Canadian Space Agency
Agence spatiale canadienne

Media Book

STS-97

Marc Garneau
Canadian Space Agency

2000-11-28

Canada

Canadian Emblem for the STS-97 Mission

This emblem commemorates the participation of Canadian Space Agency Astronaut Marc Garneau in the STS-97 Mission, also known as ISS Assembly Mission 4A. He will fly on board Space Shuttle Endeavour to help in the assembly of the International Space Station.

This emblem is simple but striking. It evokes the power of teamwork, a concept in which Marc strongly believes. The five hands gripping lightning bolts represent the five crew members, and symbolize the mission's key objective to install solar panels on the Space Station to supply it with electricity.

As Flight Engineer, Garneau will use the Canadarm and the Canadian Space Vision System to lift the solar panels from the Shuttle's cargo bay and move them to the location where they will be secured to the Space Station.

www.space.gc.ca

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Kennedy Space Center

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Johnson Space Center

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Footage and Photos

B-roll footage and a high-resolution photo disk of images related to STS-97 are available by contacting:

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http://www.space.gc.ca/asc/search.asp

NASA TV's Broadcast Coordinates

Transponder 9C of the GE-2 satellite at 85 degrees West longitude, vertical polarization frequency 3880 MHz, audio 6.8 MHz.

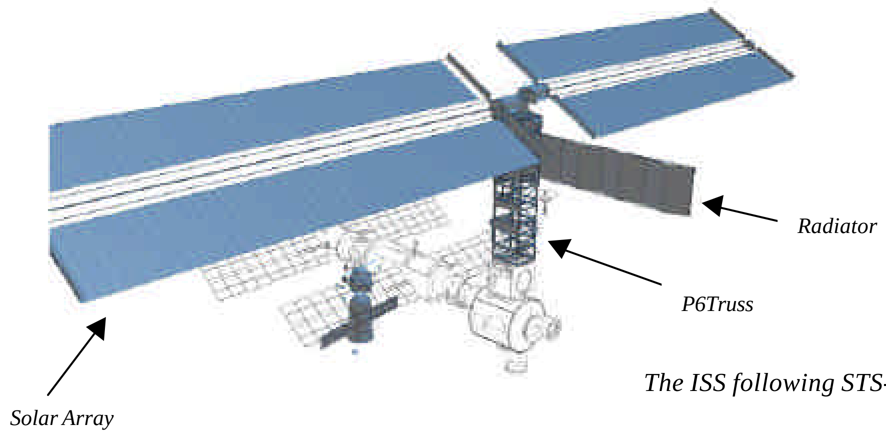
Mission STS-97 with Canadian Space Agency Astronaut Marc Garneau

The International Space Station following Misison STS-97

Fast Facts about STS-97

Marc Garneau's Reponsibilities	• Mission Specialist 2 (MS2); • Canadarm Operator to manoeuver the P6 Structure containing the arrays from the Payload Bay to its mated position; • Intravehicular (IVA) crew member, the "choregrapher" of the spacewalks; • Back-up extravehicular (EVA) crew member.
Mission Overview	• ISS Flight 4A crew: Commander Brent Jett (Rendez-vous), Pilot Micheal Bloomfield (RMS, Undock and Flyaround), MS1 Joseph Tanner (EV1), MS2 **Marc Garneau** (RMS/IVA), and MS3 Carlos Noriega (EV2); • Mission STS-97 on board *Endeavour* will be the first Shuttle to visit the first ISS crew (Expedition 1); • Expedition 1 is composed of US Astronaut Bill Shepherd, and Russian Cosmonauts Sergei Krikalev and Yuri Gidzenko.
Mission Objectives	• Provide the first US solar arrays and batteries (photovoltaic module); • Install the photovoltaic modules temporarily on Z1 truss, until Assembly Flight 13A when they can be moved to P5 truss; • Transport two Thermal Control System radiators which will provide early cooling; • Activate the S-band communications system for voice and telemetry.
Main Payload	• Integrated Truss Structure P6 with Photovoltaic Module and Radiators.
Solar Arrays	• Will be installed on the P6 Integrated Truss Structure; • The arrays will supply 18 kW of 160 VDC primary power to the Station; • Measuring about 70 meters from tip-to-tip when fully deployed, the panels will be the largest ever built and deployed in space; • The deployment of the arrays will take approximately 12 minutes per side and will be done with the help of a laptop computer.
Canadian Elements	• **Marc Garneau** will operate the Canadarm, or Shuttle Remote Manipulator System to remove the solar arrays from the shuttle's cargo bay; • The Canadian Space Vision System will be used to berth the P6 on the Z1 Truss; • IMAX Cargo Bay Camera-3D (ICBC-3D); • An S-Band TDRSS Transponder, built by Montreal-based EMS Technologies, sent up on Flight 3A, will be relocated from the Z1 to the P6 Truss.

STS-97: Mission Description



The ISS following STS-97

If you can imagine what it would be like trying to run your house or office without electricity, you'll have some idea of why Marc Garneau's next mission in space is so important to the development of the International Space Station.

Garneau and his fellow crewmembers aboard the Space Shuttle *Endeavour*, scheduled for launch on November 30, 2000, will install the first of four pairs of huge solar power arrays on the Station, which is orbiting about 400 kilometres above Earth. The planned 11-day mission, STS-97, will be Garneau's third—a record for Canadian astronauts.

He'll be working with the other Canadian on board—the Shuttle's manipulator arm (better known as the Canadarm)—to install the solar arrays that will generate electricity to run all the Station's systems, including life support, daily operations and scientific equipment. Although the two Russian station modules already in orbit do have solar panels, they're not enough to power the entire Station when it's fully built.

Using the Canadarm, Garneau will reach into *Endeavour*'s payload bay to pick up the "P6 truss structure"—a section of the Station's truss on which the solar power arrays were installed prior to launch. Garneau will then move the 16 000-kilogram package, which is about 14 metres long, to within a few centimetres of another truss that is already part of the Station. Known as the Z1 truss, it has a claw-like latch that will be used to grasp the P6 and hold it in place.

This procedure will be assisted by another Canadian technology—the Orbiter Space Vision System—which provides the Canadarm operator with precise information about the position, orientation and movement of payloads being manoeuvred by the manipulator.

After the P6 has been put in place, American astronauts Joseph Tanner and Carlos Noriega will do two space walks to fully close the Z1 latch and bolt down the four corners of the P6 to secure it firmly to the Z1. They will then attach cables to provide initial power to the Station, to establish a data link between the solar power system and a computer inside the Station, and to connect to a supply of ammonia so that excess heat can be radiated into space from special purpose radiator panels mounted on the P6. They will also remove launch restraints holding down the solar arrays and radiators mounted on the P6 so that they can be deployed.

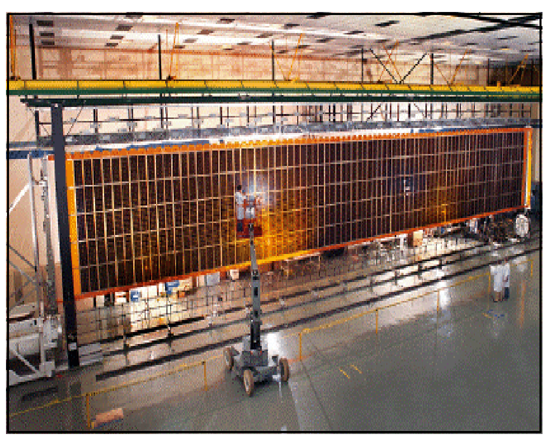
During the space walks, or extra-vehicular activities (EVAs), Garneau will assist Tanner and Noriega from inside the shuttle—a task known as IVA (intravehicular activity). His job is to co-ordinate the space walks, help the EVA astronauts to stay on track and make sure nothing's overlooked. "I'll be reminding them where to go, what to do, what tools they will need and when it's time to come in," Garneau said.

The EVA astronauts are so well trained that they don't really need much help as long as the space walks go according to plan. It's different if there are problems; Garneau said his role becomes more critical if the EVA astronauts "come to a particular task and it's not working or they develop a suit problem or they get tangled up and lose a tool. At that point, the clock is 'counting' on their life support systems. You may have to re-jig the EVA and reassign priorities—always keeping in mind that the first priority is their safety. That's where you earn your money."

Garneau is in a good position to know exactly what the EVA crew is facing because he also trained as their backup. If something prevents one of them from doing the space walk, Garneau can step in—or rather, step out into space. He practiced all the procedures in the huge water tank NASA uses for EVA training, although with all his other responsibilities, he could only put in about a quarter of the time the primary EVA astronauts invested in learning the tasks. "Yet, I have to be able to do the job if called upon to do it," he said.

Although it's not common for IVA astronauts to train as backup EVA astronauts, Garneau feels the EVA training left him much better prepared for his IVA role because he's personally performed all the tasks his colleagues will be doing. "You're not imagining them, you're actually doing them. EVA is not an intellectual process, it's a physical process."

After the solar arrays are secured on the Z1 truss, they will be unfurled one at a time on either side of the truss, commanded by shuttle astronauts using a laptop computer. Launched folded up like an accordion, the arrays will need less than 15 minutes each to reach full length. The two 34-metre-long rectangular panels, each containing thousands of silicon solar cells, will give the linked modules of the Station the appearance of having large gossamer wings. "These are truly enormous arrays and will make the Station look like a giant bird when they are deployed," said Garneau.



Solar array

times they'll be blocked by the Earth. This is why rechargeable batteries are also part of the package; they'll be used to store power so the Station can have an uninterrupted electrical supply. Since the processes involved in collecting solar energy, converting it to electricity and distributing it generate a lot of heat, the system also has a form of "air conditioning"—radiators that dissipate heat into cold space to prevent the solar power equipment from overheating.

Successful installation of the P6 truss and the first set of solar panels is a critical step in construction of the Space Station. Hard on its heels will follow a great deal of power-hungry equipment. The U.S.-built *Destiny* laboratory will be installed on the Station on the following flight STS-98, scheduled for launch in mid-January, 2001. Then comes several logistics modules—known as space "moving vans"—that will carry equipment, supplies and laboratory racks filled with scientific experiments.

Although Garneau's participation in installing the solar power system is a key part of the mission, it's not his only responsibility. An equally important job—in fact, one that consumed about half of his training time—will be to support the two shuttle pilots in the cockpit during the critical eight minutes it takes *Endeavour* to reach orbit. Garneau is the first Canadian to be assigned this role.

"It's a bit like being a flight engineer on a large passenger aircraft," he explained. "This means learning all of the shuttle systems, being ready to assist with troubleshooting if necessary and helping the crew stay on the timeline." As with being IVA, Garneau's role will be most important if any "anomalies" occur during the ascent, which is one of the most demanding and dangerous parts of the mission. There's little time to troubleshoot if things go wrong and failure could have life-threatening consequences. "The pace is really quite a bit faster than when you get into orbit," he said.

As if all this isn't enough work, Garneau has several other jobs during the mission. For example, he will participate in procedures to dock the Shuttle to the Space Station, using laser and computer tools to manage information about the position of the Shuttle relative to the Station and how fast they're closing in. "I have to operate the laser and we have a computer application that gives us a nice picture of where we are from the Station as we fly in. There's a certain amount of work required to keep that picture updated and that's my responsibility." Garneau will also be using the Canadian-developed large-format IMAX camera to film portions of the mission.

STS-97 will be the first shuttle flight to dock with the Station after the arrival of the first resident crew, American astronaut Bill Shepherd and Russian cosmonauts Sergei Krikalev and Yuri Gidzenko. They are scheduled for launch on October 30, 2000, for an expected stay of three and a half months. Garneau's crew, who will enter the Space Station nine days into their shuttle flight, will be their first visitor.

Mission Highlights

Flight Day 1: Launch from the Kennedy Space Center in Florida scheduled at 10:05 p.m. (Eastern Time) on 30 November 2000.

Flight Day 2: Preparation of the Canadarm and the Canadian Space Vision System for their role on Flight Day 3. Inspection of spacesuits for EVA 1.

Flight Day 3: *Endeavour* is scheduled to dock with the Unity module of the International Space Station shortly before 3:00 p.m. (Eastern Time). After docking, **Marc Garneau** will use the Canadarm to lift the P6 integrated truss (which contains the solar arrays) out of *Endeavour*'s payload bay. The P6 truss will be placed in a "parked" position overnight. The astronauts will also prepare the docking port for their entry into the Space Station on Flight Day 7.

Flight Day 4: Astronauts Joe Tanner and Carlos Noriega will conduct the first scheduled space walk (EVA) to install the solar arrays. **Marc Garneau** will use the Canadarm to attach the P6 truss segment to the Station, and will assist his crewmates as the onboard choreographer during their space walk. **Garneau** is also the back-up EVA crew member for all 3 space walks.

Flight Day 5: The astronauts will rest following their first space walk, and will begin preparations for their entry into the International Space Station.

Flight Day 6: Tanner and Noriega will perform their second space walk to relocate a communications antenna to the top of the P6 truss, and prepare the Station for the arrival of the US laboratory *Destiny*. **Marc Garneau** will be the Intra-vehicular crew member (IV), as well as the back-up for the EVA.

Flight Day 7: Following a second gruelling space walk, the astronauts will rest, and perform various routine tasks and preparations.

Flight Day 8: Tanner and Noriega will perform a third EVA to install a floating potential probe experiment on top of the P6 to measure plasma in the environment around the Station. **Marc Garneau** will once again choreograph their activities, and act as their back-up.

