Canadian Space Agency

2017–18

Departmental Results Report

Supplementary Information Tables

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Details on Transfer Payment Programs of $5 Million or More

Name of transfer payment program	Contributions under the Canada/European Space Agency (ESA) Cooperation Agreement.
Start date	March 28, 2012 (ratification of the current Agreement); September 20, 2012 (approval of the revised Terms and Conditions) June 2016 (approval of revised Terms and Conditions)
End date	December 31, 2019 (end date of the latest Agreement).
Type of transfer payment	Contribution
Type of appropriation	Annually through Estimates.
Fiscal year for terms and conditions	The current revised Terms and Conditions for the contributions, under the 2012–19 Cooperation Agreement, were approved in June 2016 .
Strategic Outcome	Canada’s exploration of space, provision of space services and development of its space capacity meet the nation’s needs for scientific knowledge, innovation and information.
Link to department's Program Alignment Architecture	Program 1.3 Future Canadian Space Capacity Sub-Program 1.3.2 Space Innovation and Market Access Sub-Sub-Program 1.3.2.1 International Market Access
Description	Enhance Canadian industry’s technological base and provide access to European markets for value-added products and services in the fields of Earth observation (EO), telecommunications and

	generic technological activities; foster the participation of Canadian academia and make possible the demonstration of Canadian space technologies in European microgravity and space exploration missions and programs. This is achieved through a financial contribution by the CSA to ESA optional programs.
Results achieved	For the period of January 1, 2015, to March 31, 2018, Canada achieved a return coefficient of 106%, which is much higher than the minimum guaranteed to ESA member states (i.e. 91% at end of 2019) and the ideal value (i.e. 100%). This coefficient indicates that as a result of the Canada-ESA Agreement, Canada is successful in obtaining its fair share of ESA contracts although the period for the statistics is short. Through Canada's participation in ESA Earth Observation programs, more specifically the Earth Observation Envelope Program, Copernicus Space Component, and European Earth Watch, the CSA has continued to support Canadian companies with the development of advanced space-borne instruments and subsystems and user-oriented applications, and to ensure access to the data for Canadians. In the spring of 2017, Canada announced a new subscription of $6.5M (€4.2M) in the European Earth Watch for the Climate Change Initiative (CCI+) and the ALTIUS mission elements. Canadian scientific teams were awarded contracts under the CCI+ element to work on three new Environment Climate Variables, namely Lakes, Snow and Water Vapour. The Canadian mission ePoP has been successfully incorporated as the fourth satellite of the ESA Swarm constellation, whose objective is to make precise measurements of Earth's magnetic field. It allowed the ePoP mission three additional years of instrument operation and data collection, and it enabled a close collaboration of Canadian scientists with the European counterparts in the area of ionospheric research. The firm Communication & Power Industries LLC continued the work to supply the Klystron High Power Amplifier for Wind Scatterometer Instrument on MetOp-Second Generation satellites, the first of which is scheduled for launch in August 2022.

	The CSA has supported the development and demonstration of innovative space technologies through its participation in ESA's General Space Technology Program. For example, Neptec Design Group and NGC Aerospace will be providing critical technologies for the formation flying mission Proba 3, to be launched at the end of 2020. NGC Aerospace is also involved in the development of vision-based navigation algorithms for precise landing on the Moon and Mars. Through its partnership with ESA, the CSA has continued to position the Canadian industry and scientists in future scientific and technological developments related to the Aurora planetary exploration programs, the European Life and Physical Science (ELIPS) Program, and the new European Exploration Envelop Program (E3P). The E3P is taking over activities previously covered by ELIPS and Aurora, in order to integrate ESA's space exploration efforts into one program. Under the Aurora Program, MDA and Neptec Design Group continued the significant development of their respective rover subsystems as part of the second of two ExoMars missions, which is planned for launch in 2020. In the spring of 2017, Canada announced new subscriptions of $8.1M (€5.25M) in Aurora and $7M (€4.5M) in E3P, in order to secure Canadian industry's participation in the European space exploration program. Canada's participation in the European Advanced Research in Telecommunications Systems (ARTES) has continued to allow our industry to access forward-looking studies on new telecommunications services, and to develop new satellites, technologies, equipment and applications. The additional contribution to ARTES made at the 2016 ESA Council meeting at Ministerial level, which included a supplementary $30M announced in Budget 2016 for that program, resulted in many important contracts to Canadian industry. For example, MacDonald, Dettwiler and Associates (MDA) is developing and providing antennas for the OneWeb megaconstellation and is also involved in the European Data Relay System (EDRS) Global project, a public private partnership with ESA and Airbus. Other examples include Honeywell's development on Q/V Band High Power Devices, MPB's SMART Optical Amplifier for the European TESAT satellite

