

SpaceOps-2025, ID #266

Canada and the International Space Station Program: Overview of activities to support Canadian Robotics, Science and Human Space Flight

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Abstract

The Canadian Space Station Program (CSSP) is responsible for Canada's Mobile Servicing System (MSS) robotic operations on ISS, as well as conducting scientific research aboard the ISS and the planning of CSA astronaut launches. This paper focuses on recent ISS activities, highlighting the milestones achieved by the CSSP in the recent years, and how these achievements feed into the broader context of Canadian Space Exploration activities undertaken by the Canadian Space Agency (CSA).

In March 2023, Canadian Prime minister officially confirmed Canada's commitment to the ISS program throughout 2030. The announcement also included significant Canadian investments in Space Exploration programs, such as the Canadarm3, the Lunar Rover and Gateway utilization, confirming to all nations Canada's commitment to long term Space Exploration. These past years, MSS activities have been on the rise again and the utilization of Canadian robots on board ISS (Canadarm2, Dextre and MBS) were intense due to the steady flow of visiting cargo vehicles requiring Canadarm2 for free flyer capture and berthing operations, as well as Dexter for the deployment of external logistical cargo. In parallel, as the ISS ages, request for external maintenance of its modules and payloads were even more frequent and highly depended on MSS robotics capability. Utilization of the ISS as a research platform continues for Canada and provides tangible benefits for Canadians: a wide range of these experiments focus on the development and validation of technologies that identify, characterize, and mitigates risks to human health for during long-duration spaceflights. These ongoing research have a direct impact of the future human space flight exploration capabilities, and position the CSA to provide valuable data for future exploration initiatives towards the Moon and Mars.

Six years after the launch of Canadian astronaut David Saint-Jacques to the ISS in December 2018 (CSA's third long-duration space mission), CSA is now thrilled to be planning for two Canadian astronaut space missions in 2026. Astronaut Joshua Kutryk is scheduled to launch to the ISS on CSA's fourth long-duration mission in the fall of 2026. Additionally, Astronaut Jeremy Hansen will be the first Canadian to orbit the Moon aboard the Artemis II mission scheduled to launch no later than April 2026.

Nearly 30 years after Canada entered the ISS program and with many more years of success and international collaboration to come in low Earth orbit, the CSA and Canadians are excited to participate in the Artemis program, a stepping stone towards establishing a sustainable lunar presence and paving the way for human exploration of Mars.

Keywords: ISS • Canadarm2 • Dextre • Robotics • Science • Astronaut

Acronyms/Abbreviations

AI	Artificial Intelligence	CSA	Canadian Space Agency
APFR	Articulating Portable Foot Restraint	CSSP	Canadian Space Station Program
AVU	Artificial Vision Unit	CST	Cryogen Servicing Tool
BDC	Baseline Data Collection	CSVS	Canadian Space Vision System
CFT	Crew Flight Test	ESA	European Space Agency
CIPHER	Complement of Integrated Protocols for Human Exploration Research	ESM	European Service Module
CLD	Commercial Low-Earth Orbit Destinations	EVA	Extravehicular Activity
CLPA	Camera Light Tilt-Pan Assembly	FTM	Fuel Transfer Module
		HTV	H-II Transfer Vehicle
		IDA	International Docking Adapter

COTS	Commercial-off-the-Shelf	iROSA	ISS Roll-Out Solar Array
COTS	Commercial Orbital Transportation Services	ISED	Innovation, Science and Economic Development Canada
CRS	Commercial Resupply Services	PTOC	Payload Telescience Operations Centre
ISS	International Space Station		
JSC	Johnson Space Center	R-MPSR	Remote Multi-Purpose Support Room
JAXA	Japan Aerospace Exploration Agency	ROBO	Robotics Operations Officer
JEM	Japanese Experiment Module	ROSCOSMOS	Russian Space Agency
LEAP	Lunar Exploration Acceleration Program	RRM	Robotics Refueling Mission
LEO	Low Earth Orbit	R&R	Remove and Replace
MAI&T	Manufacturing, Assembly, Integration and Test	RWS	Robotics Workstation
		SANSORI	Spaceflight-Associated Neuro-Ocular Syndrome Ocular Rigidity Investigation
MBS	Mobile Base System		
MoG	Mobil-O-Graph	SLS	Space Launch System
MOTS	MSS Operations and Training Simulator	SPDM	Special Purpose Dexterous Manipulator, aka Dextre
MSS	Mobile Servicing System		
MT	Mobile Transporter	SRMS	Shuttle Remote Manipulator System
MUHC	McGill University Health Centre	SSRMS	Space Station Remote Manipulator System, aka Canadarm2
NASA	National Aeronautics & Space Administration		
NBL	Neutral Buoyancy Laboratory	STEM	Science, Technology, Engineering, and Mathematics
NG	Northrop-Grumman		
ORU	Orbital Replaceable Unit	VIPIR2	Visual Inspection Poseable Invertebrate Robot 2
PI	Principal Investigator		
POA	Payload ORU Accommodation		

1. Introduction

Over the last few years, Space Exploration activities on the International Space Station (ISS) have brought a significant number of new challenges, and the CSA has remained dedicated to its ISS commitment by maintaining continuous MSS operations and delivering on its ISS program.

From 2012 to 2019, following the end of the Space Shuttle era, MSS operations showed a steady increase. However, the extraordinary events of the pandemic in March 2020, coupled with a planned reduction in free-flying vehicle operations, temporarily slowed the demands on MSS operations, and slightly decreased onboard activities, including Science and Utilization efforts.

