and organs. In the weightless environment of the ISS, the heart, for example, does not have to pump as much blood and the blood vessels do not have to constrict in the same way that they do on Earth. Without the effects of gravity and an upright posture, blood tends to accumulate in the head and chest of an astronaut in zero-G conditions.

The astronaut's body adapts rapidly to the reduced work load in space, but upon return to Earth, the cardiovascular system is challenged with the astronaut often feeling faint or light-headed, because not enough oxygen-rich blood is reaching the brain. In fact, 80 percent of the first astronauts who returned from extended periods on the ISS were affected by light-headedness, dizziness and fainting when they returned to Earth. Even space shuttle crew members are affected, with about 20 percent reporting similar symptoms.



Living in the weightless environment without appropriate physical exercise countermeasures will cause severe deconditioning of the cardiovascular system, but new exercise regimes are being implemented in an effort to bring astronauts back from ISS fit and healthy. In cooperation with the Canadian Space Agency, University of Waterloo researcher Richard Hughson is working to determine whether these new exercise programs are effective. His CCISS experiment—Cardiovascular and Cerebrovascular Control on Return from the International Space Station—is a comprehensive examination of how astronauts' bodies cope with microgravity over an extended period.

The CCISS experiment has broad implications. Not only will the results help protect future travelers to space, but they also have potential value for everyday medical applications. Those likely to benefit include elderly people who experience fainting spells or falls, and people who suffer from heart disease caused by a sedentary lifestyle.

The first astronaut to participate in CCISS was American Clay Anderson, a member of the Expedition 15 crew that spent 152 days onboard the ISS in 2007. Hughson's team of researchers

measured how Anderson's blood pressure and heart rate were regulated during a three part experiment. In extensive studies conducted before and after space flight, they monitored the ability of the veins to return blood to the heart and the function of the heart and blood vessels in maintaining the arterial blood pressure. Another component of the study monitored arterial blood pressure regulation in space, and a third component measured heart rate control during normal daily activities.

The in-flight monitoring of blood pressure employed the Continuous Blood Pressure Device (CBPD), a finger cuff that measures blood pressure with every heartbeat. Heart rate was monitored continuously by the Holter monitor (the CCISS experiment was the first to use the new HM2 Holter monitor) and Actiwatch devices were worn on the wrist and ankle to record body movements. Hughson and his team later analyzed the data collected during the 10-minute blood pressure study and the 24-hour collections of data on heart rate and physical activity. The final subject for the CCISS experiment was Canadian Space Agency Astronaut Dr. Robert (Bob) Thirsk, who spent 6-months in space as a member of Expedition 20/21.

Hughson, who heads the Vascular Aging Program within the Research Institute for Aging at the University of Waterloo, says the CCISS study's findings have shown the necessity of introducing regular, vigorous exercise to counter the very low physical demands of life on the ISS. This observation has key health implications for astronauts on ISS, but will be especially important for future multi-year missions to Mars.

Understanding the causes of low brain blood flow on return to Earth and providing the best countermeasures to maintain brain blood flow is imperative, researchers say. "If an astronaut is not receiving enough brain blood flow," says Hughson, "then he or she cannot think and perform critical actions properly and there is danger the astronaut could faint and hurt him or herself."

CCISS is a NASA-sponsored ISS experiment from the University of Waterloo, for which CSA has provided financial assistance, access to the ISS and some coordination support.

CCISS study's findings have shown the necessity of introducing regular, vigorous exercise to counter the very low physical demands of life on the ISS.



BONE LOSS IN SPACE: eOSTEO

Working in weightlessness poses significant health risks to astronauts on long space missions. Their muscles atrophy due to a lack of physical activity, their heart rate increases, their blood pressure rises, and they often experience a lack of coordination. Then there are the psychological effects of extended periods of isolation and monotony.