	supplier, Optelian's Optical Polarization Modulator development and Xiphos Technology providing major subsystems for the IODA platform. Finally, Canada joined the new Navigation Innovation and Support Program (NAVISP) in the spring 2018 with a subscription of $3.1M (€2.0M). It will provide Canadian companies with the opportunity to bid on tenders as part of this program.
Comments on variances	The variance of $5.1 million is due to the increase in payments, in accordance with the budgetary feasibility principle governing member states' and Canada's contributions to ESA, against Canada's binding multiyear legal obligations with respect to its participation in ESA optional programs.
Audits completed or planned	N/A
Evaluations completed or planned	The program evaluation covering the period from April 2009 to December 2014 was completed and approved by the President on July 23, 2015. A program evaluation covering the period from April 1, 2013, to March 31, 2018, began in December 2017 and is expected to be completed in October 2018. The results of this evaluation will complement the evaluations undertaken in 2010 and 2015.
Engagement of applicants and recipients	The CSA actively consulted the Canadian space sector (i.e. both industry and academia) and Government of Canada (GoC) organizations as part of the program selection process in preparation for the 2012 ESA Ministerial Council meeting during which ESA member states and Canada announced their position on contributions to the proposed ESA Programs. Similar consultations are planned for the ESA Ministerial Council meeting planned for November 2019.

Performance Information (dollars)

Contributions under the Canada/European Space Agency (ESA) Cooperation Agreement.						
Type of Transfer payment	**2015–16 Actual spending**	**2016–17 Actual spending**	**2017–18 Planned spending**	**2017–18 Total authorities available for use**	**2017–18 Actual spending (authorities used)**	**Variance (2017–18 actual minus 2017–18 planned)**
Total contributions	27,802,596	34,498,797	36,648,000	41,766,523	41,766,413	5,118,413
Total program	**27,802,596**	**34,498,797**	**36,648,000**	**41,766,523**	**41,766,413**	**5,118,413**

Name of transfer payment program	Class Grant and Contribution Program to Support Research, Awareness and Learning in Space Science and Technology.
Start date	October 1, 2009
End date	N/A – Ongoing program
Type of transfer payment	Grant and Contribution
Type of appropriation	Annually through Estimates
Fiscal year for terms and conditions	2009–10
Strategic Outcome	Canada's exploration of space, provision of space services and development of its space capacity meet the nation's needs for scientific knowledge, innovation and information.
Link to department's Program Alignment Architecture	Program 1.1 Space Data, Information and Services Sub-Program 1.1.1 Earth Orbit Satellite Missions and Technology Sub-Sub-Program 1.1.1.3 Scientific Missions Sub-Program 1.1.2 Ground Infrastructure Sub-Sub-Program 1.1.2.2 Data Handling Sub-Program 1.1.3 Space Data, Imagery and Services Utilization Development Sub-Sub-Program 1.1.3.1 Earth Observation Data and Imagery Utilization Program 1.2 Space Exploration Sub-Program 1.2.1 International Space Station Sub-Sub-Program 1.2.1.2 International Space Station Utilization Sub-Program 1.2.2 Exploration Missions and Technology Sub-Sub-Program 1.2.2.1 Space Astronomy Missions Sub-Program 1.2.3 Human Space Missions and Support Sub-Sub-Program 1.2.3.3 Health and Life Sciences Program 1.3 Future Canadian Space Capacity Program Sub-Program 1.3.1 Space Expertise and Proficiency Sub-Program 1.3.2 Space Innovation and Market Access Sub-Sub-Program 1.3.2.2 Enabling Technology Development