In January 2022, NASA announced the U.S. government’s commitment to extending ISS operations through 2030. This extension allows the U.S. and its partners to pursue their engagement towards advancing scientific and technological knowledge in Human Space Flight using the ISS as a critical LEO laboratory, while providing Industry and the Scientific community a transition period for the development of commercial destinations in Low Earth Orbit (LEO). The European Space Agency (ESA) and the Japanese Space Agency (JAXA) quickly followed with their own commitment to the ISS through 2030 in November 2022. Canada (CSA) confirmed its participation in March 2023, while Russia (ROSCOSMOS) committed to ISS program through 2028.

Since late 2020, CSA activities for MSS robotics, along with science, utilization, and astronaut assignments to ISS, have regained momentum. Actuals from 2025 demonstrate that MSS robotics utilization surpassed pre-pandemic levels, continuing the upward trend and surpassing previous records.

Now entering its third decade of operations, the ISS is busier than ever, but its aging systems present new challenges. The increased maintenance due to ISS aging infrastructure, and the eventual deorbiting of the station require careful planning and coordination among ISS partners. Partners are evaluating preliminary scenarios for deorbiting of the Station, during which the MSS will likely be asked to play a vital role for ISS pre-configurations prior to de-orbit.

More than ever, in these times of international instabilities, nations need to unite and develop synergetic initiatives for Humanity. Space exploration has always been a great venue to bring together people from different countries, ages, cultures. CSA’s core mission and the [Canadian Space Strategy](#) [1] both aim towards that direction.

2. Canadian Government

2.1 Budget for Space

In February 2019 the Canadian Government lead by Prime Minister Justin Trudeau announced an investment of \$1.9 billion over 24 years for the next generation of smart, autonomous space robotics for the U.S.-led Lunar Gateway, and \$150 million over 5 years for the Lunar Exploration Accelerator Program (LEAP).

In March 2023 during President Biden’s visit to Ottawa, the Prime Minister announced the extension of Canada’s participation to the ISS from 2025 through 2030, and this announce was followed by a \$1,066 billion budget over 14 years, beginning in 2023-24, to cover this extension.

Now five (5) years later, one can appreciate that these major investments in space by Canada have shaped and accelerated a whole new era of CSA projects and activities, focusing more than ever on space exploration portfolios, where investments in LEO are now synergistically integrated with Lunar and Deep space initiatives.

2.2 Space exploration priorities for Canada

The extension of the ISS and new requirements related to the Commercial Lunar Development (CLD), maintenance, and deorbiting of the vehicle and modules have significant implications for partner nations concerning their space programs, political priorities, internal governance, and budgets allocated to space. Additionally, these developments influence their project and activity planning in space.

Alongside substantial investments in the Cislunar environment and Deep space, the ongoing investments in the ISS until 2030 compel Canada to prioritize opportunities for Industry and Academia to conduct studies and develop technologies that will define Canadian participation in human exploration initiatives beyond LEO.

The Canadian Space Strategy developed in 2019 aims to focus on three key streams in LEO: Robotics [2], Science and Technology [3], and Human Space Flight [4] (HSF). These three pillars have shaped Canada’s commitment on the ISS since 2001.

3. Robotics Operations

Canadian robots onboard the ISS, the Space Station Remote Manipulator System (SSRMS, aka Canadarm2) and the Special Purpose Dexterous Manipulator (SPDM, aka Dextre) have accomplished countless critical tasks since their commissioning in 2001 and 2008 respectively. While SSRMS was essential for the assembly of the ISS, both SSRMS and SPDM are now heavily used for ISS maintenance and inspection, as well as for special missions dedicated to enhancing science performed outside ISS. Together with the Mobile Base System (MBS) (a platform moves on rails along the ISS trust elements), they consolidate into a Canadian robotic system masterpiece in space, that the ISS constantly depends on to achieve its mission. When Canadarm2 was launched in space in 2001, its original design-life was 15 years; 2025 marks its 9th year of operation beyond its planned lifetime.

Fig. 1 shows major robotics tasks performed by Canadarm2 and Dextre since 2017. The green histogram overlying the upper graph shows the time spent on console by the robotics operations team (in number of hours). Below the central axis, the number of commands sent to the MSS by the robotics flight control team is represented in peach. The combination of time spent on console and the number of commands sent to the MSS provides a visual representation of the high level of effort involved for robotics operations on ISS; however, it does not reflect the level of importance of the operations nor their significance to the program.

In the past 5 years, 11 cargo vehicles were captured by MSS, approximately 360,000 commands were sent to the ISS by Robotic Flight Controllers from the ground, and 2024 as equalled the record of 2019 as the busiest year for Canadian robotics operations since the MSS elements were launched.

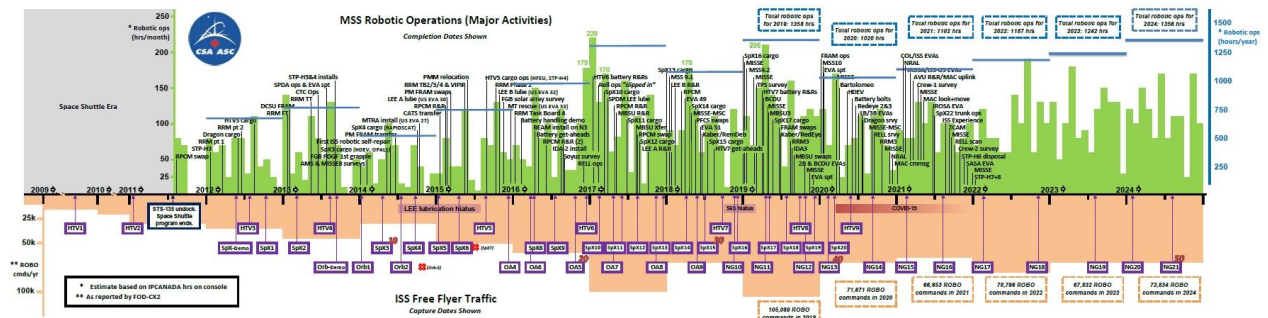


Fig. 1. Major MSS Operations, Free Flyer Traffic, and Level of Effort for 2017-2024 (as of Dec. 2024)

