

**THE INTERNATIONAL SPACE STATION:
CANADA'S INVOLVEMENT**

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N.B. Any substantive changes in this publication which have been made since the preceding issue are indicated in **bold print**.

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THE INTERNATIONAL SPACE STATION: CANADA'S INVOLVEMENT*

ISSUE DEFINITION

For many years, the United States has been actively, and generally successfully, involved in the exploration of space. It has sent unmanned and manned spacecraft into orbit and brought them back. It has landed men on the moon and seen them return safely to Earth. The Space Shuttle has demonstrated the feasibility (and the dangers) of the reusable spacecraft. The U.S. National Aeronautics and Space Administration (NASA) views the construction and operation of a permanently manned space station as the critical next step in advancing human space exploration. The mission of the space station will be threefold.

- First, it will provide an orbiting research base in which the effects of long stays in space on human physiology and well-being can be assessed. This information is essential if the space environment is to continue to be explored and exploited successfully.
- The second function will be as an advanced research laboratory in which to begin the process of understanding how to utilize the unique features of space – near-zero gravity, near-perfect vacuum and lack of atmospheric interference – to study new materials, new medicines and new technologies.
- Finally, the space station will be an engineering test-bed providing the opportunity to learn how to build, operate, and maintain complex systems in space.

In 1984, then-President Reagan committed the United States to building a permanently manned space station, and invited Canada, Japan and the European Space Agency (ESA) to join in this ambitious program. In March 1986, Canada announced its acceptance of the invitation. In the same year, 11 countries of the ESA and Japan also agreed to participate in the program. In January 1998, Canada and the other original participants signed a revised

* The original version of this Current Issue Review was published in February 1987; the paper has been updated regularly since that time.

Intergovernmental Agreement establishing a new International Space Station (ISS) partnership, which had been expanded to include Russia and Brazil. The new agreements reflected changes to the space station program resulting from significant Russian participation and design changes that had been introduced over the years.

The Canadian government agreed to develop, build, and operate one of the station's mission-critical elements – the Mobile Servicing System (MSS) – for assembly, maintenance and servicing tasks on the space station. The MSS was to consist of a Mobile Base System, two manipulators (the RMS or Remote Manipulator System, and the SPDM or Special Purpose Dextrous Manipulator) and the Canadian Space Vision System (CSVS). The following reasons were cited for Canada's becoming involved: the opportunity to build on our already well-established space industry; the potential for spin-offs from the advances in robotics and artificial intelligence engendered by this effort; and future access to the space station for scientific research and manufacturing. The estimated cost of Canadian participation was originally set at \$800 million but grew over the years to as high as \$1.9 billion by the year 2005. However, federal deficit reduction efforts necessitated a decrease in Canada's commitment. Following renegotiations after the 1994 budget, Canada reduced its financial commitment to \$496 million in addition to the \$713 million already contributed. This brings the total down to about \$1.2 billion. As detailed elsewhere in this review, although reducing our financial input, Canada has retained those portions of the program with the greatest potential for economic and scientific benefit to Canadians.

BACKGROUND AND ANALYSIS

A. The Space Station

The U.S. space station will not be the world's first; in 1973-1974, Skylab – which could house astronauts for up to three months at a time – was already in orbit above the Earth. Between that time and the 1984 decision to build the space station, the United States concentrated on developing the Space Shuttle (or STS – space transportation system). In the meantime, the Soviet Salyut program has provided permanent, manned space station facilities since 1971. Operating the MIR space station for many years had provided the Soviets with much valuable experience. After the break-up of the Soviet Union, the future of MIR was questioned,

but it was able to keep operating. Beginning in May 1995, NASA docked its Space Shuttles *Atlantis* and *Discovery* with the MIR Station 10 times as part of the phase-in of Russian participation in the ISS program.