Description	This program supports knowledge development and innovation in the CSA's priority areas while increasing the awareness and participation of Canadians in space-related disciplines and activities. The program has two components: 1. Research 2. Awareness and Learning The Research component aims to support the development of science and technology; foster the continual development of a critical mass of researchers and highly qualified people in Canada; and support information gathering and space-related studies and research pertaining to Canadian Space Agency priorities. The Awareness and Learning **c**omponent aims to provide learning opportunities to Canadian students in various space-related disciplines; to support the operations of organizations dedicated to space research and education; and to increase awareness of Canadian space science and technology among Canadian students and their participation in related activities.
Results achieved	In 2017–18, Canadian universities and for-profit and not-for-profit organizations established and operating in Canada made significant contributions to knowledge creation in space science and technology priority areas through 11 new Announcements of Opportunity (AOs) posted on the CSA's website, resulting in 100 new supported research projects. For more information regarding these initiatives consult the Programs Results Section of the DRR. Global Results: The annual Web-based follow-up project survey showed results of 506 publications among which 75% were peer reviewed and 1052 presentations among which 158 were presentations on making space science and technology more readily understandable for the general public and 217 other outreach / general scientific awareness activities. 1772 research team members were involved in the supported initiatives representing 600 persons per year in terms of Full-Time Equivalents (FTE). From these Highly Qualified Personnel (HQP), 443 were faculty members, 595 were students and post-doctoral

	fellows and 265 were technicians and other research team members. A total of 213 research organizations have been involved in the funded projects (i.e. 60% universities, 17% foreign research organizations, 16% private sector and 7% other). 69% of research partners are international and 31% are national.
Comments on variances	Grants: Due to delays in granting agreements, some of the expenditures planned for 2017–18 will be incurred in 2018–19. Contributions: The variance is mainly due to the decreased expenditures resulting from delays in Space Technology Development projects.
Audits completed or planned	2019-20 planned
Evaluations completed or planned	2020-21 planned
Engagement of applicants and recipients	Since January 2012, an initiative to engage recipients has been undertaken through an automated annual follow-up of projects. The Agency has extended this initiative in order to establish a dialogue with potential applicants and recipients. Consultations, presentations to, and discussions with, the academic and industrial communities as well with other potential recipient groups, are ongoing and will continue.

Performance Information (dollars)

Class Grant and Contribution Program to Support Research, Awareness and Learning in Space Science and Technology						
Type of Transfer payment	**2015–16 Actual spending**	**2016–17 Actual spending**	**2017–18 Planned spending**	**2017–18 Total authorities available for use**	**2017–18 Actual spending (authorities used)**	**Variance (2017–18 actual minus 2017–18 planned)**
Total contributions	6,263,510	9,146,442	13,001,000	10,523,859	10,507,215	(2,493,785)
Total other types of transfer payments	10,501,603	11,870,329	11,317,000	8,675,618	8,674,322	(2,642,678)
Total program	**16,765,113**	**21,016,771**	**24,318,000**	**19,199,477**	**19,181,537**	**(5,136,463)**

Fees

Owing to legislative changes, the 2017 to 2018 fees results will be published in a separate report. The Fees Report is currently under development, and the link to the Fees Report, once tabled in Parliament, will appear on this web page by March 31, 2019.