3.1 Free-flyer Operations

Canadarm2's capability to capture free flying vehicles was added long after the arm was launched into space in 2001 and has become vital for the ISS operations and logistics. Years of collaborative effort between CSA, NASA and NASDA (now JAXA) culminated in 2009 in the first free flyer capture of Japan's first H-II Transfer Vehicle (HTV). That milestone reached first on 17-Sept-2009, followed by the capture of HTV-2 on 27-Jan-2011, paved the way for free-flyer operations on ISS (See Fig. 2 for free-flyer vehicle capture count since 2009).

The first SpaceX Cargo Dragon vehicle, "SpaceX COTS Demo Flight 2", provided under NASA's Commercial Resupply Services (CRS-1) program, arrived at ISS and was captured by Canadarm2 on 25-May-2012. That was the first of 20 cargo Dragons to fly to ISS to be captured by Canadarm2 as part of CRS-1 program. A third cargo vehicle type, "Cygnus" manufactured by Orbital Sciences, made its debut at ISS and was captured by Canadarm 2 in Sep 2013. This was the first of a series of 21 Cygnus captures (so far) by Canadarm2.

Year 2020 saw the ninth (and final) flight of HTV vehicle and the 20th (and final) flight of the CRS-1 Cargo Dragon vehicle. The CRS-2 cargo Dragon design changed to docking at the time, rather than being captured and berthed by Canadarm2. As a result, since 2020 only Cygnus vehicles (now provided by Northrop Grumman (NG)) have been arriving at ISS needing free flyer capture by Canadarm2.

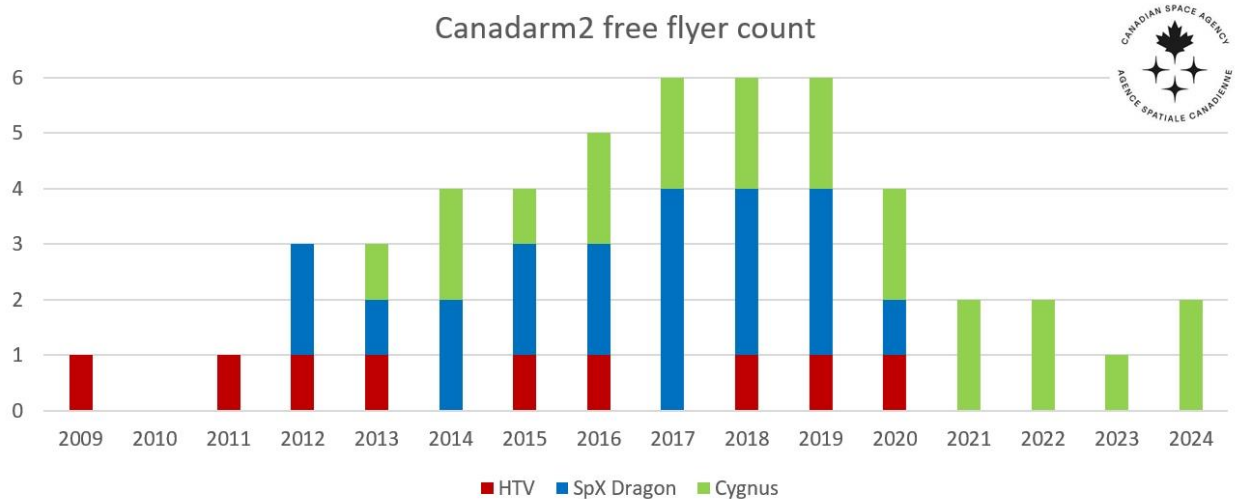


Fig. 2. Free-flyer vehicle captures by MSS

On August 6th, 2024, NASA astronaut Matthew Dominick operated Canadarm2 and performed the 50th free flyer capture of a visiting vehicle to the ISS. The NG-21 Cygnus resupply vehicle was successfully captured by astronaut Dominick and berthed to the station by CSA Robotics flight controllers and support team from the ground.

These metrics are a clear testimony of how Free flyer capture by Canadarm2 have become an integral part of ISS operations. This capability was implemented a long time after MSS commissioning. At the time, the original concept of operations was planned to have all robotic arm operations commanded from the ISS by an astronaut. Through the development of analysis tools, new operation techniques and the deployment of specific software upgrades, robotics activities are now widely performed from the ground and the ability to prepare for their execution in an efficient manner have increased significantly [5] and provided undeniable efficiencies and flexibilities to the ISS program.

Nowadays, the vast majority of MSS operations are commanded from the ground, either from JSC's in Houston, Texas, US, or from CSA's Remote Multi-Purpose Support Room (RMPSR) in Saint-Hubert, Quebec, Canada. In both cases, the Robotic Flight controllers can also count on Engineering support teams from CSA and MDA to provide real-time support pertaining to the MSS health and performance.

Looking ahead into 2025, HTV-X – JAXA's evolution of the HTV – and Sierra Nevada's Dream Chaser are both expected to fly to ISS and will thus provide new challenges for Canadarm 2 to meet as they provide new free-flyer vehicle configuration and capabilities to ISS.