Flight Day 9: The STS-97 and Expedition 1 crews (the resident crew aboard the Station) will open the hatches between *Endeavour* and the Station to greet one another and transfer equipment and supplies.

Flight Day 10: *Endeavour* undocks from the International Space Station. The rest of the day will be spent preparing the Shuttle for its return to Earth.

Flight Day 11: Preparations for landing, and routine checks of the Shuttle's systems prior to landing.

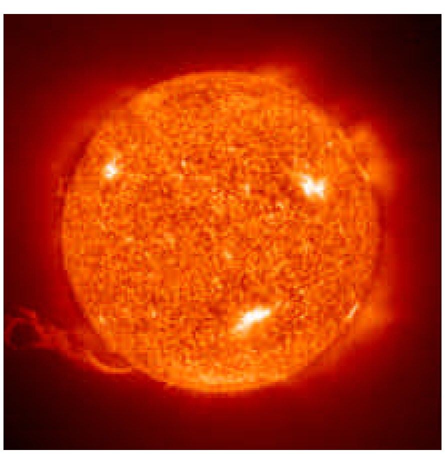
Flight Day 12: *Endeavour* lands at the Kennedy Space Center.

Powering the International Space Station

When the first set of American solar panels unfurls over the International Space Station, Canadian Space Agency Astronaut **Marc Garneau** and the crew of STS-97 will have successfully contributed a vital component of the International Space Station's Electrical Power System. The power system will not only sustain all Space Station functions (including command and control, communications and lighting), but also the lives of the inhabitants inside. Orbiting the Earth at a distance of approximately 400 kilometres, the fledgling Station must be entirely self-sufficient, and must supply its own electrical power by harnassing the Sun's light, the only readily available source of energy.

Once completed, the International Space Station's design calls for four pairs of solar panels measuring 70 metres by 10 metres from tip to tip, which will extend beyond the Station's main body like the wings of a bird in flight. Composed of 32 400 cells, each panel will capture sunlight in purified crystal ingots of silicon that convert sunlight into energy through a process known as "photovoltaics." Each panel will produce 18 kW (kilowatts) of 160 VDC (volts of direct current) of primary power to the Station, and when the Station has been fully assembled, the total electric power system will generate 110 kW in total—roughly equivalent to the amount of energy typically consumed by 55 houses. Of the total, approximately 46 kW will be available for use by the various research experiments and projects on board.

The Space Station circles the Earth at a speed of 29 600 km/h, and experiences 16 sunrises and sunsets over the course of a 24-hour day on Earth. This means that the Station is regularly swathed in darkness for up to 36 minutes of its 92-minute orbit as it is eclipsed by the Earth. The solar arrays were designed to rotate to face the Sun to maximize power to the Station. In order to provide an uninterrupted source of electricity to the Station, the converted energy must be stored in rechargeable nickel hydrogen batteries. A total of thirty-eight cells will reserve energy for the sunless portion of the Station's orbit. Like all hardware on the International Space Station, the batteries are replaceable, and have been packaged in an enclosure known as an ORU (Orbital Replacement Unit) so that astronauts can easily remove and change them.



The Sun

The Space Station is constantly travelling on its orbit from darkness to light, and is subject to temperature extremes ranging from 149ºC to –126ºC. Since heat cannot be dissipated by convection in space, the Station is equipped with a radiator system consisting of seven panels (each measuring 1,8 m by 3,6 m) through which an ammonia flow system will circulate. The ammonia (chosen because it is a safe, cost-effective substance that transports heat efficiently and resists temperature variations) will collect heat generated from the Station's electronic equipment and module cooling compartments and transfer it to the radiator panels to be dissipated into space. Additional protection for the Station is provided by its "plasma contractor unit," which acts as an electrical "ground." While on orbit, the Station will interact regularly with space plasma (charged particles in space) that could result in significant arcing (large electrical discharges similar to power surges in the average home) from its surface to the surrounding environment. This would destroy the thermal properties of the coating on the surface of the Station's structure, and could endanger the Space Station's crew and equipment. The plasma contractor unit neutralizes electrical charges by converting a small supply of gas to ions and electrons, which then release excess electrons created by the surface charge harmlessly into space.

The International Space Station is the largest science and technology project in the history of humanity, and a symbol of international cooperation and the joint effort of the world's leading industrialized nations. The five key partners are Canada, the United States, Russia, Japan and the European Space Agency (composed of eleven European nations). Without the use of Canadian robotic technologies, the International Space Station simply could not be built. Once installed, the Mobile Servicing System will move around the huge floating structure like an inchworm for assembly and repair work. On the ground, the Operations Complex at the CSA headquarters in Saint-Hubert, Quebec, will plan missions, monitor the condition of the robotic arm and train Space Station crew in its use.

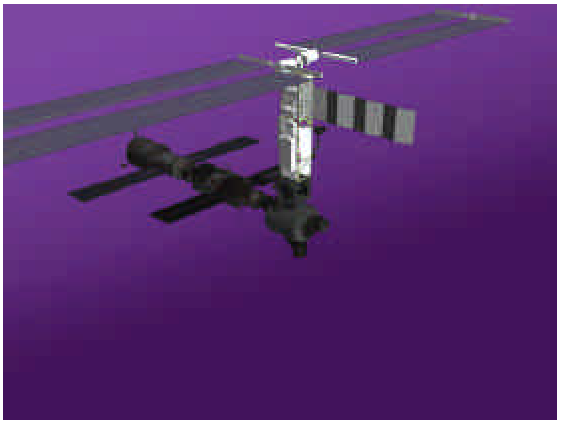


Illustration of the ISS following STS-97

Marc Garneau: Three Decades in Space

CSA Astronaut Marc Garneau

When Marc Garneau is launched aboard the Space Shuttle *Endeavour* in November—with 438 hours in space already under his belt—it will be more than just a record-setting third flight for a Canadian astronaut. The mission will also showcase the growth and evolution of the role played by Canadian astronauts in the International Space Program since Garneau became the first Canadian to fly in space in 1984.

During that first mission, Garneau was essentially a passenger with limited and largely self-contained responsibilities for conducting several Canadian scientific experiments. This time, he not only has key responsibilities in building the International Space Station, but he's had to learn quite a bit about everyone else's job as well. "I'm Mr. Support," he said. "I'm the bridesmaid for everybody on this flight."

His major role will be to operate the Canadarm to install a set of solar power arrays on the Station. He will also co-ordinate the space walks of two American crew mates who will complete the installation of the arrays and he will manage information during the docking of the shuttle with the Space Station.

Garneau also trained as a backup astronaut for the space walks, or "extravehicular activities" (EVAs), learning all the tasks required so he can step in for one of his colleagues if necessary. He will also be in the cockpit with the commander and pilot during the critical launch phase, ready to help with troubleshooting if anything should go wrong. This is a demanding job that required him to learn all of the shuttle's critical systems and consumed fully half of his training time.

It's a far cry from 1984, when he was taught little more about the shuttle than how to cook his meals, prepare his sleeping bag, use the zero-gravity toilet, escape from the shuttle in an emergency and stay away from things that could endanger crew safety.

In those days, he was what's known as a payload specialist—a category of astronauts trained to perform scientific or technical experiments who were not at the time considered career astronauts. Garneau was conscious of the fact that he was the "new kid on the block" and only the second non-American to fly as a payload specialist. "The concept was brand new and, to be honest, it was not popular within the astronaut office, for obvious reasons—they felt we were taking flight slots."

This was particularly true for Garneau because he was assigned to a flight less than a year after being selected as an astronaut. With an educational background in electrical engineering, he had been a Commander with the Canadian Forces, working as a naval communications and electronic warfare expert, when he applied for the astronaut program and abruptly found himself amidst NASA's astronauts corps.

"I was just a few months from my previous job and I was going to fly," he said. "There were people who had been waiting over 15 years. I felt eyes burning through my back when I walked down the hall." But while some of the NASA astronauts were "a little cool," others welcomed him and his backup, Bob Thirsk. "They said, you're going to be hanging your neck out just like everyone else, welcome aboard."

At the time, payload specialists had relatively little contact with the NASA astronauts on their crew. Garneau and Thirsk were given offices in a different building and only trained intensively with the rest of the crew in the last two months before flight. After the flight, Garneau told NASA officials that while two months was sufficient for the limited training on shuttle systems they received, it was "too short a time to create any bond, to form a relationship with the rest of the crew. I think they took that to heart." Payload specialists have now become an integral part of the team. "Times have changed," Garneau added.

During those early days, Garneau was acutely aware that his every move was being scrutinized by other eyes—those of millions of Canadians who were intrigued with their country's first astronaut. "There was a lot of pressure because it was the first time, it was brand new for Canada. People wanted to know everything about me; they were filming me by the pool when I was trying to relax. That was one of the hardest things to deal with. I didn't want to disappoint Canada."

Garneau also felt that the future of the Canadian astronaut program depended on him turning in a creditable performance. "A lot of things are make-or-break based on first impressions. NASA had no experience with Canadian astronauts so it was very important for Canada to get off on the right foot and I wanted to acquit myself well."

It would be twelve years before Garneau would fly his second mission—a long delay caused largely by the *Challenger* accident in 1986. During that time, Garneau served as Deputy Director of the Canadian Astronaut Program and helped to prepare Canadian space experiments to fly on future missions. He also provided support for the 1992 flight of Steve MacLean, the third Canadian in space.

Garneau in training for his first mission, STS-41-G

In 1992, Garneau and then newly selected astronaut Chris Hadfield became the first Canadians to enter NASA's mission specialist training program. Mission specialists are responsible for operating shuttle systems, including the Canadarm, and doing space walks.

For Garneau it was a "wish come true. When I landed in 1984, I said to myself, that was a fabulous experience but I'd like to do that as a mission specialist, to have responsibility for operating the arm and being knowledgeable about orbiter systems, to share part of that load. That was a secret wish of mine after the flight." By the time of his second flight—STS-77 in 1996—Garneau had graduated to the status of mission specialist.

STS-77

As with his first mission, he was determined to show that Canadians were up to the challenge of spaceflight. But this time, he had many more responsibilities and was far more integrated with the rest of his crew. "We all moved in together 10 months prior to flight. In 12 years, the program had evolved quite a bit." He said things were changing because the Space Station was "looming on the horizon." Since Space Station missions would last for several months at a time, there was a growing emphasis on developing crew cohesiveness prior to flight.

Compared with his first flight, the workload was not only greater, but different. As a payload specialist doing science experiments, Garneau said "you generally have the time to assess the situation before you take the next action. As a mission specialist with responsibility for orbiter systems, you have to make that assessment very quickly and if there's a problem, make the correct decision about what to do about it. In order to react rapidly and correctly, you have to know your systems by heart. You have to have experienced every conceivable malfunction, so if a malfunction occurs, it will look familiar to you and somewhere in the back of your brain the proper response will come out. This takes a lot of training and a lot of malfunctions, where they're literally try to overload your brain."

Although it took four years for Garneau to be assigned another flight after entering the mission specialist program—since he'd already flown once, he was near the end of the line among his cohorts—he welcomed the fact that this gave him ample time to learn all about the shuttle's systems. "It was a very nice progression in terms of becoming familiar, especially with the arm." Learning how to operate the Canadarm was, in fact, a high point of his training. "For me, it was the culmination of everything I'd hoped for because it was Canadian." He found the arm to be "a beautiful instrument"—so intuitive and natural that he felt it became an extension of his own hands.

While he was waiting for a flight assignment, one of his responsibilities was to serve as a "CAPCOM" (capsule communicator), an astronaut who works in Mission Control during shuttle flights and acts as the direct voice link between mission controllers and the crew in space. Garneau said it provided invaluable experience because it enabled him to participate in elaborate simulations of many different shuttle missions during which the ground and flight crews were required to troubleshoot all kinds of malfunctions. It honed his understanding of shuttle systems and his ability to react quickly when things go wrong, which provided a "solid foundation" when it came time to train for his own flight.

On STS-77, Garneau became the second Canadian to fly as a mission specialist (Hadfield had flown a mission in late 1995). His major responsibility was to operate the Canadarm to retrieve a scientific satellite called Spartan that had been previously released from the shuttle's payload bay. Spartan carried an inflatable antenna that was deployed to test the benefits of using light-weight inflatable structures in space. The retrieval of Spartan was also intended to test manoeuvres of the Canadarm similar to those that would be needed during construction of the Space Station. Once Garneau captured Spartan with the arm, he positioned and secured it in the payload bay for return to Earth.

Garneau also participated in conducting a number of scientific experiments, including three developed by Canadians. In that respect, it was similar to his first mission, but with the added satisfaction of having participated in shuttle operations as "a key member of the team."

Suiting up during training for STS-97

His upcoming mission carries the evolution of his responsibilities even further. Again, he will operate the Canadarm, but moving the solar arrays from the shuttle payload bay to the Space Station will be more challenging than what he did on his last mission—he won't be able to see the payload directly with his eyes and will instead have to depend on viewing the operation through cameras at the back of the payload bay.

And then there's the role he'll play during one of the most demanding and fast-paced phases of the mission—the eight-minute ascent into orbit. He'll be sitting on the flight deck behind the commander and pilot, acting as the equivalent of a flight engineer on a passenger aircraft. "This means learning all of the shuttle systems, being ready to assist with troubleshooting if necessary and helping the crew stay on the timeline. I now had to dive into specialized phases of the flight where things happen much more quickly."