As it was originally conceived, the U.S. space station program was ambitious and innovative. The station was expected to perform a wide range of functions, serving as:

- a laboratory in space, for scientific research and the development of new technologies;
- a permanent observatory, with elements in low inclination and polar orbits, from which to observe Earth and the universe;
- a transportation centre for stationing payloads and vehicles, processed and deployed to their destinations;
- a servicing facility for maintaining, repairing, and refurbishing payloads and vehicles;
- an assembly facility for assembling and checking out large space structures and systems;
- a facility to enable manufacturing in space, where the unique environment enhances commercial opportunities;
- a storage depot to keep payloads and parts on orbit for subsequent use; and
- a staging base for possible future space projects, such as a permanent lunar base, a manned mission to Mars, a manned survey of the asteroids, a manned scientific and communications facility in geosynchronous orbit, or unmanned planetary probes.

In 1990, budget restrictions – along with some misgivings about the engineering of the proposed station – led Congress to order NASA to review its design and adjust the program. As a result, a smaller version of the space station became the official proposal. This 1990 redesign did not affect the MSS design, and Canada proceeded according to the original criteria set out by NASA.

Over the years since its first approval, the U.S. Congress has not provided this project with as much funding as NASA had requested and expected. For example, NASA asked for a total of \$767 million in 1988, but Congress appropriated only \$393 million. Subsequent years have seen a similar pattern, with one Congressional Committee in 1992 even voting to stop all funding for the space station; this funding was restored by the House of Representatives but at a level of \$1.9 billion, rather than the \$2.45 billion NASA had requested. Again in 1993 there

were rumours that funding for the space station would be slashed or eliminated. Early in 1993, however, the White House announced that it would be requesting \$2.305 billion for the space station, for fiscal year 1994. Then-President Clinton reaffirmed his support for the program, but at the same time ordered yet another redesign to cut costs further. Before this new design could be presented to the President for his approval, negotiations began with Russia, which wanted to contribute its expertise and hardware to the international space station. Proponents of the ISS hope that Congress will be less keen to cut the project now that it has reached the construction phase. NASA's international partners also hope that further redesigns will not be required.

As the design has changed, so too have the official NASA program objectives for the space station, which are now more immediate, and perhaps less grandiose. The official objectives were stated as follows:

- to establish a permanently manned multi-purpose facility in low Earth orbit (LEO) in the 1990s;
- to enhance and evolve mankind's ability to live and work safely in space;
- to stimulate technologies of national importance by using them to provide space station capabilities;
- to provide long-term, cost-effective operation and utilization of continually improving facilities for scientific, technological, commercial and operational activities enabled or enhanced by the presence of mankind in space;
- to promote substantial international co-operation in space;
- to create and expand opportunities for private-sector activity in space;
- to provide for the evolution of the space station to meet future needs and challenges; and
- to foster public knowledge and understanding of the role of habitable space system capabilities in the evolution of human experience outside the Earth's atmosphere.

In its original design, the space station resembled a large rectangle of metal trusses. The trusses would have been taken into space by the Shuttle and assembled on site by the Canadian-made Mobile Servicing System (MSS). In the most recent redesign of the station, the truss will be pre-integrated and tested, with all of its subsystems in place before launch. A number of "modules" will be launched and docked first, and the integrated truss structures will

then be added. The Canadarm (or Remote Manipulator System), already in use on board the Space Shuttle, will be used in the early construction of the station, and the MSS will be used for later construction and maintenance.

The redesigned space station will be smaller than the original (108 m rather than 150 m) and will house four to six, rather than eight, astronauts. In addition, it will be capable of transmitting only about one-sixth as much information per minute back to Earth. Clearly, the range and number of experiments that can be carried out with this new configuration will be inferior to what was originally planned. However, from the Canadian point of view, these changes are not critical, because both the old and new designs require the MSS.