3.2 Robotic Refuelling Missions

Since 2009, Robotics Refuelling Missions (RRM) were successfully performed on ISS. These missions main objectives were aimed at testing and demonstrating the capabilities for servicing spacecraft through on-orbit robotics, operated from ground. Results from previous RRM [6] (RRM1, RRM2 and first phase of RRM3) lead to the positive

demonstration that such specific and precise tasks could indeed be performed, and its success showcased yet again the outstanding performance of the Canadian robots, Canadarm2 and specifically Dextre.

Those meticulous tasks included unscrewing and removing caps, cutting protective blankets, accessing valves, and installing cooling line adapters. Numerous advanced tools and techniques were developed specifically for the RRM missions.

In October 2020, Phase 2 of RRM3 was successfully executed on the ISS [7,8]. During this phase, Dextre carried out its first dual-arm operation, simultaneously manipulating two RRM3 tools: the Cryogen Servicing Tool (CST) and the Visual Inspection Poseable Invertebrate Robot 2 (VIPIR2) (Fig. 3). One of Dextre's arms guided the hose into the port with the help of the CST, while the second arm extended the snake-like VIPIR2 camera into the piping system to ensure the hose was correctly inserted.

These delicate and critical operations, developed by NASA and CSA teams, were controlled from the ground by MSS Robotic Flight Controllers. The success of these tasks once again highlighted the exceptional versatility of the MSS on the ISS, significantly advancing the overall capabilities of Canadian robots in space.



Fig. 3. Dual-arm operation by Dextre during RRM3. (Credit: NASA)

3.3 Camera Replacement

In June 2024, Dextre completed another significant dual-arm operation by swapping multiple external cameras on the ISS. While held by Canadarm2, Dextre removed a camera from its own body, another from the Mobile Base System (MBS), and retrieved a new Camera Light Pan Tilt Assembly (CLPA) from the Japanese Experiment Module (JEM) airlock slide table (Fig. 4), before performing a three-way swap [9].

The objective of this complex operation was to optimize the cameras' locations based on their condition, importance, and usage, while improving overall external video feedback during operations. By the end of the swap, the new CLPA was installed at Dextre's body site 2 (Fig. 5), the malfunctioning CLPA from the MBS mast was placed back on the JEM slide table for future refurbishment on Earth, and the third CLPA, originally from Dextre's body, was mounted on the MBS mast.

This three-way camera swap highlighted the agility of the Canadarm2-Dextre system and its capability to successfully execute complex tasks for which it was not originally designed (Fig. 6). The CSA has consistently sought solutions to on-orbit challenges and supported projects requiring Canadian robotics. Challenges such as this complex set of operations demands proactive and innovative collaboration among the various ISS teams supporting MSS and ISS operations, including CSA, NASA, other international partners, and contractors.



Fig. 4. CLPA camera waiting on the JEM slide table to be retrieved by Dextre. (Credit: CSA)



Fig. 5. Dextre installing a camera on its own body. (Credit: CSA)



Fig. 6. Visualisation of Canadarm2 and Dextre and their limited clearance to other ISS modules during three-way camera swap. Image acquired during simulation with CSA 3D-visual model MOTS (Credit: CSA).

3.4 IROSA and EVA Support

After years in low-Earth orbit, the degradation of the ISS's solar panels due to ongoing radiation became evident, making the need to increase solar power generation crucial. From its original solar capacity of 240 kilowatts in 2009, the Station's power output had decreased to just 160 kilowatts.

The ISS Roll-Out Solar Array (iROSA) project was launched in 2021 to address this issue [10,11]]. Lightweight, flexible solar panels designed to be deployed and attached to the existing solar array system were installed on the ISS. The process of installing mounting brackets, configuring and deploying the rolling arrays, and connecting the necessary cables required extensive Extravehicular Activities (EVAs). The installation of new panels on channels 2B and 4B was completed in June 2021, after five EVAs between February and June 2021. The installation of new panels on channels 3A and 4A, conducted between September 2021 and December 2022, required four EVAs. The installation of new panels on channels 1A and 1B, which took place between November 2022 and June 2023, required six EVAs.

The capabilities of Canadarm2 were heavily utilized during the deployment of the iROSA project, particularly during the numerous EVAs. First Canadarm2 extracted components from SpaceX Dragon's unpressurized cargo (Fig. 7) and temporarily mounted them on the station's truss.

Then during a series of EVAs, an astronaut would step into an Articulating Portable Foot Restraint (APFR) attached to Canadarm2, holding the pre-detached folded solar-array blankets in his hands (Fig. 8). Canadarm2 then transported the spacewalker and the panels to their permanent location. There, a second astronaut would affix the rolled-up solar array (Fig. 9) onto a mounting bracket installed during a previous spacewalk. The iROSA blankets were then unrolled, securely mounted, and connected to the power system.

With the installation of six new iROSA panels between January 2021 and June 2023, each providing an additional 20 kilowatts of power, much of the Station's lost generating capacity has been restored (Fig. 10). Two additional panels are scheduled for installation in 2025, which will complete the upgrade and ensure the Station's operations through its projected end-of-life in 2030.

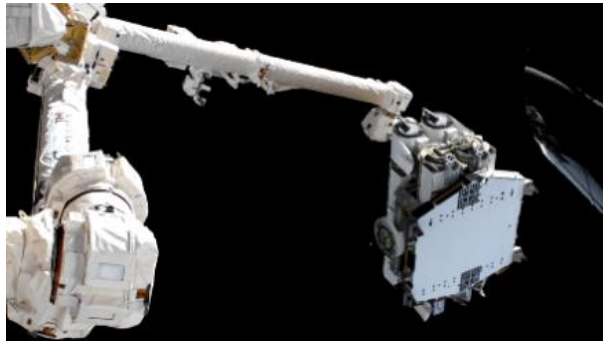


Fig. 7. Canadarm2 extracting iROSA components from SpaceX Dragon cargo trunk. (Credit: NASA)



Fig. 8. Astronaut Shane Kimbrough holding iROSA panels during first deployment. (Credit: NASA)



Fig. 9. Astronaut Thomas Pesquet into an APFR performing precise technical tasks for the deployment of solar arrays.