Because construction of the Space Station was repeatedly delayed, Garneau's launch date has been moved back several times. This gave him extra time to "get up on the curve" of his new responsibilities. "If we'd had only nine months to train, it would have been really tough. Because it stretched out to two years, it's been very reasonable."

The flight marks the culmination of a long odyssey for Garneau and the Canadian Astronaut Program. Over the 16 years of his career, he progressed from: "Don't touch anything that could get us into trouble" to "We'll need your help if we get into trouble."

Marc Garneau training at NASA's Johnson Space Center with fellow STS-97 crewmate, Mike Bloomfield

After this mission, Garneau says he will "seriously assess" where his future lies. At 51, he's ready to think beyond being an active astronaut. Although he says he "wouldn't dismiss out of hand" an invitation to work on board the Space Station, he added: "After this flight, I will have satisfied all my personal ambitions. I have to consider the personal side of life, my family. This may be a time when I should reassess." However, he wants to remain in Canada's Space Program to "expand my field of contribution. I've been an astronaut for 16 years; I would like to make a contribution to the Canadian Space Program in other areas."

If he does move on, he goes with the knowledge that those 16 years provided him with experiences shared by few other human beings. "From a purely personal point of view, the chance to experiment with spaceflight was beyond anything that words can describe in terms of personal satisfaction." And although he's received many awards and honours for his work—including the Order of Canada—he says that "what I will take away from my time as an astronaut is a sense of pride that I did a good job right from the beginning."

He noted that Canada now has seven astronauts at NASA's Johnson Space Center in Houston who have acquitted themselves well and have been assigned key responsibilities in the International Space Program. It gives him a sense of accomplishment that "I contributed to getting it all off on the right foot. If I had messed up that first flight, it would have cast serious doubt on whether NASA would want to continue working with Canadians."

Launch of STS-41-G, Garneau's first mission

Biography: Dr. Marc Garneau
Canadian Space Agency Astronaut

Personal data: Born February 23, 1949, in Quebec City, Canada. Married to Pamela Soame of Ottawa, Canada. Has four children. He enjoys flying, scuba diving, tennis, car mechanics, and home repairs. In 1969 and again in 1970, he sailed across the Atlantic in a 59-foot yawl with 12 other crewmen. His parents, Jean and André Garneau, and her parents, Diana and James Soame, reside in Ottawa, Canada.

Education: Attended primary and secondary schools in Quebec City & Saint-Jean, Quebec, and in London, England. Received a Bachelor of Science degree in engineering physics from the Royal Military College of Kingston in 1970, and a Doctorate in electrical engineering from the Imperial College of Science and Technology, London, England, in 1973. Attended the Canadian Forces Command and Staff College of Toronto in 1982-83.

Organisations: Honorary Fellow of the Canadian Aeronautics and Space Institute. Member of the Association of Professional Engineers of Nova Scotia and the Navy League of Canada. In 1988, he was named Honorary Member of the Canadian Society of Aviation Medicine.

Special honours: Recipient of the Athlone Fellowship in 1970, and the National Research Council (NRC) Bursary in 1972. Awarded the Canadian Decoration (military) in 1980, and the NASA Space Flight Medal in 1984 and in 1996. Appointed Officer of the Order of Canada in 1984. Awarded three *Honoris causae* doctorates in 1985, one by the *Université Laval*, Quebec, the second by the Technical University of Nova Scotia, and the third by the Royal Military College, Kingston, Ontario. Co-recipient of the F.W. (Casey) Baldwin Award in 1985 for the best paper in the Canadian Aeronautics and Space Journal. In 1990 the *Collège militaire royal de Saint-Jean* presented him with a doctorate (*Honoris causa*). In 1997 the University of Ottawa presented him with a doctorate (*Honoris causa*).

Experience: Dr. Garneau was a combat systems engineer on HMCS *Algonquin*, 1974-76. While serving as an instructor in naval weapon systems at the Canadian Forces Fleet School in Halifax, 1976-77, he designed a simulator to train weapons officers in the use of missile systems aboard *Tribal* class destroyers. He served as project engineer in naval weapon systems in Ottawa from 1977 to 1980. He returned to Halifax with the Naval Engineering Unit, which troubleshoots and performs trials on ship-fitted equipment, and helped develop an aircraft-towed target system for the scoring of naval gunnery accuracy. Promoted to Commander in 1982 while at Staff College, he was transferred to Ottawa in 1983 and became design authority for naval communications and electronic warfare equipment and systems.

In January 1986, he was promoted to Captain. He retired from the Navy in 1989. He is one of six Canadian astronauts selected in December 1983. He was seconded to the Canadian Astronaut Program from the Department of National Defence in February 1984 to begin astronaut training. He flew as a payload specialist on Mission STS-41-G, October 5-13, 1984. He was named Deputy Director of the Canadian Astronaut Program in 1989, providing technical and program support in the preparation of experiments to fly during future Canadian missions. He was selected for Mission Specialist astronaut candidate training in July 1992.

NASA experience: Dr. Garneau reported to the Johnson Space Center in August 1992. He completed a one-year training and evaluation program and is qualified for flight assignment as a Mission Specialist. Dr. Garneau initially worked on technical issues for the Astronaut Office Robotics Integration Team. He subsequently served as spacecraft communicator (CAPCOM) in Mission Control during shuttle flights. A veteran of two space flights (STS-41G in 1984 and STS-77 in 1996), Dr. Garneau has logged over 437 hours in space.

STS-41G (October 5-13, 1984) was an eight-day mission aboard Space Shuttle *Challenger*. Dr. Garneau was the first Canadian to fly on NASA's first mission to carry a seven-person crew. During 133 orbits of the earth in 3.4 million miles, the crew deployed the Earth Radiation Budget Satellite; conducted scientific observations of the earth with the OSTA-3 pallet and Large Format Camera (LFC); performed numerous in-cabin experiments; activated eight “Getaway Special” canisters; and demonstrated potential satellite refuelling with an EVA and associated hydrazine transfer. Mission duration was 197 hours 23 minutes.

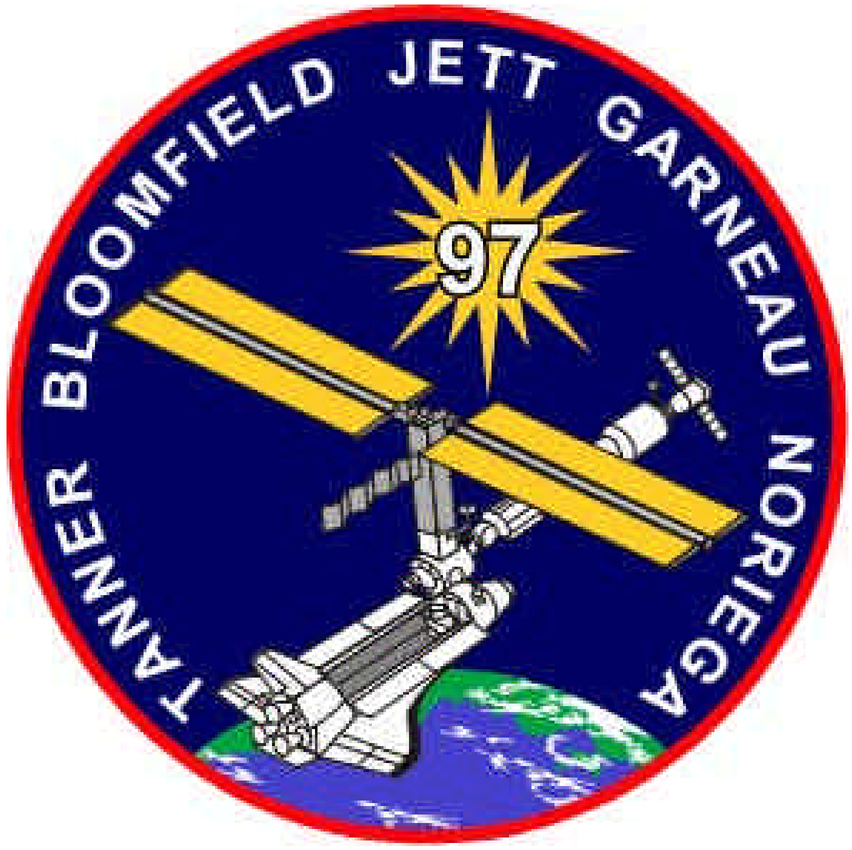
STS-77 (May 19-29, 1996) was a ten-day mission aboard Space Shuttle *Endeavour*. During 160 orbits of the earth in 4.1 million miles, the crew deployed two satellites (the SPARTAN satellite which carried the Inflatable Antenna Experiment designed to test the concept of large, inflatable space structures; and the small Satellite Test Unit designed to test the concept of self-stabilisation by using aerodynamic forces and magnetic damping) and conducted twelve materials processing, fluid physics and biotechnology experiments in the Spacehab laboratory module carried in *Endeavour*'s payload bay. Mission duration was 240 hours and 39 minutes.

Finally, STS-97 will be Marc Garneau’s third space mission. He will go into orbit aboard *Endeavour* on November 30, 2000 as Flight Engineer, to transport the first large set of solar arrays for the International Space Station. He will install the solar panels using the Canadarm.

The STS-97 Crew

Top Row (left to right): Carlos Noriega; Joe Tanner
*Bottom row (left to right): Mike Bloomfield; **Marc Garneau**; Brent Jett*

NASA's STS-97 Crew Patch



STS-97 will deliver, assemble and activate the US electrical power system on board the International Space Station (ISS). The electrical power system, which is built into a 47-foot integrated truss structure known as P6, consists of solar arrays, radiators, batteries and electronics. P6 will be attached to the Station using the Shuttle's robotic arm in coordination with the space walking crew members, who will make the final connections. The space walkers will then prepare P6 for the subsequent deployments of the large solar arrays and radiator, which are critical steps in the activation of the electrical power system. The 120-foot solar arrays will provide the power necessary for the first ISS crews to live and work in the US segment.

The crew patch depicts the Space Shuttle docked to ISS in low Earth Orbit after the activation of the P6 electrical power system. Gold and silver are used to highlight the portion of ISS that will be installed by the STS-97 crew. The Sun is central to the design as the source of energy for ISS.

The International Space Station (ISS)

The ISS as of 18 September 2000

The ISS once completed

Fast Facts about the ISS

Countries participating:	Canada, the United States, Russia, Japan, eleven European countries (Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom) and Brazil.
Canada's contribution:	• Mobile Servicing System (MSS), composed of the Mobile Base System, the Space Station Remote Manipulator System and the Special Purpose Dexterous Manipulator • Canadian Space Vision System • The ground segment—the MSS Operations Complex—is located at CSA headquarters in Saint-Hubert, Quebec. The complex provides the infrastructure, resources, equipment, and expertise for MSS space operations (training, logistics support, ground processing and sustaining engineering). The Operations Complex is used to plan missions, monitor the health of the robotic arm and train astronauts and cosmonauts in Canada.
Date completed (scheduled):	2006
Missions required:	• A total of over 50 missions will be required to transport and assemble all the ISS components. • Mission STS-97 will see CSA Astronaut **Marc Garneau** deploy the first set of American solar panels to help power the ISS.
Total hours to complete:	• About 160 spacewalks—960 clock hours—will be required over five years for the maintenance and the assembly of the Space Station. • In April 2001, CSA Astronaut Chris Hadfield will perform Canada's first EVA to install the next-generation Canadarm on board the ISS.
Size:	• Once fully assembled, the Space Station will cover an area as large as a Canadian football field. • 108 metres across and 74 metres long • 1250 cubic metres of living and working space—the equivalent of the interior of a Boeing 747, or about three average Canadian houses • Four times as large as the Russian *Mir* Space Station
Mass:	Almost 450 metric tons
Pressurized Volume:	1200 cubic metres
Orbit Inclination:	51,6 degrees
Altitude:	From 370 to 460 kilometres
Facilities:	6 laboratories with 24 experiment racks (about the size of a refrigerator)
First modules:	*Zarya* and *Unity*, launched in November and December 1998 (respectively)
Power:	Almost an acre of solar arrays able to generate 110 kilowatts of power
Crew:	• Once complete, the ISS will house a permanent international crew of 7 astronauts and their experiments • The first permanent crew, Expedition 1, will be launched on board a *Soyuz* rocket in October 2000. The crew will be commanded by US astronaut Bill Shepherd, and will include Russian cosmonauts Yuri Gidzenko as *Soyuz* Commander and Sergei Krikalev as Flight Engineer.
Cost:	The cost of designing, developing and launching the MSS into orbit is approximately $1.4 billion over 20 years (1984-2004), or approximately $3 per Canadian taxpayer per year.
Benefits:	• Some $6 billion of economic benefits are expected to result from Canada's International Space Station participation and 70,000 person-years of employment. • Contracts of $919 million have been awarded to the industry to date, generating $2.8 billion in benefits and 32,000 person-years of employment.

Canada and the International Space Station: Forging Canada's Future in Space

Canadian Space Agency Astronaut Marc Garneau once commented that Canadian children often question him about his first Space Shuttle flight as though he'd been exploring the far reaches of the galaxy with the Star Trek crew. He gently reminds them that he's been only a few hundred kilometres from Earth's surface—about the distance between Toronto and Ottawa.