Launch and construction plans and schedules are in a continual state of flux. **NASA did launch the first two elements of the space station in November and December 1998, but the launch of the third element, to be supplied by NASA's Russian partners, was repeatedly delayed, finally taking place in July 2000. The current schedule calls for completion of construction late in 2006, although further delays and changes to the schedule are probable. After just the first six assembly flights, the station reached what is called MTC or man-tended capability. The first three-person resident crew arrived in November 2000. Since that time there have continued to be numerous Shuttle flights each year for station assembly and maintenance, as well as three utilization flights each year. During the latter, the Shuttle with its seven-person crew docks with the station for about two weeks at a time; four of the crew devote their time to carrying out experiments for space station users. The countries participating in the operation of the station will share operating costs. They will have access to time and space in the laboratories in proportion to their contribution. Other countries will be able to send experiments to the space station on a commercial basis, as space and time allow.**

B. Canada's Space Station Program

1. Program Objectives: Why Should Canada Participate?

The answer to this question is not simple. The many reasons put forward to justify Canadian participation in this ambitious space program include: achieving international prestige as a technologically advanced industrial economy; securing an entrée into important new

high-tech fields; generating technological spin-offs on Earth; buying long-term access to the space environment for Canadian researchers; and developing a highly qualified work force in the fields of robotics and automation. In the short term, the technical and economic spin-offs on Earth are arguably the most significant goals, together with the creation of a pool of knowledgeable scientists and industrialists in several emerging technological fields. Officials of the Canadian Space Agency (CSA) point out that more than \$1 billion in business activity directly related to the space station has already flowed to Canadian companies, and that this figure is expected to surpass \$5 billion over the next 20 to 25 years. Many of the technologies developed for the space station, especially in the fields of robotics and automation, will have terrestrial applications, including work in “hostile” environments such as the nuclear industry, mining and offshore resource development. **In 2001, the CSA estimated that spin-offs from Canada’s entire space industry (including but not limited to communications satellites and related ground-based technology and ISS participation) amount to some \$1.25 billion annually. Nearly half of this revenue is from export activities. The industry has created approximately 5,000 new high-tech jobs throughout the country.**

In 1991, the Space Station Program Office of the Canadian Space Agency detailed the space station program objectives as follows:

- (i) To enhance Canada’s ability to operate in space and to exploit space by:
 - developing and operating the MSS to play a predominant role in assembling and maintaining the space station;
 - developing and applying strategic technologies for the MSS, particularly in the fields of automation and robotics;
 - facilitating participation in space station use by Canadian industry, government, and university sectors;
 - assuming Canada’s share of space station common operations;
 - developing user demonstration experiments emphasizing technologies with commercial potential; and
 - participating in the international management of the space station.

- (ii) To maximize social and economic benefits to Canadians by:
 - improving regional distribution of space-related government expenditures; and
 - fostering commercialization of space station technologies.

At that time, the Canadian program had four major components, namely:

- (i) Development and operation of the Mobile Servicing System. This was to be Canada's main contribution to the space station, to include a platform, a Remote Manipulator System, and a Special Purpose Dexterous Manipulator; MSS operations included sophisticated ground-based facilities for simulating operations planning;
- (ii) Operation of the space station. This task was to consist of Canada's contribution to the operation and maintenance of the space station, once launched, with the help of Canadian astronauts;
- (iii) The Strategic Technologies in Automation and Robotics (STEAR) program, which consisted of contracts to industry to develop next-generation technologies for the continued upgrading and evolution of the MSS; and
- (iv) The User Development Program (UDP) to foster, through contracts with firms and universities, the Canadian use and commercial exploitation of the space station, in particular microgravity, through development of new materials, products and processes in space.

This program has changed somewhat, particularly with respect to items (i) and (ii), as a result of the renegotiation of Canadian participation following the 1994 budget. In item (i), Canada was planning to design and build both the MSS and the SPDM (Special Purpose Dexterous Manipulator), also known as the Canada Hand. Under the 1994 agreement, Canada was still to complete the design and construction of the MSS, as well as to retain responsibility for its operation once it was on the station. Canada would, however, complete only the design of the SPDM; we were given an additional three years to make a final decision on whether we would also be involved in its construction. The CSA believed that the new program retained the most important elements of the old because it would allow Canadian scientists and companies to continue developing their design expertise in the important automation and robotics fields. However, in April 1997, the Prime Minister reversed the earlier decision and announced that Canada would indeed invest US\$150 million in building the SPDM.