Fig. 10. ISS total solar power system as of June 2023, composed of the 16 original solar panels and 6 new iROSA panels. (Credit: NASA)

3.5 All-Canadian MSS Operations

On November 6th, 2024, for the first time ever, MSS operations were fully executed by a CSA Robotics Flight Control team entirely located at CSA headquarters Mission Control Center (better known as the Remote Multi-Purpose Support Room or RMPSR) (Fig. 11). This great achievement was made possible after years of dedicated, high-quality and rigorous support to MSS operations where only a portion of the Flight Control Team positions (2 out of 3) were fulfilled by Flight Controllers located in the RPMSR. The RMPSR was commissioned as a control room for ISS robotics operations in 2004. Over time, CSA capability increased to include all three robotics Flight Control positions that are necessary to conduct MSS operations.



Fig. 11. – MSS Flight Control team from CSA RMPSR

3.6 Pushing the Envelope until 2030

Since their first presence in space, Canadarm2 (2001) and Dextre (2008) have demonstrated their extreme versatility and their adaptation to new missions and growing challenges. Today, after 23 and 16 years in space respectively, not only are the Canadians robots are still readily available and in good health to conduct operations on ISS, but their technical capabilities are increasing year after year. To maintain that posture, over the past few years, the CSA has prioritized the maintenance and monitoring of the MSS and its subsystem to keep them in the best state as possible until the end of the ISS program. Operating the MSS beyond its design life and nominal operational state has presented significant challenges for engineers and required considerable resources.

Additionally, the increased utilization of the MSS is putting greater strain on their components as they age. For example, when initial signs of wear were observed, the MSS's Latching End Effectors (LEE) internal mechanisms were lubricated via EVA in 2015, to extend their operational life on the ISS. Initially, this (re)lubrication showed tangible results, but after a few years of continuous operations, signs of wear re-appeared. In 2017, Canadarm2's LEE A and the Payload and ORU Accommodation (POA), a fully functional but less frequently used LEE located on the MBS, were swapped via EVA. The decision to replace LEE A with a "fresh" spare available on the ISS was part of a broader CSA strategy that also involved procuring other types of spare parts for Canadarm2, Dextre, and the MBS, including joints and cameras (ref. section 3.3).

Another MSS component that has been closely monitored and inspected in recent years is the LEEs snare cables. These cables endure significant stress during grappling maneuvers. Repetitive use and high loads cause fatigue in the cables. While some visible signs of wear have appeared on the cables strands, operational procedures and several software updates have been deployed to ensure maximum usage, while maintaining safety requirements and minimizing risks.

Maintenance, monitoring, inspection, and Remove and Replace (R&R) activities performed on the robots in space are supported by extensive planning, management, and engineering analysis conducted on Earth. These activities involve the implementation of complex, long-term projects that include safety and risk assessments. They also require the design and Manufacturing, Assembly, Integration, and Testing (MAI&T) of spare parts, the refurbishment of existing components, the development of software tools and upgrades, simulation models, and the enhancement of robotic capabilities (e.g., free-flyer capture). To deploy and maintain these capabilities, the CSA's Canadian Space Station Program continually plans future operations and requirements in close collaboration with private contractor MacDonald, Dettwiler and Associates (MDA) (hardware provider for Canadarm2, Dextre, and the MBS).

The upcoming years of operations for Canadian robots on the ISS will be both exciting and challenging for the CSA. As these robots continue their critical maintenance and inspection tasks, which are expected to increase as we approach the end of ISS program, they will also prepare to accommodate and capture heavier vehicles such as HTV-X (JAXA) and Dream Chaser (Sierra Nevada). . New challenges will arise for the engineering teams, once again pushing forward the envelope for the robots, and ensuring the health of these robots will remain a top priority for the CSA.

4. Science and Utilization

The CSA's ISS utilization is focused on the identification, characterization, and mitigation of risks associated with long-duration human spaceflight. This is the main mandate of the CSA Health and Life Sciences Program and is further concentrated in three main areas of study: physiological, radiation, and human behaviour and performance associated risks. The CSA also has an Operational Space Medicine Program that focuses on maintaining crew health and operational readiness.

To varying degrees, Canada has demonstrated the development, maintenance, and sustained use of instrumentation (Facilities) focused on the above-mentioned research areas, as well as various experiments (Investigations) in support of the Programs' objectives.

The CSA Payload Telescience Operations Centre (PTOC) located at CSA Headquarters in Saint-Hubert, Quebec, allows CSA team members and Canadian Principal Investigators (PIs) to monitor and support, in real-time, the conduct of these ISS research activities.

4.1 Ongoing On-Orbit Payload Operations

There has been an increasing number of Canadian Payloads, which also translates to an increase in the number of crew hours supported for on-orbit operations.

Payloads can be classified as either Facilities or Investigations. A Facility is hardware available for use by multiple Clients over an extended period, whereas an Investigation is a scientific study focused on obtaining a defined set of results. The CSA Operations team supports both.

4.1.1 Bio-Monitor (Facility) [12]

The Bio-Monitor has been operational and in use as a Facility for over 5 years. This system provides a means for continuous monitoring of crewmember physiological parameters for prolonged periods in a non-invasive and non-intrusive manner. Rather than using several devices, the Bio-Monitor measures multiple parameters in a more time efficient way as well as simplifies data management, all without limiting crewmember mobility.