Evaluations

Evaluations completed, or planned to be completed, in 2017–18

Title of evaluation	Link to the department's Program Alignment Architecture	Status on March 31, 2018	Deputy head approval date*
Evaluation of the Earth Observation Business Line of the Canadian Space Agency	1.1.1.1. Earth Observation Missions 1.1.2. Ground Infrastructure 1.1.3.1 Earth Observation Data and Imagery Utilization	Completed	July 2017
Evaluation of the Canadian Space Agency Space Expertise and Proficiency Sub-Program	1.3.1. Space Expertise and Proficiency	Completed	July 2017
Evaluation of the Space Astronomy Missions and Planetary Missions Programs	1.2.2.1. Space Astronomy Missions 1.2.2.2. Planetary Missions	Completed	March 2018

Internal audits

Internal audit engagements completed in 2017–18

Title of internal audit	Completion date
Audit of the Management Framework of the Canadian Space Agency's Ground Infrastructure Subprogram	September 2017
Audit of the Management Framework of the Canadian Space Agency's Space Astronomy and Planetary Missions Program	December 2017

Response to parliamentary committees and external audits

Response to parliamentary committees

There were no parliamentary committee reports requiring a response in 2017–18.

Response to audits conducted by the Office of the Auditor General of Canada (including audits conducted by the Commissioner of the Environment and Sustainable Development)

There were no recommendations for the Canadian Space Agency.

Response to audits conducted by the Public Service Commission of Canada or the Office of the Commissioner of Official Languages

There were no recommendations for the Canadian Space Agency.

Status report on projects operating with specific Treasury Board approval

Project name and project phase	Original estimated total cost (dollars)	Revised estimated total cost (dollars)	Actual total cost (dollars)	2017–18 Main Estimates (dollars)	2017–18 Planned spending (dollars)	2017–18 Total authorities (dollars)	2017–18 Actual spending (dollars)	Expected date of close-out
1.1 Space Data, Information and Services								
RADARSAT-CONSTELLATION MCP EPA	600,000,000	1,089,510,532	988,660,771	67,079,896	83,705,095	87,032,828	75,640,928	2020-2021
MARITIME MONITORING AND MESSAGING MICROSATELLITE (M3MSAT) EPA	5,404,000	16,653,419	15,274,488	0	0	65,410	65,373	2017-2018
SURFACE WATER & OCEAN TOPOGRAPHY (SWOT-C)	8,496,507	9,963,696	4,878,040	1,824,905	2,095,905	2,438,843	857,424	2021-2022
1.2 Space Exploration								
OSIRIS-REx LASER ALTIMETER (OLA) EPA	26,696,400	35,760,462	35,760,462	0	48,000	63,156	63,156	2017-2018
JAMES WEBB SPACE TELESCOPE MCP (JWST) EPA	67,160,000	172,860,953	169,213,011	1,315,325	1,870,871	2,300,239	1,384,686	2021-2022
MOBILE SERVICING SYSTEM REPLACEMENT CAMERA (MSS RCAM)	15,465,270	19,145,825	16,466,228	2,339,100	2,339,100	1,283,109	1,274,103	2019-2020
DEXTRE DEPLOYABLE VISION SYSTEM (DDVS)	23,351,302	22,126,990	6,196,110	8,080,817	9,455,817	7,793,690	3,560,998	2021-2022
LIFE SCIENCE RESEARCH SYSTEM (LSRS)	15,268,161	16,748,151	12,579,731	6,476,059	7,790,843	7,788,005	7,097,176	2019-2020

Project name and project phase	Original estimated total cost (dollars)	Revised estimated total cost (dollars)	Actual total cost (dollars)	2017–18 Main Estimates (dollars)	2017–18 Planned spending (dollars)	2017–18 Total authorities (dollars)	2017–18 Actual spending (dollars)	Expected date of close-out
1.4 Internal Services								
DAVID FLORIDA LABORATORY INFRASTRUCTURE ACCELERATED REFIT (DFL-IAR)	12,022,802	13,544,547	9,525,016	4,365,000	7,811,805	8,630,713	6,170,091	2019-2020

Note: dollar amounts exclude both the goods and services tax (GST) and the harmonized sales tax (HST).