One of the most serious risks, however, is bone loss. Over a long period in space, astronauts' bones become weaker. In fact, they can lose up to 10 percent of their bone mass in just three months in space. Worse yet, the deterioration can continue long after they return to Earth—and some of the lost bone mass may not be recovered.

The concern is that this bone loss increases the risk of fractures, particularly in the hips, spine and legs. As well, the calcium from lost bone ends up in the bloodstream, which in turn increases the load on the kidneys. The final result is an increased risk of renal stones and related problems.

To address the problem of bone loss in space, the Canadian Space Agency teamed up with industrial and



academic partners to design, build and operate a fully automated space mini-laboratory. Known as eOSTEO, this laboratory has enabled scientists to gain a greater understanding of the processes that lead to bone loss in the unique conditions of microgravity. Through eOSTEO, Canadian scientists studied:

- how bone cells in microgravity react to signals that increase and decrease bone formation
- if microgravity compromises bone cell architecture
- whether a hormone that promotes bone creation can, in weightless conditions, prevent the death of cells that build bone

Canadian engineer Lowell Misener of Calm Technologies (formerly Systems Technologies) helped to develop the electrical systems for the original OSTEO (OSTeoporosis Experiments in Orbit) project in 1998, and led the development of the eOSTEO mission hardware, an enhanced version of OSTEO. Both systems were developed to study how bone loss works both in space and on Earth.

Body weight and the stress that movement and gravity put on our bones stimulate the growth of bone cells. When the weight and stress are removed—as is the case in zero gravity—bone cells start absorbing bone tissue, releasing minerals into the bloodstream. As well, bones that usually support the body, such as those in the legs and hips, become thinner and reduce in density, so bone loss is exacerbated when compared to the arms, for example.

The bone loss experienced by astronauts in space is similar to advanced osteoporosis, a condition that affects about one in four women and one in eight men over the age of 50. In adults, 5 percent to 7 percent of bone mass is renewed each year as it is broken down and then rebuilt. But as the body ages, the rebuilding process fails to keep pace with the absorption process, resulting in lower bone density.

The lack of gravity in space accelerates this process. In fact, bone loss in microgravity occurs up to 10 times faster than on Earth, even for healthy and physically fit astronauts. As a result, says Misener, space provides an ideal setting for the study of osteoporosis, saving time and money and allowing for more focused research.

Clearly, research into the causes of bone loss in space will not only benefit astronauts. What scientists discover through eOSTEO is expected to lead to a greater understanding of osteoporosis and related diseases. Researchers are confident it will advance the search for countermeasures or even cures.

The original OSTEO experiments are considered one of Canada's great successes in space. Launched in 1998 aboard the Space Shuttle *Discovery* on a mission devoted to the study of aging, the experiments gave life scientists their first opportunity to examine bone cell cultures in space. Scientists are confident that the results from the eOSTEO mission will build on their success.

McGill University and the University of Toronto lead the Canadian science teams, with the participation of the Canadian Space Agency and international collaboration of the European Space Agency, Roscosmos and TsSKB. Calm Technologies contractor (formerly System Technologies) was the prime for the eOSTEO cell culture system and Orion Canada Inc. for quality assurance services.

Known as eOSTEO, this laboratory has enabled scientists to gain a greater understanding of the processes that lead to bone loss in the unique conditions of microgravity.



CANADA ON MARS: THE PHOENIX MARS LANDER

Just hours after the Phoenix Mars Lander touched down on the planet's surface on May 25, 2008, Canada's contribution to that historic mission was already being felt back on Earth. The meteorological station (MET) aboard Phoenix, designed and built in Canada, immediately began recording atmospheric pressure and temperature. Throughout the mission, MET transmitted daily weather reports from one of the most hostile and unknown environments on Mars. The University of Aarhus in Denmark's wind sensor, known as a "telltale," was also perched at the top of the meteorological station's mast. The instrument measured wind speed and direction, and detected the presence of at least one dust devil at the landing site.