The Bio-Monitor is utilized by all the currently active Canadian Investigations on-orbit.

4.1.2 Mobil-O-Graph (Facility) [13]

As of September 2024, CSA has a second Facility supported – the Mobil-O-Graph (MoG). The MoG is a Commercial-off-the-Shelf (COTS) product that performs interval blood pressure measurements over an extended period.

The MoG is utilized by 3 of the 4 currently active Canadian Investigations on-orbit.

4.1.3 CARDIOBREATH (Investigation) [14]

Principal Investigator: Dr. Andrew Blaber, Simon Fraser University, Vancouver, British Columbia, Canada.

This study uses a novel physiological model and advanced data analysis techniques to study contributions of the heart, breathing, and posture on blood pressure regulation, and their changes during and after spaceflight.

The results of this study will help to provide insight into the adaptations of blood pressure control and help in the development of countermeasures and recovery programs for the maintenance of human health and performance in long-duration space missions.

4.1.4 Space Health (Investigation) [15]

Principal Investigator: Dr. Carolyn McGregor, Ontario Tech University, Oshawa, Ontario, Canada.

The Autonomous Health Monitoring for Adaption Assessment on Long Range Missions Using Big Data Analytic (Space Health) Investigation looks at how the cardiovascular system is impacted by the spaceflight environment.

Space Health makes use of an Artificial Intelligence (AI) computing platform called Artemis to provide a near real-time assessment of the cardiovascular system. The goal is to use these AI algorithms to find patterns and identify risks using large sets of medical data.



Fig. 12. Canadian astronaut David Saint-Jacques wears the Bio-Monitor garment and MoG. (Credit: CSA/NASA)

4.1.5 Vascular Aging (Investigation) [16]

Principal Investigator: Dr. Richard Lee Hughson, Schlegel-University of Waterloo, Waterloo, Ontario, Canada.

This study follows the completion of Vascular and Vascular Echo which were both also led by Dr. Richard Hughson. The focuses of Vascular Aging are on determining the cause of arterial stiffening in astronauts and the confirmation of if, and when insulin resistance develops during a mission. It also aims to clarify the effects of radiation exposure on cardiovascular health.

The study continues to follow astronauts once they return from the ISS to track their recovery process. These findings will help to further inform what actions can be taken to help counteract the effects of being sedentary because of weightlessness.



Fig. 13. Astronaut Akihiko Hoshide of the Japan Aerospace Exploration Agency (JAXA) scans the femoral artery in his right leg with an ultrasound device for the Vascular Aging study. (Credit: NASA)

4.1.6 Vascular Calcium (Investigation)

Principal Investigator: Dr. Richard Lee Hughson, Schlegel-University of Waterloo, Waterloo, Ontario, Canada.

Vascular Calcium is encompassed within NASA's Complement of Integrated Protocols for Human Exploration Research (CIPHER) Program [17]. The most recent addition to the Vascular series [18], this study will continue to examine the effects of long-duration spaceflight on the cardiovascular system.

Like its predecessors, Vascular Calcium will further examine arterial stiffness, insulin resistance, and bone health, but will also determine how these are impacted by an increase in mission duration to one year rather than the more common six months.

4.2 Ongoing Pre- and Post-Flight Investigations

There are additional CSA-supported Investigations with no on-orbit activities and only pre- and post-flight Baseline Data Collection (BDC). These are: Spaceflight-Associated Neuro-Ocular Syndrome Ocular Rigidity Investigation (SANSORI) [19], TBone2 [20], and Wayfinding [21].

SANSORI is examining the causes of vision changes that astronauts may experience during their missions and how physical differences in eye structure may contribute to this. TBone2, also part of NASA's CIPHER Program, continues the work of the TBone experiment to look at the effects of microgravity on an astronaut's bones. Finally, Wayfinding is looking at the impacts of spaceflight on brain health and how structural and functional changes of the brain may contribute to challenges with spatial orientation.

4.3 Completed Payload Operations

In the last few years, the following Investigations completed their protocol: Marrow [22], Radi-N2 [23], Vascular Echo [24], and VECTION [25]. These are further detailed in the references provided.

4.3 Outreach

Various outreach initiatives were also recently supported by the Operations team. This included manifesting materials on different vehicles for launch to or return from the ISS as well as coordinating resources for historical photos or videos with crewmembers on-board the ISS.

Tomatosphere has now completed 8 campaigns (2 within the last 5 years) where tomato seeds were sent to the ISS. Once they returned, the seeds were distributed to students so that they could perform their own experiments to examine the differences in germination between seeds that have flown in space and those that have not.

The astronauts on-board the ISS have also been keen to support outreach initiatives in addition to their busy schedules performing science (and many other tasks). Thomas Pesquet recorded a video for use in the CSA's 2021 Junior Astronauts campaign [26], and Samantha Cristoforetti did the same for the 2022 edition of Space Brain Hack [27]. Space Brain Hack is an ongoing initiative to expose the next generation to the opportunities that exist in Science, Technology, Engineering, and Mathematics (STEM) careers.



Fig. 14. Canadian astronaut Jeremy Hansen meets with students and Let's Talk Science to examine tomato seed germination. (Credit: CSA/Let's Talk Science)

4.4 ISS Utilization

In summary, the CSA Utilization program aims to use CSA-allocated resources to make full use of this well-equipped space laboratory. Countermeasures are continuously in development, several reports have been published using the data gathered through Investigations on the ISS, and follow-on generations of studies are in progress following the success of their predecessors.