And yet, even that short distance has carried him from the familiar world we all know to one that only a few people have experienced in all of human history. Foreign and beautiful to our senses, space is also dangerous. Devoid of air to breathe, subject to extremes of hot and cold in the absence of the gravity that binds us to Earth, lacking atmospheric pressure and all the other necessities of life, it offers unprecedented challenges as we learn to live and work in this extraordinary environment. There is so much we don't know about how well we'll adapt.

The International Space Station (ISS), now taking shape on the doorstep to outer space, is our portal to this new world. It's a home-away-from-home with the essentials of life and at least some of the creature comforts that humans need to function for longer periods of time in space. It's a scientific laboratory that will help us unravel the mysteries of the space environment and its impact on the human body and mind. And it provides a vantage point from which to study the Earth below and the stars above. "Space is a brand new environment opening up whole new areas of research," says Alain Poirier, Director General of Space Systems for the Canadian Space Agency.

The International Space Station

The Space Station is too big an undertaking for any one country to go it alone, so it's being built by a partnership of spacefaring nations—Canada, the United States, Russia, 11 European countries, Japan and Brazil. Construction began in late 1998 with launches of the first two components—the Russian module *Zarya* and the US module *Unity*. Several more elements have since been installed and the work is expected to continue until 2006, requiring a total of some 50 flights.

In October 2000, the first resident crew—American astronaut Bill Shepherd and Russian cosmonauts Sergei Krikalev and Yuri Gidzenko—took occupancy for an expected three-and-a-half-month mission. The Station may never again be uninhabited during its lifetime.

The crew of Expedition 1 (left to right: William M. Shepherd, Yuri P. Gidzenko, Sergei K. Krikalev)

Canada has been involved from the outset and its role evolved naturally from its participation in the Space Shuttle program and the development of the Canadarm, the Shuttle's robot arm. In early 1984, when former US President Ronald Reagan invited other countries to join the US in building the Station, Marc Garneau was preparing to become the first Canadian to fly aboard the Shuttle. Just three years earlier, the Canadarm made a successful debut as the Shuttle's remote manipulator system. These events, which significantly raised the profile of space exploration among Canadians, were only the most visible and dramatic manifestations of the collaboration going on behind the scenes that set the stage for Canada's continued involvement in human spaceflight.

"Our people were working with NASA closely and knew the people who were beginning to plan the post-Shuttle program," says Mac Evans, President of the Canadian Space Agency, who was involved in those early discussions. "We spent two years negotiating what our role would be. It became clear that Space Station could not be built without significant advances in robotics and we offered to do that." In the end, Canada won the right to build the Space Station Remote Manipulator System (SSRMS). After more than a decade in development, the SSRMS is scheduled for launch in April 2001 along with Canadian Space Agency Astronaut Chris Hadfield, who will perform a space walk—the first for a Canadian—to install it on the Station.

Building the SSRMS accomplished two important goals for Canada. First, it encouraged the continued evolution of Canadian expertise in robotics. "Robotic technology was and still is a strategic technology in Canada," Poirier adds. "Since we decided to invest in the SSRMS, we've seen already seen the benefits in job creation, the development of advanced skills and also in terms of spin-offs."

These spin-off applications include a robotic vision system that can monitor hazardous waste containers for leaks, an instrument that checks aircraft landing gears and a radar vision system that enables emergency workers to see through smoke.

The SSRMS is also leading the way to further development of advanced planetary robotics, just as the Shuttle arm gave Canada entry to the Space Station program. For example, Canada is currently discussing with NASA the contribution of robotic systems for Mars landing and sample-return missions.

"Our view is that if there's a robotic element, it should be Canadian," says Poirier. "It's always the logical step for us to consider the robotics."

This will also open the door for Canadians to participate in the scientific side of Mars exploration and, eventually, human exploration. "We have no plan to send humans to Mars—nobody has—but once the time has come and other programs are fleshed out with the partners, I believe that Canada will be part of that," Poirier adds.

The second major benefit of the SSRMS is that it bought Canadian scientists access to the Space Station's research facilities. It entitles Canada to a 2.3% share of the "racks" used to hold scientific equipment inside the non-Russian part of the Station, plus access to exterior platforms for instruments that function in open space. This amounts to the use of one full rack per year over the lifetime of the Station. In addition, Canada's astronauts are entitled to a minimum of one three-month tour of duty on the Station every three years.

The Station offers an opportunity to expand the work that Canadian scientists have been doing for years on the Shuttle. Barry Wetter, Director General of Space Science at the Canadian Space Agency, explains that the Shuttle provides "very limited possibilities for research. There are only four to six flights a year and they last from 10 to 14 days. A scientific payload for the Space Station costs about the same as for the Shuttle, but it may stay in space for years. This will allow our researchers and their students to participate in ongoing research. What we'll get out of our investment, the science we do on Space Station, will be several orders of magnitude more than we've ever able to achieve in the past."

From the beginning (in 1984), Evans says, Canada "made it very clear we wanted to be users of this laboratory. But at the time, we only had Marc's first flight under our belt; microgravity science was a whole new science and we didn't know all that much about it." Consequently, CSA began working with potentials users within the Canadian research community and aerospace industry to define projects worth pursuing. "It's now become a well-established field and we've developed quite a scientific capability in Canada."

To assist scientists doing research on the Station, the Canadian Space Agency built facilities at its Saint-Hubert headquarters near Montreal, Quebec, to allow more direct communications between researchers on Earth and Space Station astronauts who will run their experiments. This will expand the opportunities for scientists to participate in space research because they "won't have to become astronauts overnight," Poirier explains. "They'll be able to do research from their lab and from the CSA research facility by uplinking to the Station."

Poirier emphasizes, however, that a human presence in space is essential to good science because it speeds up the research cycle. "We need to use our brains on-site to make decisions and change the course of an experiment."

In Canada, there's interest in two broad areas of space research. One involves understanding and exploiting the near-absence of gravity—known as microgravity—to develop new processes and materials, such as novel alloys and drugs that cannot be made on Earth. "We've got some industries who are starting to get serious about working in microgravity," Evans says.

The second focuses on space life sciences—studying the impact of the space environment, including microgravity, on humans and other living things. These studies are particularly crucial to ensure the health and safety of humans who live and work for ever-longer periods of time on the Station, and who may eventually venture farther afield to the Moon or Mars.

To address these questions, the Canadian Space Agency established an operational space medicine group within the Canadian Astronaut Office that will focus on applied studies related to the physiological, psychological and social impacts of long-term living in space. Canadian scientists already have a long history of studying the fundamentals of physiological effects of microgravity through the Canadian Space Agency's Space Life Science Research Program, but studies of the social and psychological effects are just starting.

Poirier says more research must be done on "how to live in space before we can hope to do it on the Moon, Mars or other places. The Space Station will serve that purpose." This is particularly important because further exploration will undoubtedly involve international crews comprised of people from different backgrounds and cultures. Such missions will take much more time—for example, up to three years for a trip to Mars— and will not be able to return quickly to Earth. This puts an enormous premium on anticipating the behaviour of individuals and the social interaction of crews in space.

Poirier believes Canada is particularly well-equipped to tackle these questions because it is a multicultural country and because the relatively small size of its space program has always forced it to work in partnership with other countries. "We have a reputation as a good partner and I think we have something to contribute."

Evans argues that fostering international cooperation, in fact, will be "one of the greatest legacies of Space Station. The space-faring nations of the world have found a way to work together to accomplish more than any of us could individually. We've all had to adapt. What we've got now is a real multinational co-operative program that relies on all the partners doing their thing."

He believes this is just as critical to the future of human spaceflight as scientific studies and technological advances. "If you accept the premise that further exploration is going to be a multinational event, and I can't believe otherwise, that means you're going to have astronauts from many nations involved. On long duration flights, you really are pushing up against cultural differences that will display themselves over longer period of time. We have to find a way to make sure these differences don't get in the way of doing missions."

Evans envisions the Space Station as "a good test ground for how nations select astronauts and how they train them. Through the experience gained on Space Station, we'll learn things to do and not to do. We're as interested as any of the other partners in making sure the multicultural aspect of space exploration is a positive experience."

Canada's Next Generation Canadarm to Build the International Space Station

In April 2001, the Canadian Space Agency's next generation of space robots will be unfolded from its protective metal cradle. Then, like a baby gingerly taking its first step, it will climb out to begin exploring its new home—the International Space Station.

The new robotic arm—known as the Space Station Remote Manipulator System, or SSRMS—will attach one of its two identical "hands" to a device that provides the lifeblood it needs to survive in this new environment: electrical power and a link to the robotic control centre inside the Station.

Then, after a few limbering-up exercises—including handing its cradle back to the shuttle's Canadarm—it will swing its free hand around to latch onto another of the connection devices, known as a Power Data Grapple Fixture, thus allowing the first hand to be released.

For Canadians, this moment will be comparable to the day when the Canadarm was first lofted above the space shuttle's payload bay. Like the Canadarm, the SSRMS will be a distinctive Canadian contribution to the international space program, an essential tool without which the Space Station could not function.

"The Canadarm's successful track record on the shuttle made robotics a natural choice as Canada's contribution to the Station," says Alain Poirier, Director General of Space Systems for the Canadian Space Agency. "Robotics was identified as a strategic technology for

This 17-metre, 1,5-ton arm is essential to the construction of the ISS, to many Station operations and to the maintenance of the Station throughout its service life.

Canada. It was a critical component of infrastructure which gave Canada an important role and status in building the International Space Station."

Canada selected a robotic system as its main contribution to the Space Station in order to fortify its world leadership in space robotics and encourage innovation and ingenuity in Canada's high-tech industries. Canada's participation in the Space Station also ensures Canadian scientists a boarding pass to conduct leading-edge research in the Station's microgravity environment to advance our knowledge in fields like biotechnology, biomedical research, fluid physics, materials science, Earth observation and space science. And perhaps most importantly, as one of the

The SSRMS

five partners in the International Space Station (along with the United States, Russia, Japan, and the European Space Agency), Canada is a key player on the world stage as nations learn to work together in the largest peace-time collaborative effort in human history.

When the SSRMS takes its first step, it will provide a dramatic demonstration of robotic evolution. Unlike the Canadarm, the SSRMS is not permanently anchored at one end; instead, either hand can be used as an anchor point while the opposite one performs various tasks, including grabbing another connecting point on the Station. This design gives the SSRMS the unique ability to move around the Station like an inchworm," flipping end-over-end among grapple fixtures located on exterior structures.

It's a simple and elegant concept, but according to James Middleton, Vice-President of Business Development for MacDonald Dettwiler Space and Advanced Robotics Ltd., transforming it into working hardware was a challenge. Middleton, who led the engineering team that designed and built the SSRMS for the Canadian Space Agency, says that "the Space Station was very large and it was clear that we had to be able to provide mobility—the ability to relocate the arm from spot to spot."

Another difficult task was designing the SSRMS to withstand the forces of lift-off. Larger and heavier than the Canadarm—it has a mass of about 1640 kilograms compared with 400 kg for the Canadarm—it will be subjected to greater loads during the eight and a half minute ride into orbit.

Unlike the Canadarm, which is secured full length along the side of the shuttle's cargo bay, the SSRMS will be folded into a U-shaped pallet that fits across the width of the bay. "We had to bend it in pieces," Middleton explains. "How to fasten it down was a very complex design process. To be able to hold it in a manner that the loads were adequately relieved during the shuttle launch was a tough challenge for the engineering team."

The SSRMS on its pallet awaiting its launch in April 2001

The complex process of preparing the SSRMS for launch has been going on since it was delivered to the Kennedy Space Center in May 1999. In August 2000, it was folded into its final launch configuration and nestled in its pallet, ready to be placed in the payload bay of the Shuttle *Endeavour* a few weeks before launch.

Canadian Space Agency astronaut Chris Hadfield will play a major role in installing the SSRMS on the Station next April and, in the process, will become the first Canadian to perform a space walk. In a spectacular moment, two generations of Canadian technology will come together as the Canadarm lifts the pallet with the SSRMS out of the payload bay and attaches it to the Station's US-built laboratory. Hadfield and his partner, American astronaut Scott Parazynski, will then unbolt the arm, unfold its booms manually and secure the hinges in the middle that allowed the booms to be folded.

While still on its pallet, the arm will be commanded to grasp a grapple fixture on the US lab and step out of the pallet. "It will do a few tests, then the SSRMS will pick up the pallet and give it back to the Canadarm, which will put it back in the cargo bay," said Poirier. This procedure has already been dubbed the first "handshake" between the two arms.

Next comes the first "inchworm" manoeuvre; the SSRMS will grasp a second grapple fixture on the US lab, transferring its anchor point from one hand to the other. By the end of the flight, the arm will be put through all of its basic functions and will be ready to assume its role in helping to put together the rest of the Station.

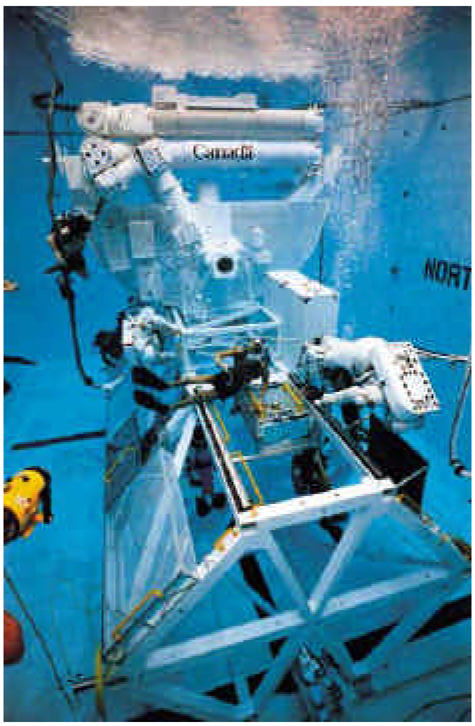
According to Alain Poirier, the installation of the SSRMS is "absolutely critical" to the Station's development. "We simply would not be able to build the International Space Station without the SSRMS," he adds. "Every single Space Station mission will need it."