Meanwhile, a leading Canadian innovation, an instrument known as LIDAR, tracked daily weather patterns and seasonal climate changes above the landing site. The shoebox-sized Light Detection And Ranging device probed the Martian atmosphere daily throughout the mission for a total of approximately 137 hours—about one hour each Martian day—emitting more than 49 million laser shots in total. LIDAR is a powerful technique for detecting fog and

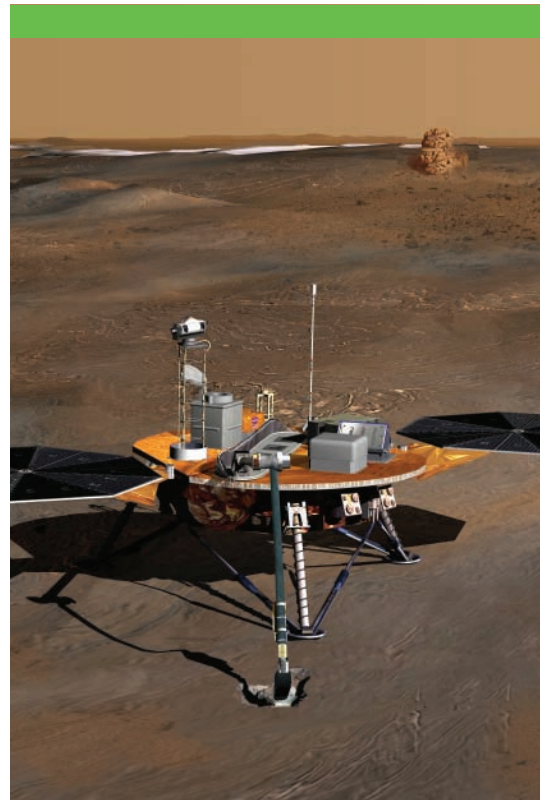


Photo: NASA Jet Propulsion Laboratory/University of Arizona

cloud, as well as tracking dust patterns that provide information about atmospheric turbulence.

Thanks in part to Canada's significant involvement, the Phoenix mission was an unparalleled success. From its challenging landing spot—a high arctic region around Mars's northern polar cap that Phoenix confirmed as water-rich soil—the lander beamed back a wide range of data for the five months of Mars's polar summer, well beyond the mission's estimated lifespan of three months.

During that time, the meteorological station measured a downward trend in surface pressure as some of Mars's carbon dioxide atmosphere condensed onto the polar cap on the winter side of the planet. Meanwhile, clear skies turned cloudy, and MET had a chance to study one of the mysteries of Mars's current climate: what happens to the water ice in the north polar cap in summer—is it transported through the atmosphere and deposited somewhere else?

MET's detection of snow on Mars certainly suggests it is possible for water vapour that has travelled great distances high in the atmosphere to reach the ground

far from its icy surface source. However, the paper by Canadian scientists involved in the project—"Mars Water-Ice Clouds and Precipitation"—presents a different hypothesis, suggesting that the water ice crystals observed above the Phoenix site today may be trapped in a shallow daily cycle. Water vapour originating from the icy ground is lofted upwards during the daytime, forming clouds of ice crystals low in the atmosphere that resemble cirrus clouds on earth. Water then precipitates and falls as snow through the atmosphere at night.

The lead scientist for MET, Dr. Jim Whiteway of York University, says the snow signal that Canada's meteorological station detected is similar to the phenomenon known as "diamond dust" in the Arctic. For the periods where snow is observed, it falls, he said, as a steady, light precipitation in the form of fine ice crystals.

Before the Phoenix mission, scientists were unsure as to the presence of any sort of precipitation on Mars; nor did they know that clouds formed as low as they did in the Martian atmosphere. "We knew that the polar ice cap advanced as far south as the Phoenix site in

winter," says Dr. Whiteway, "but we didn't know how the water vapour moved from the atmosphere to ice on the ground."