The revolutionary CSVS (Canadian Space Vision System) – which is being developed in a co-operative program by the Canadian Space Agency and NASA – is now also a part of Canada's involvement in the ISS. It is designed to provide the station's robotic arms with "synthetic visual cues," so they can "see" what they are doing. The CSVS began on-orbit testing

during a 1992 Space Shuttle flight. In November 1995, an advanced version was flown on a mission, during which it was used in a docking operation in the cargo bay of the Space Shuttle. In December 1998, the CSVS was used in docking the first two space station components: Zarya and Unity. **Its operational performance continues to meet all expectations.**

The second major change to Canada's participation in the space station is that our commitment to participate in the ongoing operation of the space station – item (ii) – has been dropped completely, for a savings over 10 years of approximately \$270 million. Although Canada has deferred using its share of space station resources, we still have the option of allowing Canadian scientists access to the station on a case-by-case, pay-as-you-go basis. Nevertheless, Canadian astronauts have been assured of one flight per year until construction of the station is complete. After that time, foreign astronauts will undertake the experiments sent to the station by Canadian researchers. By not using our share of the station resources (2.3%) on a regular basis, Canada is saving another \$75 million. **This change in participation also reduced the necessity for item (iv), the User Development Program, which has now been replaced by the ISS Commercialization Program.**

It might appear that giving up regular use of the space station negates Canada's reason for becoming involved in the first place. Officials at the Canadian Space Agency, however, insist that the most economic and technological gains for Canada will be realized by the research and development and industrial activity resulting from the design and/or construction of the MSS, the SPDM and the CSVS. The fact that \$1 billion in benefits have already been realized from the \$713-million government investment would seem to lend credence to this claim. In addition, Canadian space scientists will still have access to the station, albeit on slightly different terms from those previously envisioned. **Item (iii), the STEAR program, concluded in March 2000, after awarding several hundred contracts involving more than 150 Canadian technology development companies and 50 Canadian universities and research institutes. A new program, the STDP (Space Technology Development Program), has been established, and part of its mandate is to continue the ISS-related developments begun under STEAR.**