Status report on transformational and major Crown projects

General information

Project name	RADARSAT Constellation Mission (RCM)
Description	The RADARSAT Constellation Mission (RCM) is the next generation of Canadian Earth observation (EO) radar satellites. RADARSAT-1 was launched in 1995 and continued its operation until March 2013. RADARSAT-2, developed by the private sector in partnership with the Government of Canada (GoC), was launched in 2007 for a seven-year mission, but given its current performance, it is expected to remain operational for several more years. Canada has established itself as a leading global supplier of C-band satellite radar data for EO. The successor mission to RADARSAT-2, the RCM will maintain the leadership and position of Canadian industry in space radar technology and value-added product markets. The RCM is comprised of three identical satellites. The launch of the constellation is planned for 2018. With a constellation, the time between successive imaging of a specific point on Earth is significantly reduced from 24 to four days. The creation of a three-satellite constellation will increase the frequency of available information, as well as the reliability of the system, making it better suited to the requirements of operations of both public and private users. The scope of the RCM Major Crown Project includes the requirement definition, design, development, manufacturing, integration, testing and launch of the satellites as well as the design, development, manufacturing and installation of the associated ground segment. One year of operation of the three-satellite constellation is also included as well as an application development program. The RCM will provide reliable data in all weather and illumination conditions in support of federal departments' operations and mandates in areas such as maritime surveillance, disaster management, environmental monitoring and natural resource

	management. The satellite constellation will provide average daily coverage capacity of most of Canada and its surrounding waters. In the North, the constellation will provide two to three times daily coverage capacity of the Arctic and the Northwest Passage. In support of the maritime surveillance requirements of federal departments, the RCM is the principal data source envisaged for wide-area surveillance of Canada's remote areas and marine approaches. Only satellite data can offer regular cost-effective information to task ships and aircraft in order to intercept suspicious vessels. The daily coverage of marine areas will also support fisheries monitoring, ice and icebergs monitoring, pollution monitoring, and integrated ocean and coastal zone management. The RCM's maritime surveillance capabilities also support Canadian sovereignty and security. The RCM satellites will be able to capture ship-originated Automatic Identification System (AIS) signals from space. The combination of space-based radar images and AIS signals will provide a powerful surveillance capacity over Canada's maritime approaches and elsewhere in the world. In support of disaster management, both in Canada and around the world, the RCM will provide critical and timely data to support disaster mitigation, warning, and response and recovery activities, while helping Canada meet its obligations with respect to international disaster relief. The types of disasters for which RCM data will be used for monitoring and relief purposes include floods, oil spills, volcanic eruptions, earthquakes and hurricanes. In support of environmental monitoring, the RCM will provide data for wide-area change detection in order to provide support for activities such as water monitoring, wetlands mapping, coastal change monitoring and changes in the permafrost in northern Canada. RCM data will contribute to the production of more accurate weather forecasts and warnings pertaining to marine conditions, winds, severe storms and floods. In support of natural resource management, RCM data will be a critical source of information to monitor the changing state of Canada's

	agricultural areas, forests and wildlife habitats. RCM data will also be used in the mining and energy sectors for resource exploration operations to ensure that critical infrastructure is monitored properly for safety and integrity. In addition, the RCM will sustain the development of Canadian high-technology design and manufacturing capabilities and the integration of satellite data into information products and services. Canada's space and geomatics industries will benefit from better positioning in international markets and privileged access to data deemed essential by many international users.
Project outcomes	This Major Crown Project (MCP) contributes to Program 1.1 Space Data, Information and Services, which includes the provision of space-based solutions and the progression of their utilization. It also serves to install and run ground infrastructure that processes the data and operates satellites. This Program utilizes space-based solutions to assist Government of Canada (GoC) organizations in delivering growing, diversified and cost-effective programs and services within the purview of their respective mandates, each related to key national priorities such as sovereignty, defence, safety and security, resource management, environmental monitoring and the North. It also provides academia with data required to perform its own research. The contribution of the MCP to the program objectives is measured through the Performance Measurement Framework (PMF) (i.e. Program Alignment Architecture (PAA) results and performance indicators). Program 1.1 Space Data, Information and Services Result: Government of Canada (GoC) organizations offer more diversified or cost-effective programs and services due to their utilization *of space-based solutions.* *Performance Indicator* #1: Number of new GoCs programs offering more diversified or efficient services. Sub-Program 1.1.1 Earth Orbit Satellite Missions and Technology