Not only did scientists find snow on Mars, but the soil chemistry and minerals they examined indicate that Mars had a wetter and warmer climate in the recent past, perhaps in the last few million years. Known changes to the orientation of Mars as it orbits around the Sun mean that warmer climatic periods are expected again in the future, perhaps warm enough to allow liquid water to form—a dramatic evolution given that the warmest temperature recorded during arctic summer was minus 19.6 degrees Celsius (the coldest was minus 97.7 degrees Celsius).

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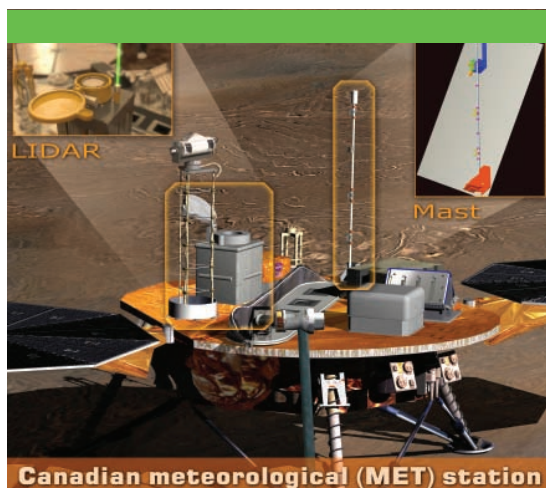


Photo: NASA/University of Arizona/CSA

Canada's contribution to the Phoenix mission speaks volumes about our space expertise as well as recalling our long history in space development and research. When Canadian Space Agency President Steve MacLean was working at York University some 30 years ago, the researcher in the lab next to his was Allan Carswell. At that time, Carswell was already developing early prototypes of the laser probing system that would eventually become the LIDAR instrument on the Phoenix mission.

The presence of Canadian instruments on Mars—the first time Canadian technology has landed on the surface of another planet—did more than answer important scientific questions. Thanks to the Phoenix MET and LIDAR instruments, we have a better idea of what the weather might be like on a typical summer day at the edge of the polar cap of Mars. One day, this information may be essential to the success and safety of manned missions to Mars.

York University leads the Canadian science team with the participation of the University of Alberta, Dalhousie University, Optech and Natural Resources Canada (Geological Survey of Canada), the Canadian Space Agency and international collaboration from the Finnish Meteorological Institute. MDA Space Missions is the prime contractor for the meteorological station, in partnership with Optech. The telltale on the meteorological station's mast was contributed by the University of Aarhus, with support from the University of Alberta.

The Phoenix Mission is led by Principal Investigator Peter H. Smith of the University of Arizona, supported by a science team of CO-Is, with project management at NASA's Jet Propulsion Laboratory and development partnership with Lockheed Martin Space Systems. International contributions are provided by the Canadian Space Agency; the University of Neuchatel, Switzerland; the universities of Copenhagen and Aarhus Denmark; the Max Planck Institute, Germany; and the Finnish Meteorological Institute.



CANADA AND THE HERSCHEL SPACE OBSERVATORY

The fourth and final Cornerstone mission of the European Space Agency's (ESA) space science program, the Herschel Space Observatory launched on May 14, 2009 and has a projected three-year life span. During that time, scientists will seek answers to important astronomical questions, from how galaxies formed and evolved to how stars and planets form today. Herschel will observe cold celestial objects (much of the Universe is too cold to emit light in the visible spectrum) by capturing the radiation emitted in the spectrum.

Given that water is essential to life on Earth, scientists have long believed that it is also essential to life on other planets in our solar system and others. Until recently, however, no one has ever developed a way to precisely detect and quantify water molecules in space.