2. The Mobile Servicing System (MSS)

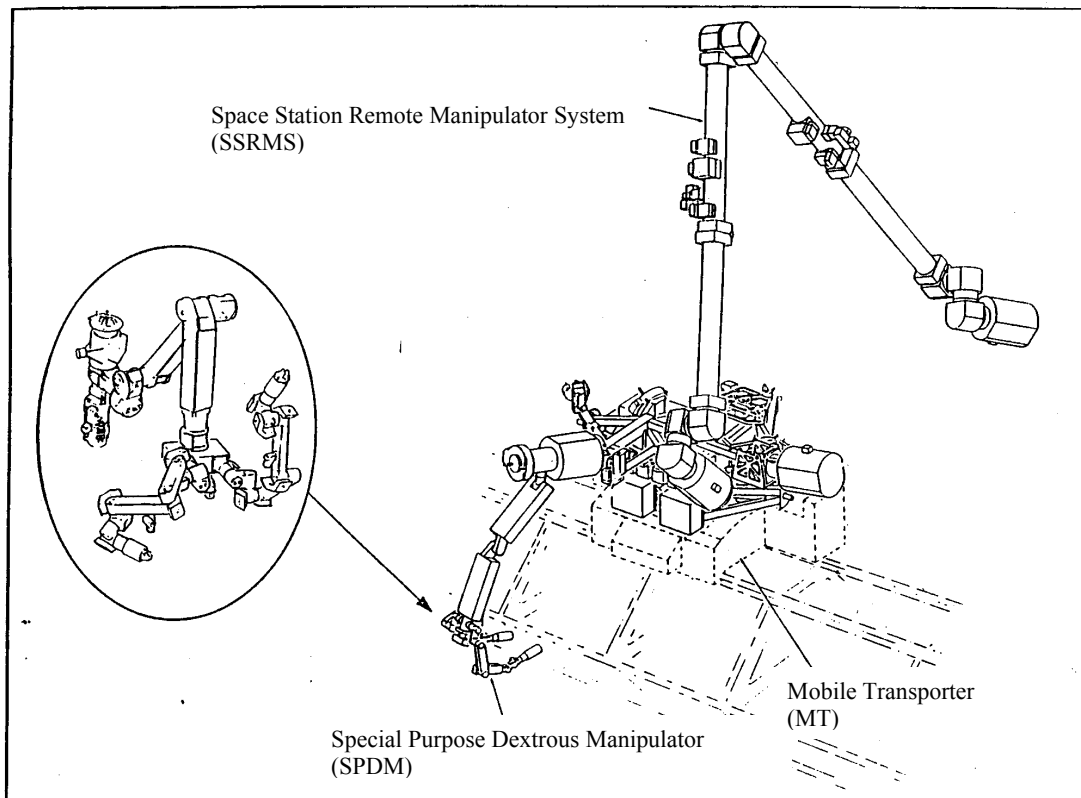
In the past, Canada contributed to the U.S. space program with the very successful Canadarm, which now flies on almost every Space Shuttle flight. When asked to join in the space station program, it was logical for Canada to build on this expertise. Canada insisted that our participation should entail more than the provision of a piece of hardware because we wanted to ensure that our involvement would continue after the station became operational. After the United States had agreed to this demand, Canada agreed to design, build, and operate the MSS. It is worth noting that, until Russia became involved in the program, Canada was the only foreign country supplying what is known as a mission-critical element of the station, i.e., one that must operate on time and in the prescribed fashion in order for the mission to continue.

Figure 1 presents an artist's impression of the design of the MSS. This system will play the main role in the assembly and maintenance of the space station by: moving equipment and supplies around the station; supporting astronauts during EVAs (extra vehicular activities); and servicing instruments and other payloads attached to the station. In addition, the MSS will be used for docking the visiting Space Shuttles and for loading and unloading the Shuttle cargo bay. Canada is responsible for the total design, development and long-term operation of the MSS.

As can be seen in Figure 1, the MSS consists of two main elements. The first is the RMS (or, in more recent U.S. terminology, the SSRMS or Space Station Remote Manipulator System), which represents the next generation of the Canadarm now flying on the four Space Shuttles. The new arm has seven, rather than six, motor-driven, computer-controlled joints. The extra joint means the arm can now mimic most human arm movements. The arm is 17.6 m (58 feet) long and has a payload capacity of 116,000 kg (128 tons). **The SSRMS was delivered to NASA in February 1999 and sent into space in April 2001 aboard the Shuttle. The arm is attached to the Canadian-built mobile servicing base system. The base, in turn, is attached to the U.S.-supplied mobile transporter system. The latter is like a small railway track running along the truss structure of the station.**

The SSRMS is also designed to accommodate the SPDM or special purpose dextrous manipulator. This robot (known affectionately to its developers as "Hector the Erector") will have two seven-jointed arms, each about 2 m (6.65 ft) long. Its remarkable mechanical dexterity will enable it to undertake more delicate jobs such as working on electrical

Figure 1
Space Station Mobile Servicing System
and Special Purpose Dexterous Manipulator



Source: Technical and Administrative Services, NASA, *Space Station Freedom Media Handbook*, p. 78.

circuits, fuel lines and cooling systems. Advances in robotics, vision systems and artificial intelligence have provided the SPDM with very human-like senses. For example, the SPDM will have three separate cameras which allow it to “see” its way around the station. It can recognize targets and adjust its own position in response. Sophisticated software programs also prevent the two arms from colliding with one another, and automatically keep the elbow from hitting anything, or anyone, when the arms are reaching to grasp a target. In addition to seeing, with the help of the space vision system, this robot can also “feel.” It is equipped with force-sensing systems which tell it just how hard it is touching, pushing, pulling or twisting something. Given

this ability, the SPDM can be used to repair and/or replace delicate electronic parts or tighten bolts without risk of stripping them. These abilities will relieve astronauts of the necessity to go out into space to undertake routine repairs.