The Canadarm—the most widely recognized piece of Canadian technology—and the SSRMS—Canada's new state-of-the-art robotic technology—will work together, handing payloads to one another. The SSRMS is more flexible because the number and placement of its joints provides seven degrees of freedom rather than just six. This gives it a greater ability to bend, rotate and maneuver itself into difficult spots—a crucial capability since the Space Station is a larger and more complex operational environment than the shuttle's payload bay.

This flexibility will be greatly enhanced by the Canadian Space Agency's Special Purpose Dexterous Manipulator, a smaller robot with two arms that has 15 degrees of freedom. Currently slated for launch in late 2003 or early 2004, the SPDM has complex "hands" capable of wielding specialized tools for delicate maintenance and servicing tasks. It also gives operators feedback about the forces and movements it experiences as it works, providing a "touch and feel" capability akin to that of the human hand and will reduce the time that astronauts spend working in the hostile and dangerous environment of space.

Artist's rendering of the Special Purpose Dexterous Manipulator

What makes the SSRMS and SPDM so important is that most of the equipment on the outside of the station will be made up of "Orbital Replacement Units"—self-contained packages that can be swapped for new units when they wear out or fail. "The whole Space Station design is based on ORUs so we can repair and maintain it in space," explains Poirier. "We don't have to bring anything down."



Testing the SSRMS in the Neutral Buoyancy Lab at the Johnson Space Center

That includes the SSRMS itself—all of its components are replaceable. Unlike the Canadarm, it will probably never return to Earth.

Astronauts on board the Space Station will control the SSRMS, but like Shuttle astronauts, they will be in constant contact with Mission Control. Here, too, Canada will play a role. The Canadian Space Agency has built a control centre for the SSRMS at its Saint Hubert headquarters that will be linked directly to NASA's Mission Control at the Johnson Space Center in Houston.

Containing half a dozen computer consoles similar to those in Mission Control in Houston, the Canadian Space Agency's Space Operations Support Centre (SOSC) will function as a technical "back room," offering real-time support and troubleshooting while SSRMS operations are going on in space. The performance of the SSRMS will be monitored through the operations centre and analyzed by robotics specialists at the Canadian Space Agency, who will be on standby to help with any problems that the astronauts can't solve first using standard malfunction procedures.

The Canadian Space Agency has also created another facility, the Mission Operations and Training Simulator, to train astronauts from all the partner countries in the basics of operating the SSRMS. In April 2000, two American astronauts, Dan Bursch and Carl Walz, became the first to obtain "robotic operator's wings" qualifying them to operate the SSRMS. All Space Station astronauts will receive their training at the operations facility in Saint-Hubert, Quebec, in order to practice complex maneuvers before they are attempted in space.

Helping to build and maintain the Space Station will be the most tangible role for the SSRMS, but it has another less visible but equally significant role: it has provided Canadian scientists with access to Space Station laboratory facilities to conduct scientific experiments.

The Space Operations Support Centre at the Canadian Space Agency's headquarters in Saint-Hubert, Quebec

The contribution of the robotic system buys Canadians the right to use 2.3% of the space designated for scientific equipment inside the non-Russian part of the Station, as well as access to a platform outside for experiments exposed to the space environment. Canada is also entitled to send one astronaut to the Station every three years on a tour of duty lasting three to four months.

All of the countries involved in the Space Station Program also have to pay user fees to cover operating costs. "It's like a condominium—you have to pay condo fees," Poirier notes.

Many of the partners, Canada included, are making technical contributions to offset their share of these fees. CSA is contributing the SPDM to "pre-pay" about 20% of Canada's user fees. It's also negotiating to receive credit for supporting the repair and overhaul of the SSRMS, which would bring the prepaid portion to about 50%.

Although there will be about five more years of heavy construction on the Space Station, Canadian scientists will be among the first to get their hands on Space Station real estate as early as 2002. But for Canadian scientists—and indeed, for all Canadians—the countdown will truly begin next April when the SSRMS takes that first step off its pallet and into Canadian technological history.

The Mobile Servicing System

Canada's Next Generation of Space Robotics for the International Space Station

The Mobile Servicing System

The Mobile Servicing System (MSS) is a 17-metre, 1.5-ton element that is essential to the construction of the Station, to many Station operations, and to the maintenance of the Station throughout its service life.

The Mobile Servicing System, which includes facilities on Earth for mission support and astronaut training, is actually composed of three separate parts:

- a next-generation Canadarm called the Space Station Remote Manipulator System;
- the Special Purpose Dexterous Manipulator, a smaller, detachable two-armed robot that can be placed on the end of the space arm to perform sophisticated, delicate operations; and
- the Mobile Remote Servicer Base System, a movable platform for the robotic arm and its "hand," which slides along rails located on the Space Station's main structure to transport the robotic arm to various points on the Station.

Technical Details

	SSRMS	**SPDM**	**MBS**
Length (metres)	17 m	3.5 m	5.7 m x 4.5 m x 2.9 m
Mass (approx.)	1750 kg	1662 kg	1500 kg
Mass Handling Transportation Capacity	116 000 kg	600 kg	20 900 kg
Degrees-of-Freedom	7	15	Fixed
Peak Power (operational)	2000 W	2000 W	825 W
Average Power (keep alive)	1360 W	600 W	365 W
Stopping Distance (Under Maximum Load)	0.6 m	0.05 m	N/D

CSA Astronaut Chris Hadfield to Deliver and Install the Latest Canadian Robotic Technology on the International Space Station

CSA Astronaut Chris Hadfield

Having successfully completed rigorous testing, Canada's latest achievement in space robotics technology will be launched in April 2001 on board the Space Shuttle *Endeavour* and installed on its permanent home—the International Space Station.

During STS-100, Canadian Space Agency astronaut Chris Hadfield and his crew will deliver and install the Space Station Remote Manipulator System. This robotic arm is the first element of the Mobile Servicing System, Canada's main contribution to the Space Station. The 17-metre-long arm is more sophisticated and more versatile than its predecessor, the Canadarm, and will assist astronauts in assembling, inspecting and repairing the Station, conducting ongoing operations and transporting equipment and supplies. In order to reach all areas of the Station to perform its critical tasks, the arm features an innovative technology: it is able to relocate itself to different points on the Station by detaching itself from its base and flipping end-over-end.

Chris Hadfield training in the Neutral Buoyancy Laboratory at the Johnson Space Center in Houston, Texas

In November 1995, Chris Hadfield became part of Canadian history as the first Canadian astronaut to board the Russian space station *Mir*, the first Canadian Mission Specialist in space and the first Canadian astronaut to operate the shuttle's Canadarm. When he installs the SSRMS on Mission STS-100, Col. Hadfield will once again make history when he becomes the first Canadian astronaut ever to perform an extravehicular activity (EVA), or space walk. Four days into the mission, Chris and his fellow crewmate, US astronaut Scott Parazynski, will venture out of the shuttle for the first of three planned space walks. Among their many tasks will be to unfold the Space Station Remote Manipulator System, bolt the segments together and connect it to the *Destiny* module of the Space Station.

STS-100 Mission Facts

Mission:	STS-100/ISS-6A (the sixth American ISS Assembly Flight)
Projected launch date:	19 April 2001 (To be confirmed)
Orbiter:	*Endeavour* (OV-105)—its sixteenth flight
Launch site:	Launch Complex 39A, Kennedy Space Center, Florida
Orbital inclination/ Altitude:	51.6 degrees/320.4 km
Crew of seven:	Commander: Kent V. Rominger (NASA); Pilot: Jeffrey S. Ashby (NASA); Mission Specialists: Chris A. Hadfield (Canadian Space Agency);Umberto Guidoni (European Space Agency); Yuri Lonchakov (Russian Space Agency); Scott Parazynski (NASA); and John L. Phillips (NASA).
Resident station crew:	The crew members of Mission STS-100 will meet the crew of *Expedition-2* (formed of Russian commander Yuri V. Usachev and US astronauts Susan J. Helms and James S. Voss), who are scheduled to arrive on the Space Station on 15 February 2001.
Payloads:	• The Canadian Space Agency’s Space Station Remote Manipulator System (SSRMS) —stowed in a Spacelab pallet. • The Italian-built *Raffaello* Multi-Purpose Logistics Module (MPLM), carrying 6 system racks and 2 storage racks to be installed in US *Destiny* Lab Module. • An Ultra High Frequency (UHF) antenna providing space-to-space communications capability for space walks.
Mission objectives:	• Delivery, installation and deployment of Canada’s Space Station Remote Manipulator System on the *Destiny* Lab Module • *Destiny* Lab Module outfitted with *Raffaello* MPLM content • 3 space walks (EVAs—Extravehicular Activities) to be performed by CSA astronaut Chris Hadfield (EVA-1) and US astronaut Scott Parazynski (EVA-2), to install Canada’s Space Station Remote Manipulator System.

The Canadian Space Agency and the Canadian Space Program

The Canadian Space Agency

Since its creation in 1989, the Canadian Space Agency (CSA) has set out to promote the peaceful use and development of space, advance the knowledge of space through science and ensure that space science and technology provide social and economic benefits for all Canadians. The Canadian Space Agency also strives to support and promote a highly competitive space industry and address the needs of Canadian society.

As the organization responsible for managing Canada's activities in space, the CSA implemented a new Canadian Space Program in 1999. Under the renewed program, the CSA seeks to expand Canada's leadership in five areas of critical importance:

- Earth and Environment: dedicated to using space technologies to understand, monitor, predict, and protect the Earth and its environment;
- Satellite Communications: supports Canadian industry in helping Canada to become the most connected nation in the world;
- Space Science: pursues knowledge of the near-Earth space environment, the solar system, the universe, and how normal physical and biological processes change in the environment of space—some of the most fundamental questions facing science today;
- Generic Space Technologies: promotes a more competitive space industry, generates spin-off technologies here on Earth, develops high-tech expertise, and creates new jobs for Canadians; and
- Human Presence in Space: ensures the participation of our astronauts in space missions, maintains Canada's position as a world leader in space robotics by designing and developing the technology for human space flights, and fulfills the nation's role as a crucial partner in the International Space Station—the largest science and technology project in the history of humanity.

With almost half of Canada's GDP growth in the knowledge-intensive sectors of the economy, the Canadian Space Program is a key driver behind our nation's continued leadership on the world stage, and creates new opportunities for industry and scientists, as well as long-term social and economic benefits for all Canadians. The CSA contracts out approximately 80% of its budget for projects involving industry, universities, and specialized research institutes, and provides contracts to small and medium-sized enterprises with the goal of ensuring that Canada's space investments are made in all regions of the country. The Canadian space industry is comprised of some 250 firms across Canada, and employs 5500 people. Nearly 45% of its approximately $1,5 billion in annual revenues are from exports—the highest ratio in the world.

The CSA is equally dedicated to inspiring Canadians and bolstering our sense of pride in our nation's achievements in space, especially among our nation's youth. The CSA's space awareness initiatives use the unique appeal of space science and technology to improve science literacy and foster a science and technology culture in Canada for the benefit of present and future generations.

The Canadian Space Program: A Bright Future for Canada in Space

Canada’s Historical Milestones in Space*

1839 Sir Edward Sabine establishes an observatory in Toronto to study irregularities in the Earth’s magnetism and the connection between the Sun’s magnetic activity and its effects on the Earth, such as the majestic Northern Lights.

1959 5 September: The first Canadian sounding rocket, Black Brant 1, is launched. By 1989, more than 3500 similar rockets would be launched to probe the atmosphere.

1962 29 September: With the launch of Alouette-1 to study the Earth’s ionosphere, Canada becomes the third nation in space.

1969 30 January: The satellite ISIS-1 is launched to study the upper section of the ionosphere, and to produce the first images of the Northern Lights from space.

20 July: Canada becomes the first nation to “step” onto the Moon as the feet of the Canadian-built landing gear of *Apollo 11* touch down on the Sea of Tranquility.

1972 29 September: The David Florida Laboratory is inaugurated and becomes a world-class facility for the assembly, integration and environmental testing of spacecraft and space hardware.

9 November: With the launch of Anik A-1 (the first in a series), Canada becomes the first country to have its own domestic communications satellite system in geostationary orbit.

1976 17 January: Canada’s CTS-Hermes, the most powerful communications satellite of its time, is launched and introduces the world to direct-to-home broadcasting. Interestingly, the world’s first direct-to-home satellite television broadcast on 16 May 1978 beams Game Two of the Stanley Cup finals between the Montreal Canadiens and the Boston Bruins from Canada to Lima, Peru. (Incidentally, Montreal beats Boston by a score of 3-2).

1981 13 November: The Shuttle Remote Manipulator System, better known as the Canadarm, is deployed for the first time on board the Space Shuttle *Columbia*.

1983 5 December: Canada’s first astronaut team is selected, and consists of: Roberta Bondar, **Marc Garneau**, Steve MacLean, Ken Money, Robert Thirsk and Bjarni Tryggvason.