Now, not only does such an instrument exist, but it is a vital component of the Herschel Space Observatory. The Heterodyne Instrument for the Far Infrared (HIFI) is a spectrometer developed with the assistance of a research team at the University of Waterloo. HIFI is the first instrument to analyze the chemistry of our galaxy from space with sufficient precision to characterize

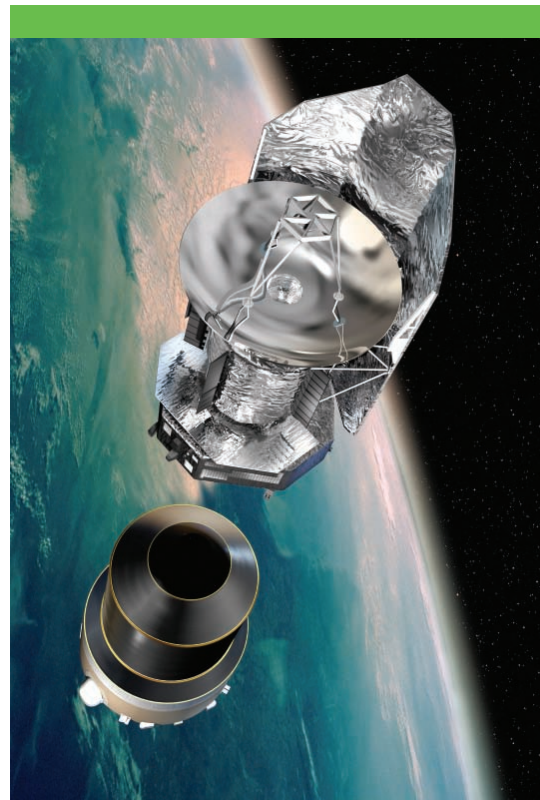


Illustration : ESA - D. Ducros, 2009

the abundance of water and other molecules in the interstellar medium. As part of this mission, it looks for water in different space environments, including intermediate mass star-forming regions.

While scientists know a lot about the formation of low-mass stars like our Sun, less is known about intermediate-mass star formation. However, scientists have learned a great deal about the star-forming process itself. Now, thanks to HIFI, they will know even more.

Focusing on the quietest, coolest and youngest of the intermediate-mass, star-forming regions, the Canadian research team recently discovered the presence of an extremely hot molecular gas. Pre-Herschel models suggested they could expect the hottest gas on the object they were observing to be just under 400K—about the temperature of boiling water. Instead, the gas on the object reached 1500K, very near the temperature where molecules start to break up.

The object scientists had selected for the HIFI experiment was a protostar inside an envelope—a cloud of gas being drawn onto the protostar by gravity. This

accreting material increases the mass of the protostar until it becomes capable of blowing the envelope away. The hottest region in such an envelope, scientists believed, is only 400K; to reach 1500K would require an extremely high energy outflow material producing shocks or strong ultraviolet light. Until Herschel and HIFI provided otherwise, scientists felt a young object such as a protostar would be incapable of such extreme temperatures.

The gas at the centre of these remarkable discoveries is comprised mainly of carbon monoxide. The Canadian team has since turned its attention to gases comprised primarily of water, a more difficult task because water is a more complex molecule that produces a more precise diagnostic. While scientists can measure only the temperature of carbon monoxide, water observations are taken at a much higher velocity resolution. As a result, it's possible to measure other things, such as the speed of the outflowing material.

Led by Waterloo physics and astronomy professor Michel Fich, Canadian scientists developed a local oscillator source unit for HIFI, similar to a radio tuner, which gives the instrument the stable reference signal

required for it to function in a harsh environment. Unlike a radio, however, the oscillator unit produces an exceptionally pure and stable signal, more so than any oscillator unit ever developed.

The oscillator unit has been described as the heart of HIFI: low in weight yet robust, powerful yet precise, and able to function through vibrations and G-force. The component gives HIFI its unique ability to detect molecules in the far-infrared spectrum, radiation that is largely blocked by Earth's atmosphere. Because of this, scientists are closer than ever to answering questions that have been asked for centuries: are there other planets similar to Earth? Was there always water on Earth, and if not, how did it get here?