The SSRMS and SPDM are designed for a lifetime greater than 10 years, and must withstand the stresses of prolonged exposure in space with maximum reliability. Canada's success in meeting the stringent demands for the Canadarm led NASA to entrust us with the SSRMS and SPDM development. The industrial team responsible for most of the SSRMS and SPDM components reflects the goal of spreading the government space-related expenditures throughout the country. The team is headed by Spar Aerospace (based in Montréal and Toronto). Other companies involved include IMP Group (Halifax), CAE Electronics (Montréal), CAL Corporation (Ottawa), SED Systems (Saskatoon) and MacDonald Dettwiler Associates (Richmond, B.C.). **The SPDM is scheduled to be installed aboard the International Space Station during a mission in 2003.**

Canada's Space Station Program also includes highly sophisticated ground facilities. The ground-based segment is known as the MSS Operations Complex (MOC) and is located at the Canadian Space Agency (CSA) headquarters in Saint-Hubert, Quebec. It provides the infrastructure, resources, equipment and expertise for MSS space operations. The MOC is a state-of-the-art centre that houses a number of operations and training facilities, including the Space Station Operations Support Centre, MSS Simulation Facility, Operations Kinematic Simulator and the Canadian SSRMS Training Facility. As the CSA notes, "Controllers will use the MOC to plan complex SSRMS manoeuvres, before they are put into action on the Space Station. They will also monitor the health of the MSS and its complex hardware and software systems. Space Station astronauts and cosmonauts from many countries will visit the MOC to learn about the MSS and how to operate it in the rigours of space" (International Space Station FAQs, 20 March 2000).

C. Other International Contributions

1. Kibo – The Japanese Experimental Module (JEM)

Japan, like Canada, is participating in the space station project. Its contribution will be a laboratory to accommodate general scientific and technology development research activities, including microgravity studies. The JEM was recently given the name Kibo, which means “hope.” It will have a pressurized module, which will be a 10-m long tube with a 4.2-m diameter. There will also be a smaller exposed facility, and an airlock joining those first two elements, as well as a local remote manipulator and an Experiment Logistics Module (ELM). The ELM attaches to the laboratory and can be removed, returned to Earth to deliver experiments and products made in space, refilled with new materials and supplies, and returned to the station to be reattached to Kibo. Kibo itself attaches to the basic truss framework of the station. The ELM is being made compatible with Japan’s own launch vehicle, the H-2. **Japan has agreed to spend about \$2 billion on its space station contribution, which is now scheduled to be launched in 2004 or 2005.**

2. Columbus – The European Space Agency’s Pressurized Module (ESA Module)

The European Space Agency (ESA) is developing an attached, pressurized, “multi-purpose” laboratory as part of its contribution to the space station. This facility, which will be almost 12 m long with a diameter of 4.5 m, will be permanently attached to the space station. It is designed for international use principally in the fields of fluid physics, life sciences research and materials research. The module will provide a shirt-sleeve environment in which scientists can work.

Like Japan’s Kibo and the U.S. laboratory and habitation modules, Columbus will include storage capacity and accommodation for what is known as “crew safe-haven capability.” In other words, in the event of an emergency, the space station crew would have sufficient supplies and accommodation to await rescue. Columbus is currently scheduled for launch in 2004.