	Result: GoC organizations are using space-based data to deliver their mandate. Performance Indicator #1: Number of GoC programs using space data or derived information to deliver their mandate. Performance Indicator #2: Percentage of RADARSAT data used in program delivery.
Industrial benefits	The RCM is expected to generate significant industrial benefits in the space and Earth Observation sectors, such as employment, economic growth and improved productivity. Investments in RCM also support the growth of small and medium-sized companies as well as Canadian capabilities in terms of infrastructure and services. The prime contract includes a requirement for 70% Canadian content, excluding launch services and subsystems for which there are no suppliers available in Canada. As of September 30, 2017 (the latest date for which data is available) this corresponds to a Canadian content requirement of $485.2 million. For the same period, the CSA had provided the Canadian industry with funding of more than $575.3 million to carry out work resulting directly from the design of the RCM MCP, thus surpassing the requirement. The prime contract also requires that 3.5% of the 70% Canadian content be subcontracted in the Atlantic Canada region. For the same period, the actual Atlantic Canadian content was $22.6 million, considerably higher than the requirement of $17.0 million. The prime contract includes reporting obligations and performance measurements as well as financial penalties for not meeting the minimum Atlantic Canada content requirement.
Sponsoring department	Canadian Space Agency (CSA)
Contracting authority	Public Services and Procurement Canada (PSPC)

Participating departments	Agriculture and Agri-Food Canada Canadian Coast Guard Environment and Climate Change Canada Canadian Ice Service Fisheries and Oceans Canada Global Affairs Canada Indigenous and Northern Affairs Canada Innovation, Science and Economic Development Canada National Defence and the Canadian Armed Forces Natural Resources Canada Parks Canada Public Safety Canada Royal Canadian Mounted Police Statistics Canada Transport Canada
Prime contractor	MDA Systems Ltd. (a division of MacDonald, Dettwiler and Associates), Richmond, British Columbia
Major subcontractors	Tier 1 Major Subcontractors: - MDA Montreal, Ste-Anne-de-Bellevue, Quebec - Magellan Aerospace, Winnipeg, Manitoba - MDA, Halifax, Nova Scotia - SpaceX, Hawthorne, California, USA - Airbus Defence and Space, United Kingdom - Honeywell Aerospace, United Kingdom

	Tier 2 and Tier 3 Canadian Subcontractors: - Stelia Aerospace North America, Lunenburg, Nova Scotia - IMP Group, Halifax, Nova Scotia - DRS, Ottawa, Ontario - Mecachrome, Mirabel, Quebec - Maya, Montreal, Quebec
Project phase	Phase D – Implementation
Major milestones	Phase A: Requirement Definition (March 2008) Phase B: Preliminary Design (March 2010) Phase C: Detailed Design Review (November 2012) Phase D: Launch satellite #1, #2, and #3 (2018) Phase E1: Operations (part of MCP) (2020) Phase E2: Operations (not part of MCP) (2026)
Progress report and explanation of variances	On December 13, 2004, the Domestic Affairs Committee of Cabinet granted approval-in-principle to a 10-year program to implement a RADARSAT Constellation Mission (RCM) aimed at addressing the operational needs of users from the public and private sectors in relation to Canadian sovereignty and marine surveillance, environmental monitoring and change detection, and disaster management. The RCM would be government-owned and operated. On June 6, 2005, Treasury Board granted Preliminary Project Approval (PPA) for the RCM and expenditure authority for the Project Initial Planning and Identification (i.e. Phase A). During Phase A, feasibility studies were completed, user requirements were defined, and risk mitigation activities and options analysis for the bus and payload were carried out. The initial scope of work for Phase A was completed in December 2006. Phase A was then extended to allow additional technical risk reduction activities to continue during the