Yet the device that makes HIFI's remarkable abilities possible was not an overnight success. In fact, work on the oscillator unit has been underway since 1998. Still, says Professor Fich, the perseverance that resulted in its completion was evident throughout the multi-national collaboration that led to Herschel and the world's first astrochemistry observatory.

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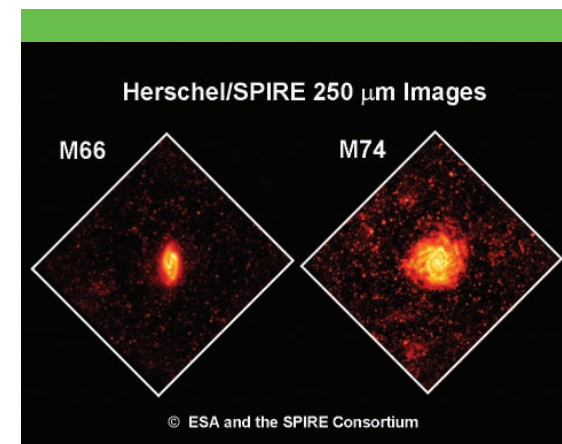
HIFI is one of the three main instruments aboard the Herschel Space Observatory. A second instrument also includes critical Canadian expertise: a team of Canadian researchers, led by Professor David Naylor of the Department of Physics and Astronomy at the University of Lethbridge, designed the SPIRE (Spectral and Photometric Imaging Receiver) instrument. Using both an infrared camera and an imaging spectrometer, SPIRE has the ability to view a large region of the sky simultaneously. A team of programmers from the company Blue Sky Spectroscopy, in cooperation with Professor Naylor, is leading the development of the data analysis software for the SPIRE imaging FTS. This Canadian-made software is a key to the successful generation of high-quality scientific data products from this ground-breaking instrument.

In the summer of 2009, SPIRE made its first successful observations, targeting two star-forming galaxies near the Milky Way. Designed to look for emissions from clouds of dust linked to star-forming regions in the Milky Way and other galaxies, SPIRE imaged two galaxies, known as M66 and M74, on June 24. M66 is a barred spiral galaxy—a galaxy with a bar-shaped centre like our own Milky Way—located about 35 million

light-years from Earth, in the constellation Leo. M74 is a face-on spiral galaxy with well-defined spiral arms located about 30 million light-years from Earth, in the constellation Pisces.

The SPIRE spectrometer, with its instantaneous spectral coverage and mapping, has detected a wide range of molecules, atoms and ions, including water—not only in our galaxy, but also nearby galaxies. One of the exciting developments with SPIRE is the detection of a high red shift lensed galaxy through the measurement of the red shifted ionized Carbon line at 158 microns. Dr. Naylor is one of the three co-inventors of the SPIRE spectrometer design, which is based on a system he has used at the James Clerk Maxwell Telescope in Hawaii.

In return for its important contributions to HIFI, SPIRE and the Herschel project, Canada has been allowed to place nine scientists on the Observatory's science team. They have been guaranteed access to the observing time required to support their research. Furthermore, HIFI's presence aboard Herschel will enable a consortium of Canadian astronomers to be involved in a key science project aimed at the studies of water in star-forming regions.



Professor Michel Fich of the University of Waterloo is the Principal Investigator for HIFI in Canada. COM DEV, Cambridge, Ontario, is the prime contractor for Canada's contribution to HIFI. Professor David Naylor of the University of Lethbridge is the Principal Investigator for Canada's contribution to SPIRE. Blue Sky Spectroscopy, Lethbridge, Alberta, hosts the centre of expertise for the SPIRE imaging spectrometer. The Canadian Herschel team includes scientists from the universities of British Columbia, Calgary, Western Ontario, Toronto, Victoria, McMaster University and the National Research Council Canada.

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