1984 5 October: **Marc Garneau** becomes the first Canadian in space when he flies aboard *Challenger* and supervises the CANEX-1 experiments during Mission STS-41G.

1986 Canada begins the development of the Mobile Servicing System for the International Space Station.

1988 29 September: Canada signs an Intergovernmental Agreement with the US, ESA and Japan and becomes a full partner in the International Space Station Program.

1989 1 March: The Canadian Space Agency is created to manage Canada's Space Program.

1992 22-30 January: Roberta Bondar becomes the second Canadian and the first Canadian woman in space when she flies aboard *Discovery* and participates in experiments in space life sciences and materials sciences (STS-42).

8 June: Chris Hadfield, Julie Payette and Dave Williams join Canada's astronaut team.

22 October-1 November: CSA astronaut Steve MacLean flies aboard *Columbia* to perform experiments in life sciences, space science and space technology, including the Space Vision System (STS-52).

1995 4 November: RADARSAT-1, Canada's first Earth Observation satellite, is launched.

12-20 November: Chris Hadfield flies on board *Atlantis* (STS-74), and becomes the first Canadian to operate the Canadarm, the first Candian Mission Specialist, and the first and only Canadian to board *Mir*.

1996 19-29 May: **Marc Garneau** becomes the first Canadian ever to return to space when he flies aboard the shuttle *Endeavour* as a Mission Specialist and operates the Canadarm to retrieve the Spartan 207 platform (STS-77).

29 June-7 July: CSA astronaut Bob Thirsk becomes the fifth Canadian in space on the STS-78 Mission aboard *Columbia*, a mission dedicated chiefly to life and microgravity sciences. Bob's 17-day mission is the longest in which a Canadian astronaut has ever participated.

2 October: The Canadian Space Agency's headquarters is inaugurated in Saint-Hubert, Quebec. The facility is named the John H. Chapman Space Centre in honour of the "Father of the Canadian Space Program."

1997 7-19 August: Canadian astronaut Bjarni Tryvasson flies aboard *Discovery* as a Payload Specialist responsible for the Microgravity Isolation Mount (MIM), which he co-designed (Mission STS-85).

14 September: RADARSAT-1 begins an 18-day mission to produce the first ever homogenous, almost near real-time, high-resolution satellite map of Antarctica—a region the size of Canada and Alaska combined that had previously only been partially charted.

1998 17 April-3 May: Dave Williams becomes the seventh Canadian astronaut in space aboard the Shuttle *Columbia* when he participates in the Neurolab mission to investigate the effects of microgravity on the nervous system.

3 July: Canada’s Thermal Plasma Analyzer (TPA) is launched on board Japan’s first martian probe, *Nozomi.* It will measure Mars’s atmosphere when it arrives in late 2003 or early 2004.

29 October-7 November: US astronaut John H. Glenn returns to space 36 years after his historic first flight, and is responsible for tending two of three Canadian experiments: OSTEO, which studies growing bone cells in microgravity, and SepTech, a fluid physics experiment designed to separate healthy cells from cancerous ones.

20 November: *Zarya* (Russian for “sunrise”), the first element of the International Space Station, is launched in Baikonur, Kazakhstan. *Unity*, the second component, is launched on 4 December. The two are joined using the Canadian-led Space Vision System.

1999 1 March: The Canadian Space Agency celebrates its tenth anniversary.

27 May-6 June: Mission Specialist Julie Payette becomes the eight CSA Astronaut in orbit, and the first Canadian to board the International Space Station during her 11-day logistics mission. Among her many duties, Julie also becomes the third Canadian to operate the Canadarm when she uses it to inspect the Canadian Space Vision System.

18 December: A Canadian sensor, known as MOPITT (Measurement of the Ozone Pollution in the Troposphere), is launched on board the American satellite *Terra*. MOPITT is the first Canadian instrument to monitor pollution of the Earth’s atmosphere from space.

2000 30 November: **Marc Garneau** will make his third space flight when he participates in mission STS-97 to install the first set of solar panels on the International Space Station.

2001 February: The Canadian Optical Spectrograph and InfraRed (better known as OSIRIS) is scheduled to be launched on board the Swedish satellite Odin to investigate a number of important issues in astronomy and atmospheric sciences. OSIRIS will provide the most detailed data ever on ozone depletion by measuring the concentration of ozone depleting pollutants and identifying positively the human-generated events that contribute to the problem.

15 February: Canada’s first Space Science experiment for the International Space Station, H-Reflex, is scheduled to be launched. H-Reflex will attempt to determine if spinal cord “excitability” (i.e. the spinal cord’s ability to respond to, encode and transmit chemical and electrical signals) decreases during extended space travel. If so, the experiment will measure the extent and speed of the change, and how long the effects linger upon return to Earth.

19 April (to be confirmed): CSA Astronaut Chris Hadfield will participate in Mission STS-100. Hadfield will perform the first Canadian space walk when he uses the Shuttle’s Canadarm to install the Space Station Remote Manipulator System, the next-generation Canadarm that will assemble the International Space Station.

2002 (Date to be determined): Scheduled launch of Anik F2, which will carry a specialized multimedia communications demonstration payload that will commercialize the use of the Ka band. The payload promises to deliver cheaper, faster and more highly efficient communications services and expand access to telemedicine, tele-education, e-commerce, high-speed Internet access and government services to citizens living in urban, rural and remote communities throughout Canada.

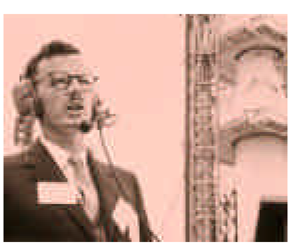
February (Date to be determined): The microsatellite MOST (Microvariability and Oscillations of Stars) is scheduled to be launched. Weighing only 50 kg, with a diameter no bigger than a pie plate, MOST will be the world's smallest astronomical space telescope, and will be capable of measuring the ages of stars in our galaxy and perhaps even unlocking mysteries of the universe itself.

February is also the scheduled launch date for RADARSAT-2, Canada's second Earth Observation satellite, which will be the most advanced Synthetic Aperture Radar satellite in the world.

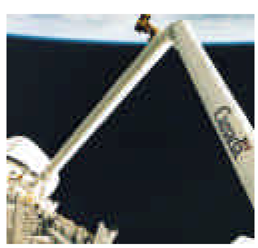
June (Date to be determined): SCISAT-1, the first Canadian space science satellite since 1971, is scheduled for launch. SCISAT-1 will carry the Atmospheric Chemistry Experiment, known as ACE, on board to measure and understand the chemical processes that control the distribution of ozone in the Earth's atmosphere.

2004 May (Date to be determined): The Canadian Insect Habitat is scheduled for launch for permanent integration on board the International Space Station. The Insect Habitat will be part of NASA's Gravitational Biology Facility, which will conduct life sciences research on the effects of microgravity on the biological processes of living organisms. By using insects such as fruit flies, researchers will be able to conduct multigenerational studies to study biological development over successive generations, which may contribute to scientific understanding of topics ranging from birth defects to the aging process.

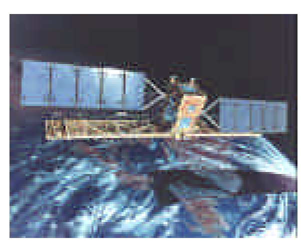
* For more detailed information regarding Canada's history in space, please consult our Web site: www.space.gc.ca.



John H. Chapman



Canadarm



RADARSAT-1

Investing in Canadian Industry: Success Stories

While space conjures up images of distant stars and galaxies, satellites and spacecraft and the endless expanse of the universe, the Canadian Space Agency has developed a vision of Canada's space activities that is, paradoxically, focused on Earth. A key aspect of the CSA's mandate is ensuring that all Canadians benefit from Canada's Space Program. Consequently, the CSA is actively developing ways to apply space-based technologies to some of the main issues with which Canadians are concerned today, including health care, environmental management and maintaining Canada's competitiveness in the high-tech, knowledge-based global economy.

The space industry in Canada, represented by some 250 firms, generates annual revenues of $1,5 billion, and provides jobs for more than 5500 Canadians across the country. By contracting out approximately 80% of its budget, the CSA supports Canadian industry, universities and specialized research institutes. Through its various programs, the CSA has provided funding and technological leadership to companies for a variety of initiatives in every Canadian region, including:

- SHAPE TAPE™, a flexible, fibre optic tape (about the same size as a conventional measuring tape) capable of capturing shape and motion of the complex curves of the human body or inanimate objects. Developed by Measurand Inc. of Fredericton, New Brunswick, the fibre optic tape can be used to transfer data to a computer, which can then animate machines or robots to mimic complex forms and movements.

  SHAPE TAPE™ may eventually assist astronauts in performing delicate and complex tasks outside the International Space Station (or even from the Mission Control Centres in Houston, Texas and Saint-Hubert, Quebec) by allowing them to remotely operate robots thus reducing the danger, constraints and costs associated with space walks.

  SHAPE TAPE™ has also been used on crash-test dummies to help improve safety during car collisions and to design car bodies and seats; the technology could also be applied to improve prosthetics, aid surgeons in the operating room, assist physiotherapists, guide submarine exploration and even create wearable musical instruments. With SHAPE TAPE™, Measurand Inc. has successfully penetrated international markets (most notably in the US, Australia, Asia and several countries in Europe), and has acquired a number of prestigious clients, including: General Motors, NASA, Walt Disney Co. Inc., Eastman Kodak, MIT Media Lab and MIT Ocean Engineering. Between 1997 and 2001, Measurand Inc. is projecting sales of approximately $4 million for SHAPE TAPE™.

- Using imagery produced by Canada's renowned Earth Observation satellite, RADARSAT-1, Montreal-based Tecsult International Ltd. has created a method for improving the accuracy of finding groundwater sources in developing countries. By combining RADARSAT-1 satellite images (which can detect soil type and humidity) with a Geographic Information System (GIS), Tecsult has been able to pinpoint natural geologic linear features, called lineaments, which help locate promising sites for water drilling. Tecsult has already conducted three studies in Mali and Burkina Faso, and has found that their methodology is more precise and can cover a larger surface area than conventional methods (chiefly aerial photography), which reduces the costs involved in unsuccessful drills.

  The CSA has also collaborated with Tecsult in other endeavours, including the development of a method of producing maps for land use classification and forest management in tropical regions, such as Ethiopia, Gabon, Cameroon and the Ivory Coast.

  Another division of the company, Tecsult Eduplus Inc., has also been awarded a $4,5 million contract to develop training software for astronauts, cosmonauts and mission controllers to use the Mobile Servicing System, Canada's robotic system for the International Space Station. Eduplus credits the expertise that it gained from this contract for their successful bid on a major contract with Hydro-Québec for technical training.

- Dendron Resource Surveys Inc. of Ottawa is developing a project that targets the prevention of, and response to, natural disasters in Latin America. Using RADARSAT-1 images, combined with existing data on key areas, the company will produce a "fly-through video" of a region before, during and after the occurrence of a natural disaster or emergency response incident. This video will be used to provide a specialized disaster prevention and response resource for Latin American countries that are particularly vulnerable to serious damage due to natural disasters like floods and landslides. The development of this specialized application will promote RADARSAT-1 imagery, the services of Dendron Resources Survey Inc. and the International Center for Tropical Agriculture (CIAT) in Columbia.

  Dendron has collaborated with the CSA on other initiatives, including a contract worth $813 000 in 1997 to develop the "RADARSAT-1 Forestry Project," a software and training package for forestry monitoring and database updating. Using RADARSAT-1 data, the software provides operational personnel in the forestry industry with a greater capacity to detect and record recent man-made and/or natural changes to the forest cover.

- With the assistance of CSA funding, Calgary-based ITRES Research Ltd. is developing a special artificial vision system that could help Canadian peacekeepers detect deadly land mines left behind in the wake of war. One of the greatest problems facing Canadian peacekeepers is detecting hidden and/or camouflaged land mines. Mines introduced recently are composed of a reduced metal content that makes them more of a challenge to detect. ITRES's stand-off detection system uses the company's electro-optical imaging technology to identify land mines, reducing the risks involved to human beings. ITRES's vision system could potentially be used in space to help astronauts operate robotic systems, like the Canadian-built robotic arm for the International Space Station.

- MacDonald Dettwiler and Associates, which employs more than 1500 people in British Columbia, Ontario, Nova Scotia and several international locations, is applying space technologies to develop telemedicine for Canadians in remote communities. For example, the I-SITE project (Intelligent Screening of Imagery via Teleophthamology), funded by PRECARN Associates Inc., the University of Alberta, the Canadian Space Agency and MacDonald Dettwiler, is helping medical professionals provide the same quality and reliability of care in remote areas as is currently available in major Canadian cities. I-SITE is an application that facilitates screening for eye disease via wireless technology, and has already saved the vision of 13 Canadians in Fort Vermillion (700 km north of Edmonton), who were found to have diabetic retinopathy (the leading cause of adult blindness in North America)—seven of which could have gone blind had it not been for early intervention. Using satellites and advanced digital-image processing technologies originally developed to observe the Earth from space, I-SITE is as accurate as conventional methods using film, and can be processed and transmitted more quickly. Thus, in addition to providing increased access to specialist diagnoses, and encouraging more frequent and early screening, I-SITE provides residents in remote locations with better services without increased costs. I-SITE has tremendous potential to benefit First Nations communities in remote areas, in which diabetes is 3 to 5 times higher than the national average, and is reaching epidemic proportions.