The ISS presents opportunities to make progress on important gaps in our knowledge of human adaptation and maladaptation to weightlessness, and to the extreme psychosocial isolation of long duration space habitation. The CSA, along with the other ISS partners, intends to use this opportunity in the most effective and efficient manner. The CIPHER Program has already demonstrated the benefits of collaborative scientific efforts, and the CSA intends to continue these collaborations with Canadian and international non-space funding agencies as we expand our exploration beyond Low-Earth Orbit. These efforts will help us bring more scientists into space research and to best exploit current life science research advances.

5. Astronaut office

5.1 Astronaut activities and training

In the summer of 2020, after 11 years of posting at NASA JSC and a few months after returning from his long duration mission to ISS, astronaut David Saint-Jacques returned to CSA Headquarters in Saint-Hubert. He recertified with the Quebec College of Physicians and took leave of his astronaut duties for most of the COVID19 pandemic period to serve on Montreal COVID wards, returning to CSA full-time in the summer of 2022. He currently supports the CSA Health Beyond Initiative as Jury for the Deep Space HealthCare Challenge and the Aqualunar Challenge. He is also supporting the Canadarm3 Human-in-the-loop requirements development. Since 2023 he is on assignment as Deputy Director for the new CSA Lunar Exploration Program, helping define Canada's contributions to the Artemis Program.



Fig. 15. Canadian astronaut David Saint-Jacques returning to his roots, donning scrubs to help with the COVID-19 pandemic at the McGill University Health Centre (MUHC). (Credit: David Saint-Jacques)

David maintains his active flight duty status and continues to support ISS Operations during regular trips to JSC where he serves as Capcom, supports EVA procedure development at the Neutral Buoyancy Laboratory (NBL), and as Instructor Astronaut.



Fig. 16. Canadian astronaut Jenni Gibbons as Ground IV crewmember who talked to the EVA astronauts on ISS during the iROSA deployment in June 2023. (Credit: NASA)

Astronauts Jeremy Hansen, Jenni Gibbons and Joshua Kutryk continue to be posted to JSC. Until their recent mission assignments, they underwent pre-assignment training including flight, languages (French and Russian), spacewalk, robotics, field geology, ISS and launch-vehicle systems training. Jeremy was assigned to Artemis II in April 2023; Jenni was assigned as one of two back-up crewmembers for Artemis II in November 2023, at the same time as Joshua's assignment as one of four crewmembers on an upcoming long-duration ISS mission.

Jenni Gibbons served as the official Ground IV (Intravehicular Activities) for 5 of the ISS Advanced Solar Array Upgrades (iROSA) EVAs; this work, which took place through simulations, as well as sessions in and out of the pool at the Neutral Buoyancy Laboratory (NBL), and in the Mission Control Center (MCC) at JSC, took place in 2021 and 2023. Jenni also undertook the important task of improving the EVA training and qualification process for the new NASA astronaut candidate classes in support of the NASA EVA office.

5.2 Artemis II

Artemis II, NASA's first crewed mission to the Moon since the Apollo program, remains on track for its target launch date planned for no later than April 2026. The mission will carry four astronauts* – Reid Wiseman, Victor Glover, Christina Koch, and CSA astronaut Jeremy Hansen – on a 10-day journey around the Moon, testing critical systems and paving the way for future lunar exploration.

The uncrewed Artemis I mission, launched in November 2022, revealed several issues that are being addressed for Artemis II. The most significant was the unexpected erosion of the Orion spacecraft's heat shield during re-entry. NASA is investigating the root causes and making necessary modifications to ensure crew safety. Additional issues included the melting and erosion of separation bolts, uncommanded power disruptions attributed to radiation exposure, and damage to the Mobile Launcher 1 [28]. These problems are being addressed through redesigns, software updates, and enhanced protective measures.

The Orion spacecraft, which will carry the Artemis II crew, underwent a successful power-on test in November 2023. This milestone verified the integration of the American crew module with the European Service Module (ESM). The Space Launch System (SLS) rocket components, including the twin solid rocket boosters, are being assembled at NASA's Kennedy Space Center. The final integration and testing phases are scheduled for the upcoming months. The Artemis II crew has engaged in extensive training, including geological fieldwork in Canada. This training, conducted at the Kamestastin (Mistastin) crater in Labrador, focused on honing skills necessary for lunar surface exploration on future Artemis missions. The crater's geological similarities to the Moon's surface provided a realistic environment for hands-on practice. Additional training modules have included medical procedures, such as emergency response and routine medical care, to prepare the crew for potential in-mission scenarios. The next critical milestones for Artemis II involve the final assembly and testing of the SLS rocket, further launch and re-entry/splashdown simulations, and continued intensive training for the crew. The Artemis II crew has also actively participated in outreach activities to raise public awareness about the mission.



Fig. 17. Artemis II astronauts showing, from left, NASA astronauts Christina Koch, Victor Glover and Reid Wiseman, and Canadian Space Agency astronaut Jeremy Hansen. (Credit: NASA/Josh Valcarcel)

* CSA astronaut Jenni Gibbons and NASA astronaut Andre Douglas were assigned as Artemis II back-up crewmembers.

5.3 CAN4

This mission, termed CAN4 internally to CSA, will be CSA's fourth long-duration mission to the ISS, and the first CSA mission under NASA's Commercial Crew Program, scheduled to launch to the ISS fall 2026. CSA astronaut Joshua Kutryk was assigned to this mission in November 2023; he joins three other NASA and international partner astronauts.