The ESA is also developing the automated transfer vehicle (ATV), which will handle the carrying of supplies to – and waste from – the ISS. **The first ATV mission is scheduled for April 2004.**

3. Russia's Contribution

With the end of the Cold War, Russia and the United States began a number of joint scientific undertakings. Russia's experience with the MIR Space Station prompted the United States to invite Russian participation in the ISS. Russia agreed to allow U.S. astronauts access to the MIR station to gain experience and also undertook to use its expertise to build several elements of the ISS. The United States provided the design and the financing for construction in Russia of the Zarya (Sunrise) module, otherwise known as the Functional Cargo Block. This, the first element of the ISS in space, will eventually function as a storage facility.

Russia also agreed to contribute Soyuz spacecraft to act as crew-escape vehicles. This component has been delivered. In addition, Russia agreed to the use of its Proton heavy lift vehicle (rocket) to launch elements of the station. This contribution was welcomed by the United States, as it would have relieved the U.S. of the need to develop its own heavy lift vehicle, needed to supplement Space Shuttle flights during assembly of the ISS. However, the 1999 crash of two different Proton rockets shortly after lift-off caused NASA a great deal of concern with respect to Russia's ability to meet this commitment. It also delayed the launch of the Russian-built Zvezda Service Module.

The Zvezda Service Module is the most complex Russian contribution. This module will serve as the early living quarters for astronauts assembling the ISS and contains vital life-support and propulsion elements. Zvezda was originally scheduled for launch on a Proton rocket in November 1999; however, lack of financial resources and Proton rocket failures caused many delays and the launch date was repeatedly pushed back. **NASA eventually provided additional money in the hope of getting the project on track and this element was finally launched in July 2000. Although Zvezda has now been launched, Russian authorities announced that, because of financial constraints, all work has stopped on the remaining smaller space station elements that Russia had agreed to supply. In addition, it is likely that Russia will not be able to provide the ongoing Proton-rocket launch support it had promised.** Financial problems in Russia are raising serious concern in the U.S. Congress over the rising costs that will ensue if NASA ultimately has to supply the Russian elements.

4. Progress of ISS Assembly

The Russian-built Zarya (Sunrise) module was launched from Baikonur in Kazakhstan on 20 November 1998. The module contains engines, fuel and communications devices. On 4 December 1998, the second element of the space station was launched aboard the Space Shuttle *Endeavour*. The *Endeavour* carried the U.S. docking module, Unity, into orbit. In the weeks following the launch, the Space Shuttle crew carried out three space walks to connect power and data transmission cables between Zarya and Unity. Unity is a six-sided structure; each side has an attachment port to which future modules will be connected.

In May-June 1999, Canadian astronaut Julie Payette, along with six others, travelled aboard the Space Shuttle to the fledgling ISS. No new elements of the station were added, as this was a “logistics flight.” The crew transferred about 3,600 pounds of parts, tools, computers, water and clothes from the Space Shuttle to the station, in preparation for the arrival of the first long-term residents in 2000. The Shuttle crew was also able to repair a communications system on Unity and replace flawed battery packs on Zarya.

The next scheduled launch was to be in November 1999, when Russia was expected to launch its Zvezda module aboard a Proton rocket. As already noted, this launch was delayed, but did finally take place on 12 July 2000. On 26 July 2000, Zvezda successfully docked with the Zarya and Unity modules.

Throughout the remainder of 2000 and continuing into early 2001, the pace of activity connected to the ISS increased. A total of three missions to the space station occurred in October and November 2000.

- First, the Shuttle carried the girder-like truss structure and associated electronics to the ISS. The crew installed this equipment, which will support the additional elements of the station as they arrive on site.
- The next to arrive at the station were the three members of the Expedition 1 crew who were the first long-term residents of the station. They were scheduled to remain there for approximately four months. The Expedition 1 crew travelled to the ISS aboard a Russian Soyuz spacecraft. The Soyuz module will remain at the station to act as the emergency crew evacuation vehicle.

- On the next shuttle flight in November 2000, the first solar photovoltaic arrays – which will power the space station – were delivered and installed. The arrays travelled in the Space Shuttle in a compacted form and had to be installed and then deployed after reaching the station.