The CSA's Automation and Robotic Testbed system

- British Columbia's International Submarine Engineering Ltd. has been working closely with the Canadian Space Agency for approximately 10 years on several different projects, including: sensor technology for computer vision, robot navigation and obstacle avoidance; robotic manipulators for astronaut training, task verification (performing tasks on the ground prior to executing them in space) and developing robotic control strategies; improving the CSA's Automation and Robotic Testbed system; and developing the Shell Smart Pump™, a fully automated robotic system that can refuel cars.

Most recently, ISE has been awarded a $1 million contract to build the hydraulic manipulator system that will be used as a part of the CSA's Task Verification Facility for Canada's Special Purpose Dexterous Manipulator (SPDM), the small, two-armed robot designed to function as a "hand" for the Space Station's robotic arm. ISE has built over 170 robotic submersibles for customers such as the US Navy, the Canadian Navy, Oceaneering International and AT&T, and has manufactured more than 250 robotic manipulators used for nuclear reactor decommissioning and decontamination, research and sub-sea work, as well as astronaut training. In 1991, its unique expertise helped ISE secure a $1,5 million contract from the US Air Force to develop a robotic refueling system for fighter aircraft. The company is now adapting its robotic technologies to a wide variety of potential uses in fields such as forestry, mining and manufacturing.

Investing in Canadian innovation

Why do We Go into Space?

Because we live in practical times, this question usually elicits practical answers. We go into space because of the benefits it produces for life on Earth: it provides us with better communications and a vantage point that allows us to understand and manage better the Earth's natural resources. It encourages industrial development and creates high-tech jobs. It inspires students to pursue careers in science and technology. It promotes international technological co-operation.

These reasons are part of the answer—but not all of it. We go into space for more than practical reasons; even though it has become less fashionable to speak of them, there are deep-seated philosophical and psychological imperatives that drive us to explore beyond the boundaries that encompass us. We go into space because it appeals to the most deeply human traits: curiosity and the compulsion to take on great challenges.

It has been said that we climb mountains simply because they exist. Space lies before us as a mysterious "mountain" of unimaginable, almost infinite proportions. It is a challenge that our human nature finds impossible to ignore. No doubt from the moment humans first looked up at the stars, we wondered what they were, where they were and what else is out there. Through the millennia, we have wondered if there are other places, other species, out there and what we will do when we find them. We are intent on finding them, whatever and wherever they may be, for it is simply not in our nature to willfully turn away from the quest for knowledge. But indulging our curiosity, our thirst for knowledge, our need for challenge, is neither easy nor cheap. Some people find that reason enough not to try, but for many, the difficulty is precisely the point. As President John F. Kennedy said in 1962 when he committed the US to reach for the Moon: "We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone and one which we intend to win."

The ability to take on great challenges, and to learn from failure while building on success, is the hallmark of the human spirit. Whatever practical, social and economic benefits the effort affords, the underlying reward is that trying, in itself, pushes the envelope of creativity and problem-solving and nurtures the skills needed to venture even further. Without the will to try, we would stagnate.

Canadian astronaut Chris Hadfield is one of only a small handful of humans who have had the privilege of seeing the Earth and the stars from the unique perspective of space. Reflecting on the significance of the launch of *Zarya*, the Russian-built module that became the first component of the International Space Station to rise into space, Hadfield described it as "a triumph of hope over history, of will over won't, and of optimism over cynicism. For the first time in history, we had blasted off from Earth as one nation of human beings. Not in competition with each other, not for short-term profit, not to bounce TV signals to each other, not to spy on each other, but as the first step in permanently leaving Earth together. As one world, we have successfully climbed off our mother planet's knee, and have begun to venture forth into the limitless possibilities of the universe."

It is fitting, he says, that this millennium is ending with the advent of "an amazing new era—the Interplanetary Age." He sees *Zarya* and the fledgling Space Station as a "portal to the future, and we have begun to step through. It flies in the face of historical conflict. It flies in the face of human jealousy and competition. It flagrantly flies in the face of cynicism, apathy and the daily grind. But above all, it flies. Effortlessly, over our heads, *Zarya* floats weightless—waiting for the future to unfold."

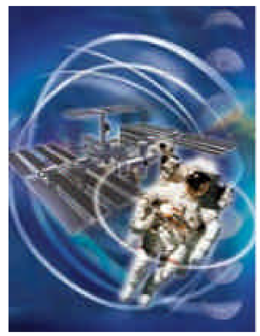
We still have a long way to go. If we mark its start from the launch of *Sputnik* in 1957, the Space Age has not yet spanned a single human lifetime. Despite what we have accomplished in that short time, we are, as a space-faring species, still mere children, barely able to manage more than camping out in the backyard. Yet, like young children, we excitedly explore every new marvel of our rapidly expanding universe, finding in each new phenomenon something to fire our imagination and prompt yet more questions.

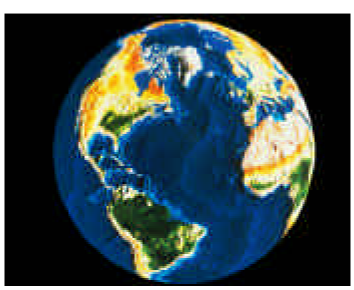
In the process, we are acquiring the knowledge and survival skills needed to carry us down the road that leads away from home. Like all children, we will all leave home eventually and the fact that the world awaiting us is vast, mysterious and undoubtedly dangerous is not an obstacle; rather, it is what compels us to continue. We have always been driven to test our mettle against the unknown and to unravel the complexities that nature and the universe place before us. In the end, it is this trait more than any other that has produced the greatest practical benefits that science and technology have brought us.

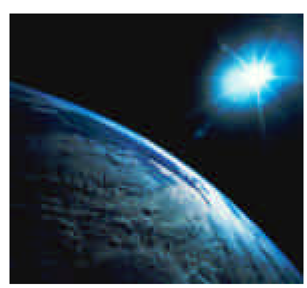
That it has also produced some of our worst mistakes, such as weapons of mass destruction and the ability to ravage the Earth's environment, is a reality we should ponder as we stand poised on the threshold of space. Managing the fruits of our curiosity wisely has become, in itself, one of our greatest challenges. We face an unparalleled opportunity to meet that challenge by orchestrating a united and peaceful migration into space.

Facts and Resources





Did you know...? Interesting Facts about...

The International Space Station

- The International Space Station is visible to the naked eye. In fact, it is the third brightest object in the night sky. Only the Moon and Venus shine more brightly.
- When fully constructed, the International Space Station will be visible to 95% of the world's population.
- The International Space Station circles the Earth every 92 minutes, and covers about 85% of the Earth's land masses.
- The International Space Station will be the largest object ever constructed and flown in orbit. It will encompass 43 000 cubic feet of living and working space—the equivalent of the interior of two Boeing 747s.
- When CSA astronaut Chris Hadfield becomes the first Canadian ever to perform an EVA in 2001, he will be "walking" in space at a speed of almost 27 000 km/hour (the speed at which the Space Station orbits the Earth). He will spend almost 15 hours in space, and will see about 30 "Earth-rises"!

Inside the US Habitation Module on the ISS

- A typical day for astronauts on board the International Space Station consists of 14 hours of work (including planning sessions, physical exercise, activities before and after rest period and mission operations), 1,5 hours for meals and 8,5 hours of rest.
- When completed, the International Space Station will be the size of a Canadian football field, and will have a volume of about 43 000 cubic feet—about the size of 3 average Canadian houses.
- The International Space Station will also be the largest microgravity laboratory ever constructed. Scientists and researchers will use the low-gravity environment of the Space Station to conduct research in the areas of biotechnology, engineering, Earth observation, telecommunications and space exploration.

Canadiana

- Advanced Canadian technology will be building the International Space Station. In addition to the skills of highly trained Canadian astronauts, Canada is contributing the robotic system (known as the Mobile Servicing System) to the International Space Station. This three-part system consists of the Space Station Remote Manipulator System, a robotic arm hailed as the next-generation Canadarm; the Special Purpose Dexterous Manipulator, a smaller two-armed robot that can be placed on the end of the arm; and the Mobile Remote Service Base System, a movable platform for the arm. The Mobile Servicing System will move around the huge floating structure of the International Space Station like an inchworm to assemble and maintain the

Station—a task comparable to building a cruiseliner in the middle of the ocean during a sea storm!

- A veteran of space travel, in his previous two missions **Marc Garneau** has logged over 437 hours in space, has orbited the Earth about 293 times, and has traveled the equivalent of 12 million kilometres in space.
- Astronauts report that food tastes sweeter and less spicy in space. The change in taste may be caused by the upward shift of body fluids in space; or, it may be that weightlessness affects taste buds in some other way. During his first mission, **Marc Garneau** performed an experiment to investigate changes in taste and smell in space.
- Canadian Space Agency astronaut Chris Hadfield is a "Top Gun" pilot, and was the first Canadian fighter pilot to intercept an enemy Soviet aircraft in our northern airspace. He was also the first and only Canadian ever to extend a handshake of peace to a Russian cosmonaut during his mission to the Russian Space Station *Mir* in 1995. Following **Marc Garneau**, Chris Hadfield will be the next Canadian astronaut in space on his mission to install Canada's Space Station Remote Manipulator System in April 2001.

The Space Shuttle

The US Space Shuttle

- One of Canada's greatest contributions to space flight, the Canadarm (also known as the Shuttle Remote Manipulator System) was first used on board the Space Shuttle *Columbia* in 1981. Four Canadarms have been built since then. Its average weight on Earth is approximately 411 kilograms (905 pounds), and it can move a cargo in space about the size of a school bus and weighing up to 29 938 kg (66 000 pounds)—almost 73 times the Canadarm's weight on Earth!
- It takes only about eight minutes for the space shuttle to accelerate to a speed of over 27 358 km (17 000 miles) per hour.
- There are over 10 000 separate tasks or events to be performed in order to prepare a shuttle for flight. The preparations take place over a 65-day period, and involve about 40 000 technician labour hours.
- Each of the shuttle's solid rocket boosters burns 5080 kg (5 tonnes) of propellant per second for a total of 500 000 kg (1,1 million pounds) in 120 seconds.

Marc Garneau's Menu during STS-97

Meal	Days 2 & 9	Days 3 & 10*	Day 4
A	Breakfast roll (FF) Dried apricots (IM) Seasoned scrambled eggs (R) Orange-pineapple drink (B) Coffee w/ 1% milk and sugar (B) x2	Granola w/blueberries (R) Scrambled eggs (R) Trail mix (IM) Breakfast roll (FF) Orange-mango drink (B) Coffee w/ 1% milk and sugar (B) x2	Granola w/blueberries Mexican scrambled eggs (R) Dried apricots (IM) Orange-mango drink (B) Coffee w/ 1% milk and sugar (B) x2
B	Cheese spread (T) Tortilla (FF) x2 Broccoli au gratin (R) Tapioca pudding (T) Peanuts (NF) Grape drink (B) x2	Mushroom soup (R) Tuna salad spread Crackers (NF) x2 Apple (FF) Brownie (NF) Grape drink (B) x2	Ham (T) Cheese spead (T) Tortilla (FF) x2 Pineapple (T) Candy coated chocolates (NF) Peach-apricot drink (B) x2
C	Smoked turkey (I) Creamed spinach (R) Italian vegetables (R) Banana pudding (T) Candy coated peanuts (NF) Orange drink (B)	Shrimp cocktail (R) Beef w/BBQ sauce (T) Italian vegetables (R) Granola bar (NF) Candy coated peanuts (NF) Orange-mango drink (B)	Macaroni & cheese (R) Creamed spinach (R) Italian vegetables (R) Chocolate pudding (T) Shortbread cookies (NF) Peach-apricot drink (B)

*Day 10 consists of Meal A only

B Beverage
FF Fresh Food
I Irradiated
IM Intermediate Moisture
NF Natural Form
R Rehydratable
T Thermostabilized

Packages of "space food"

Meal	Day 5	Day 6	Day 7	Day 8
A	Oatmeal w/raisins (R) Mexican scrambled eggs (R) Trail mix (IM) Peach-apricot drink (B) x2 Coffee w/ 1% milk and sugar (B) x2	Oatmeal w/brown sugar (R) Scrambled eggs (R) Dried apricots (IM) Orange-pineapple drink (B) Coffee w/ 1% milk and sugar (B) x2	Granola w/blueberries (R) Mexican scrambled eggs (R) Trail mix (IM) Peach-apricot drink (B) Coffee w/ 1% milk and sugar (B) x2	Granola w/raisins (R) Dried apricots (IM) Vanilla instant breakfast (B) Orange-mango drink (B) Coffee w/ 1% milk and sugar (B) x2
B	Dried beef (IM) x2 Italian Vegetables (R) Tortilla (FF) Apple (FF) Granola bar (NF) Almonds (NF) Orange drink (B) x2	Macaroni & cheese (R) Italian vegetables (R) Crackers (NF) Butterscotch pudding (T) Apple (FF) Grape drink (B) x 2	Frankfurters (T) Macaroni & cheese (R) Tortilla (FF) x2 Pears (T) Macadamia nuts (NF) Apple cider (B) x 2	Beef stroganoff (R) x2 Cauliflower w/ cheese (R) Tortilla (FF) Pears (T) Granola bar (NF) Cashews (NF) Lemonade (B) x 2
C	Shrimp cocktail (R) Frankfurters (T) Broccoli au gratin (R) Italian vegetables (R) Trail mix (IM) Tapioca pudding (T) Lemonade (B)	Beef w/BBQ sauce (T) Shrimp cocktail (R) Creamed spinach (R) Applesauce (T) Brownie (NF) Orange-mango drink (B)	Shrimp cocktail (R) Spicy chicken & veggies (R) Broccoli au gratin (R) Italian vegetables (R) Pineapple (T) Vanilla pudding (T) Pineapple drink (B)	Smoked turkey (I) Turkey tetrazzini (R) Pasta vegetable parmesan (R) Peaches (T) Butter cookies (NF) Grape drink (B)