Fig. 17. Double CSA astronaut mission assignment: Joshua Kutryk is selected as crew member for the next ISS mission, and Jenni Gibbons is selected as the Canadian backup crew member for the Artemis II mission. (Credit: CSA)

5.4 Mission Support

As the Artemis II and ISS missions progress, the CSA mission teams continue to provide comprehensive support to Jeremy, Jenni, and Joshua, as well as to their respective families. This support includes coordinating crew training, medical support, nutrition, exercise countermeasures, and human behaviour and performance initiatives to ensure the astronauts' safe and successful participation in these two missions. The mission preparations also encompass readiness for nominal and contingency operations, logistics management related to the astronauts, as well as CSA's participation in the launch and landing campaigns.

6. Conclusion

The Canadian Space Program, led by the Canadian Space Agency in Saint-Hubert, Montreal, Canada, focuses on three main areas of activity aboard the ISS: Robotics, Science and Utilization, and Human Spaceflight. Over the past five years, the Canadian government has made significant budgetary commitments to space exploration in LEO and in the cislunar environment.

Since the beginning of ISS program, Canada has played a critical role. Its extraordinary robot Canadarm2 was crucial in building the Station by assembling its various elements and modules. Since the deployment of Canadarm2 in 2001, followed by the Mobile Base System in 2002 and Dextre in 2008, the Canadian Mobile Servicing System has achieved remarkable robotic capabilities. These capabilities have been continuously upgraded due to the diversity of operations and the increasing pressure on the robots year after year. Back on Earth, ground teams have consistently collaborated and responded positively to the challenge of reaching higher levels of robotics performance. In just six years, when the ISS program concludes in December 2030, Canadarm2 will mark its 30th year of operation in space, almost double its original design life. Increased vigilance and maintenance of the robots will remain key priorities until the Station's planned deorbit in 2030.

Canada is also deeply involved in scientific research aboard the ISS. An increased number of science payloads have been commissioned over the past five years. With four ongoing investigations and three facilities currently in orbit, Canada has long established itself as a major partner in the advancement of space science. Canadian Industry, Academia, and Government have taken a leading role in studying and defining the requirements for human spaceflight in low Earth orbit and beyond. The CSA is committed to supporting numerous programs and projects until the conclusion of the ISS program.

The Canadian Astronaut Corps has completed three long-duration missions aboard the ISS. Additionally, three Canadian astronauts are currently assigned to upcoming missions and are undergoing extensive training with NASA and its partners. With the CAN4 mission, Canada will embark on its fourth long-duration mission to the ISS, and with the Artemis II flight, Canada will participate in the first crewed mission to the Moon since the 1970s.

The future of Canada's involvement in space looks promising. The coming years of space exploration will present incredible opportunities, and once again, Canada is poised to expand its influence and capabilities in space.

END-NOTE: BACKGROUND TO CANADA'S ISS CONTRIBUTION

Canada's Contribution

Canada's contribution to the ISS is the external robotics suite collectively called the Mobile Servicing System (MSS). This contribution also includes a ground segment. Between April and July 2001, Canadarm2 (or Space Station Remote Manipulator System – SSRMS), the first flight-element of Canada's contribution to the ISS, was successfully launched, installed, checked out and then used for assembly of the Station's Quest Airlock. In April 2002, the US-supplied Mobile Transporter (MT) was positioned on-orbit, paving the way for the launch that June of the next element of Canada's MSS, the Mobile Base System (MBS). The final element of the MSS is the Special Purpose Dexterous Manipulator (SPDM) – a 2-armed robot called Dextre. Dextre was launched to the ISS and assembled on-orbit in March 2008.

MSS – Space Segment

The MSS space segment includes several major elements: 2 Robotic Workstations (RWS), located inside the ISS pressurized modules; Canadarm2 (the SSRMS); the MBS, which is installed on the US-provided MT; and Dextre (the SPDM). Canadarm2 has two symmetrical booms with three joints and a latching end-effector at each end. An elbow joint connects the booms, and the overall arm is 16.9 meters long. The manipulator's 7 motorized joints give it a greater range of motion than the Canadian-designed Shuttle arm (the "Canadarm"), which had 6 joints. The symmetrical nature of Canadarm2 allows it to self relocate (or move end-over-end) from one grapple fixture to another about the ISS, as well as to operate from its mobile base. Unlike its predecessor, the Shuttle arm, Canadarm2 never returns to Earth and is designed to be maintained on-orbit. The MBS, constructed primarily of aluminum, weighs 1,450 kg and measures 5.7m×4.5m×2.9m. As its name suggests, it is the main base of operations for Canadarm2 and Dextre. It incorporates 4 Power & Data Grapple Fixtures PDGFs), which are anchor points to which Canadarm2 and Dextre can attach themselves for operations or maintenance activities. It also provides the capability to attach large payloads directly on a Payload ORU Accommodation (POA) or smaller payloads such as experiments mounted on a pallet on its MBS Common Attach System (MCAS). The MBS can provide power to its payloads while stored on its attachment systems. The MBS was installed on the US-provided MT during the STS-111/UF-2 mission in June 2002. Dextre is capable of millimetre-level precision and can install and manipulate small payloads and tools. It has 2 arms that are each 3.5m long, and each with 7 degrees of freedom. A body roll joint adds another degree of freedom for greater manoeuvrability. Dextre was officially handed over to the CSA in April 2003 and was assembled on-orbit in March 2008. It has been used for on-orbit ORU replacement operations and inspections as well as technology demonstrations. The Canadian Space Vision System (CSVS) – now retired from use – supported the Canadian-built Shuttle Remote Manipulator System (SRMS) operations. Its ISS counterpart, the Artificial Vision Unit (AVU), was used with Canadarm2 during ISS assembly. These systems incorporated a sophisticated and high speed computational process, and provided manipulator operators with precise position and orientation information by processing images from the MSS cameras. The AVUs include Pentium processors that are now being utilized for development of robotics autonomy features for the MSS and for exploration beyond LEO.

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