In February 2001, the Space Shuttle again travelled to the ISS. This time it carried the U.S. laboratory module – Destiny – which is one of the largest single elements to be added to the station thus far. It will be the centre for research activities on the ISS. An unprecedented number of “space walks” were required to attach the Destiny module safely to the truss structure and to the other modules. This task was successfully completed. During the next Shuttle flight, in March 2001, the Expedition 1 crew was exchanged for the next residents (Expedition 2). That flight also entailed the delivery and installation of the Italian-built reusable Leonardo logistics module (the equipment racks that will outfit the Destiny laboratory).

In April 2001, Canada’s major contribution – the Space Station Remote Manipulator System (SSRMS) – was launched and installed. The new generation of robotic arm will work with the Shuttle-based Canadarm to lift and hold subsequent parts of the ISS as they arrive and are installed. The second Multi-Purpose Logistics Module, Raffaello, was delivered on the same Shuttle mission. This flight was followed in July 2001 by delivery and installation of a second (Russian) docking port (airlock).

In August 2001, the Expedition 2 crew exchanged places with the Expedition 3 crew on the next Space Shuttle mission to the ISS. **Throughout the rest of 2001 and early 2002, additional flights to the ISS saw delivery of truss elements to expand the station, the Mobile Remote Services Base System for the Canadian remote manipulator (Canadarm 2), and several more crew exchanges.**

CHRONOLOGY

- 25 January 1984 – The President announced that the United States would have a permanently manned space station by the end of the decade.
- 18 March 1986 – The Prime Minister announced Canada’s acceptance of the invitation to participate in the space station program.

- December 1987 – Canadian and U.S. negotiators agreed on the text of a Memorandum of Understanding governing Canadian participation in the Space Station Project. (It was finalized after Cabinet and Congressional approval early in 1988.)
- 21 April 1988 – The government announced its decision to commit \$1.2 billion over 15 years to the realization of the Mobile Servicing System (MSS) for the U.S. Space Station.
- 10 May 1990 – Bill C-16, An Act to establish the Canadian Space Agency and other matters in relation to space, was given Royal Assent. The Space Station Management Program, formerly part of the National Research Council, became part of the mandate of the new Canadian Space Agency.
- August 1994 – A redesigned space station, with Russian participation, received U.S. Congressional approval. Construction of station components was now under way.
- November 1995 – An advanced version of the Canadian Space Vision System flew on a Space Shuttle mission and was used in a docking exercise.
- April 1997 – Canada agreed to construct the SPDM (Special Purpose Dexterous Manipulator) for the International Space Station (ISS).
- 29 January 1998 – Canada signed the revised Inter-Governmental Agreement, an international treaty establishing the new ISS partnership including Russia.
- October 1998 – Canada's space station robotic arm, the SSRMS, was delivered to NASA.
- 20 November 1998 – The first ISS element, the Russian-made Functional Cargo Block (FCB), called Zarya (Sunrise), was launched from Baikonur in Kazakhstan.
- 4 December 1998 – The docking module, Unity 3, was launched aboard the Space Shuttle *Endeavour*. It was mated to the Zarya module on 5 December, using the Canadarm aboard the *Endeavour*, and guided by the Canadian Space Vision System.
- 12 July 2000 – The Zvezda Service Module was launched. It successfully docked with the ISS and was added to the growing station.

October-November 2000 – The main truss structure that will support the ISS was added, as were the first large solar arrays that will supply power to the station. The first residents of the ISS, a three-man crew, took up residence in the station for a four-month stay.

February 2001 – The U.S.-built laboratory module, Destiny, was added to the ISS.

March 2001 – The Expedition 2 three-man crew arrived to replace the Expedition 1 crew, and the Leonardo logistics module was delivered and installed in Destiny.

April 2001 – The Canadian Remote Manipulator System was delivered to the ISS and successfully installed.

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