- Estimated Nutritional Needs: 3242 kcals/day
- Menu (on average) provides: 2913 kcals/day, of which 14 % is protein, 56% is carbohydrates and 31% is fat
- No vitamin or mineral concerns

Helpful Web Links

CSA Links

The Canadian Space Agency
http://www.space.gc.ca

STS-97 Mission Site
http://www.space.gc.ca/garneau-sts97

Human Presence in Space - Canadian Astronaut Office
http://www.space.gc.ca/cao

Human Presence in Space - Canada and the International Space Station
http://www.space.gc.ca/csa_sectors/human_presence/en/index_en.htm

ISS Assembly Sequence
http://www.space.gc.ca/csa_sectors/human_presence/en/iss/assembly_en.htm

Upcoming Missions
http://www.space.gc.ca/csa_sectors/human_presence/en/canastronauts/upcomflights_en.htm

ISS Status Reports
http://www.space.gc.ca/whatsnew/checkitout/default.asp

Track the ISS in the Sky
http://www.space.gc.ca/csa_sectors/human_presence/en/kid/track_en.htm

CSA Press Room
http://www.space.gc.ca/whatsnew/releases/default.asp

CSA Contacts
http://www.space.gc.ca/about/csacon/default.asp

CSA Gallery
http://www.space.gc.ca/asc/search.asp

CSA Publications
http://www.space.gc.ca/space/publications/default.asp

Related Sites
http://www.space.gc.ca/space/related_sites/default.asp

Canadian Space Milestones
http://www.space.gc.ca/about/canspamil/default.asp

Success Stories
http://www.space.gc.ca/about/sucsto/default.asp

Canadian Space Power Initiative
http://www.space.gc.ca/cspi

International Space Agencies

ASA - Austrian Space Agency	http://www.asaspace.at/purpose.html
ASI - Italian Space Agency	http://www.asi.it/
BNSC - British National Space Centre	http://www.bnsc.gov.uk
CNES - Centre national d'études spatiales	http://www.cnes.fr/index.htm
CSG - Centre spatial guyanais	http://www.csg-spatial.tm.fr/
CDTI - Centro para el Desarrollo Tecnologico Industrial	http://www.cdti.es/
DSRI - Danish Space Research Institute	http://www.dsri.dk/
ESA - European Space Agency	http://www.esa.int
INTA - Instituto Nacional de Técnica Aerospacial	http://www.inta.es/entrada/entrada.html
NASA - National Aeronautics and Space Administration	http://www.nasa.gov/
NASDA - Japanese Space Agency	http://www.nasda.go.jp/index_e.html
NAAP - Netherlands Agency for Aerospace Programmes	http://www.nivr.nl/
NSC - Norwegian Space Centre	http://www.spacecentre.no/
CERT - Centre d'études et de recherches de Toulouse of the Office national d'études et de recherches aérospatiales (ONERA)	http://www.cert.fr/
DLR - German Aerospace Research Establishment	http://www.dlr.de/
IKI - Russian Space Research Institute	http://arc.iki.rssi.ru/Welcome.html
RKA - Russian Space Agency	http://www.rka.ru/english/eindex.htm
INPE Space Agency - Brazil	http://www.dgi.inpe.br/
ISSI - International Space Science Institute	http://ubeclu.unibe.ch/issi/index.html
NLR - National Space Laboratory, the Netherlands	http://www.nlr.nl/public/
OSTC - Belgian Prime Minister's Office for Scientific, Technical and Cultural Affairs	http://www.belspo.be/
SSC - Swedish Space Corporation	http://www.ssc.se
SRON - Space Research Oganization Netherlands	http://www.sron.ruu.nl/
UNOOSA - United Nations Office for Outer Space Affaires	http://www.oosaunvienna.org

Glossary of Terms and Acronyms

Canadarm: Also known by its technical name, the Shuttle (or Orbiter) Remote Manipulator System (RMS). A 15-metre long robotic arm used on board each of the four space shuttles to move large payloads, like satellites, into and out of the shuttle's cargo bay. First deployed on orbit in 1981, the Canadarm's spectacular performance earned Canada an international reputation for excellence in space robotics.

Canadian Space Agency (CSA): The organism within the Government of Canada (specifically, the Industry Canada portfolio) responsible for managing Canada's Space Program. The Canadian Space Agency promotes the peaceful use and development of space, advances the knowledge of space through science and ensures that space science and technology provides social and economic benefits for Canadians.

CAPCOM: CAPsule COMmunicator; the only person (usually an astronaut) who communicates with the astronauts on orbit.

Canadian Space Vision System (CSVS): A computer software program designed and built by Canadian scientist and engineers (including Canadian astronaut Steve MacLean) that provides information on the exact location, orientation and motion of a specific target, which allows the Canadarm or the SSRMS to handle its payloads precisely and safely.

Degree of freedom: A measurement indicating a mode of motion that represents the flexibility of a mechanical system, or its ability to rotate with respect to a coordinate system (e.g. the SSRMS has 7 degrees of freedom).

Endeavour: The NASA Space Shuttle that will carry the STS-97 crew. The other shuttles are named *Columbia*, *Atlantis* and *Discovery*.

Extravehicular Activity (EVA): The official term for what is commonly known as a "space walk," or an excursion outside the Shuttle or International Space Station.

FD: Flight Day.

ISS: The International Space Station.

ISS 4A: The fourth International Space Station assembly flight, also known as STS-97.

Intravehicular Activity (IVA): An activity that takes place inside the shuttle or the Space Station.

JEM: The Japanese Experiment Module, Japan's contribution to the ISS. The module, which has been named "Kibo" (Japanese for "hope"), is a laboratory for space research and experiments.

Johnson Space Center (JSC): Located near Houston, Texas, the Johnson Space Center is the site of Mission Control and the training centre for the mission.

Ka-band: A specific frequency band used in radar.

Kibo: See JEM

Kennedy Space Center (KSC): NASA's Kennedy Space Center, located at Cape Canaveral, Florida, is the site of the Shuttle launch and the scheduled site for its landing.

Mobile Remote Servicer Base System (MBS): A moveable platform to transport the Space Station Remote Manipulator System and the Special Purpose Dexterous Manipulator to various locations on the International Space Station. Part of the Mobile Servicing System, the Mobile Remote Servicer Base System slides along rails located on the Station's main structure.

Mir: (Russian for both "peace" and "Earth") The third-generation Soviet space station, which was lauched on orbit in 1986.

Mission Specialist: Astronauts that are responsible for the operations of orbiter systems during spaceflight, like operating the Canadarm or conducting EVAs to work outside the Shuttle. Mission specialists are trained in the basic theory, design and operation of all the Shuttle's major systems, including data processing, electrical power, propulsion, manoeuvring, life support, navigation, communications and camera/TV systems. Mission specialists do not fly the shuttle, but they must be able to repair something if it breaks down.

Mobile Servicing System (MSS): A sophisticated robotic system that is Canada's main contribution to the International Space Station. The Mobile Servicing System consists of the Space Station Remote Manipulator System, the Special Purpose Dexterous Manipulator, the Mobile Remote Servicer Base System, as well as facilities on Earth for mission support and astronaut training. It will play a key role in the construction of the Station in orbit, as well as in its continuing operation during the 10-year planned life of the facility.

National Aeronautics and Space Administration (NASA): The American federal administrative body responsible for the US space program.

NASA TV: A resource designed to provide live coverage of missions and NASA's activities, as well as offer video resources to the media and education programs targeted at teachers, students and the general public.

Orbiter Vehicle-105 (OV-105): The official name of the Space Shuttle *Endeavour*, the newest addition to NASA's fleet of four orbiters.

Payload Specialist: An astronaut trained to conduct an experiment or, more often, a set of experiments during a mission aboard the space shuttle. Months prior to the mission, the payload specialist begins intensive scientific training with the scientists responsible for the experiments, called the Principal Investigators. The payload specialist must become completely familiar with the payload and equipment necessary for the experiments (including the materials and the hardware). Despite careful planning, equipment may fail. A well-trained payload specialist will likely be able to fix the equipment or come up with an alternate plan so that the experiment will not be lost.

Photovoltaics: The process by which electromagnetic radiation is converted into electrical current.

RADARSAT-1: Canada's renowned Earth Observation satellite system developed to monitor environmental change and the planet's natural resources. Launched in November 1995, RADARSAT-1 provides Canada and the world with data for both commercial and scientific users in the fields of agriculture, cartography, disaster management, hydrology, forestry, oceanography, ice studies and coastal monitoring.

RMS: Remote Manipulator System (see Canadarm).

Space Vision System: See the Canadian Space Vision System.

Special Purpose Dexterous Manipulator (SPDM): A small, detachable two-armed robot that can be placed at the end of the Space Station Remote Manipulator System to perform more sophisticated, delicate operations. The Special Purpose Dexterous Manipulator is part of the robotic system known as the Mobile Servicing System, which is Canada’s key contribution to the International Space Station.

Space Station Remote Manipulator System (SSRMS): A 17-metre-long robotic arm that has been dubbed the “next-generation Canadarm.” More sophisticated and more versatile than its predecessor, the SSRMS will assist astronauts in assembling, inspecting and repairing the Station, conducting ongoing operations (such as the positioning of visiting shuttles) and transporting equipment and supplies. The SSRMS is the first element of the Mobile Servicing System, Canada’s main contribution to the Space Station.

STS-97: Space Transportation System, or Shuttle Mission, number 97, Marc Garneau’s mission to the International Space Station.

Unity: The first major American component of the ISS, the *Unity* node serves as a connecting passageway to the living and working areas of the ISS. Unity is joined to the Russian module, *Zarya* (FGB).

Zarya (or *Zaria*): The Russian control module, which was the first component launched for the ISS. Also known by its technical name, the Functional Cargo Block, and its Russian acronym, FGB, *Zarya* is Russian for “sunrise,” and was designed to provide the Station's initial propulsion and power. The 19 350-kilogram pressurized module was launched on a Russian Proton rocket in November 1998.

Zvezda (also *Svezda*; Russian for “Star”): The Russian service module of the ISS that will provide the early Station living quarters, electrical power system, as well as life support, data processing, flight control, communication and propulsion systems. Zvezda was launched on 25 July 2000.

Hotel Listings

Titusville, Florida		
Best Western (321) 269-9100	Budget Motel (321) 267-4211	Days Inn (321) 269-4480
Highway Inn (321) 269-9310	Holiday Inn (321) 269-2121(321)	Lucks Way Inn (321) 269-7110
Pinto's Motel (321) 269-2505	Ramada Inn (321) 269-5510	Riverside Inn (321) 267-7900
Royal Oak Arms (321) 264-0380	Royal Oak Resort Golf Club (321) 269-4500	Siesta Motel (321) 267-1455
South Wind (321) 267-3681	Three Oaks Motel (321) 267-6272	
Cocoa Beach and Merritt Island		
Best Western-Cocoa Inn (321) 632-1065	Budget Inn Interstate (321) 632-5721	Budget Inn of Cocoa (321) 636-1426
Campbell Motel (321) 636-6111	Cocoa Beach Hilton (321) 799-0003	Days Inn (321) 636-6500 or 1-800-329-7466
Dixie Motel (321) 632-1600	Econo Lodge (321) 632-4561	Fawlty Towers Motel (321) 784-3870 or 1-800-887-3870
Holiday Inn (321) 783-2271	Howard Johnson's (321) 783-8855	Inn at Cocoa Beach (321) 799-3460 or 1-800-343-5307
Luna Sea Bed Motel (321) 783-0500	Motel 6 (321) 783-3103 or 1-800-466-8356	Pelican Landing Motel (321) 783-7197
Radisson Resort at the Port (321) 784-0000	Royal Mansions Resort (321) 784-8484	Sea-Aire Motel (321) 783-2461
Silver Sands Motel (321) 783-2415	South Beach Inn (321) 784-3333	Surf Studio Motel (321) 783-7100
Wakulla Motel 783-2230		

Youth Media!

Check out our Web site during Marc Garneau's mission for new activities every day! Follow every step of Marc's mission and his tasks! Learn more about space, solar energy and astrophysics! Keep a Space Log!

www.space.gc.ca/kidspace

Blast off on Launch Day with CSA Astronaut Chris Hadfield

On Launch Day, 30 November 2000, at 1 :05 EST, join Canadian Space Agency Astronaut Chris Hadfield on the Internet as he hosts a Webcast and talks about what it is really like to go into space! Chris will host a behind-the-scenes special on Marc Garneau's mission. He will also answer questions from students across the country.
Don't miss it! Log on to:

www.schoolnet.ca/space/

For more information about the Canadian Space Agency, the Canadian Space Program, Canada's accomplishments in space and opportunities for students, educators and companies, visit the CSA Web site at:

www.space.gc.ca