	period prior to the Phase B contract award. This was completed in March 2008. In March 2007, Treasury Board approved a revised PPA submission to proceed to Phases B and C. Following a competitive Request for Proposal (RFP) process, PWGSC obtained authority to enter into negotiations with MDA, the prime contractor, and awarded the contract for Phase B in November 2008. The Preliminary Design (i.e. Phase B) was completed in March 2010. The contract for Phase B was subsequently amended to include the detailed design (i.e. Phase C). A second revised PPA was approved by Treasury Board in December 2010. The purpose of this revised PPA was to provide additional expenditure authority to include the procurement of long-lead items during Phase C and also to include a technology demonstration for Automatic Identification System (AIS) payloads, funded by the National Defence. The final review of the overall mission-level system detailed design, the Mission Critical Design Review (CDR), was conducted in November 2012. A selected set of activities, such as completing the design qualification activities and the procurement of long-lead items, pursued under Phase C were completed in November 2015. These selected activities were scheduled to be completed in March 2014 but were delayed due to technical difficulties encountered during the building of the qualification models. The delay has no impact on the project. Treasury Board granted Effective Project Approval for the RCM in December 2012, which provides expenditure and contracting authorities to complete the project and carry out the first year of RCM operations (Phases D and E1). The contract was awarded on January 9, 2013. Since contract award, planning activities were completed and major milestones achieved to initiate the implementation phase of the satellites and associated ground system. In 2013, a Deputy Ministers' Governance Committee (DMGC) was established to provide oversight, coordination and accountability on

	the RCM MCP. The DMGC reports to the Minister of Innovation, Science and Economic Development and provides strategic direction while making timely decisions to address issues and risks that could affect the success of the MCP. Significant progress continued in the manufacturing of the RCM satellites throughout 2016–17. Assembly, integration and testing of the last of the three synthetic aperture radar (SAR) and automatic identification system (AIS) payloads were completed, and the payloads were delivered. Challenges in completing the flight software were addressed. Assembly and integration of the first satellite were completed, and its testing is well underway. Assembly, integration and testing of the second satellite have started. Assembly, integration and testing of the third satellite will start once the third satellite bus is completed and delivered early in 2017–18. Three of the eight ground segment subsystems were completed. Upgrades to the CSA headquarters in Saint-Hubert to accommodate the RCM ground segment also progressed significantly. The launch dispenser was completed and, as the scheduled launch date approaches, the period of the launch event was narrowed from twelve months to three months (July 17, 2018, to October 14, 2018). Significant progress continued in the manufacturing of the RCM satellites throughout 2017–18. Assembly, integration and testing of the last satellite bus was completed and delivered. The three satellites have progressed to a state of completion of 87%, 61% and 41% respectively. All of the ground segment subsystems were delivered to and integrated into the Primary Control Facility in Saint-Hubert, Quebec. Upgrades to the CSA headquarters in Saint-Hubert to accommodate the RCM ground segment were also completed in time for the arrival of the ground segment subsystems. Significant progress was also achieved in finalizing the Data Policy. A provisional Operating Licence was issued by Global Affairs Canada. The period of the launch event was narrowed from three months to 30 days (October 30, 2018, to November 29, 2018).

Project name	James Webb Space Telescope
Description	The James Webb Space Telescope is a joint international mission involving National Aeronautics and Space Administration (NASA), the European Space Agency (ESA) and the Canadian Space Agency (CSA). The mission concept is for a large field-aperture telescope to be located 1.5 million km from Earth. Like Hubble, the James Webb telescope will be used by the astronomy community to observe targets ranging from objects within our solar system to the most remote galaxies which can be seen during their formation in the early universe. The science mission is centred on the quest to understand our origins: • Observing the very first generation of stars to illuminate the dark universe when it was less than one billion years old; • Understanding the physical processes that have controlled the evolution of galaxies over cosmic time and, in particular, identifying the processes that led to the assembly of galaxies within the first four billion years after the Big Bang; • Understanding the physical processes that control the formation and early evolution of stars in our own and other nearby galaxies; and • Studying the formation and early evolution of proto-planetary disks, and characterizing the atmospheres of isolated planetary mass objects. The James Webb telescope is currently planned to launch in 2018. James Webb instruments will be designed to work primarily in the infrared range of the electromagnetic spectrum, with some capability in the visible range. The James Webb telescope will have a large mirror, 6.5 metres in diameter and a sun shield that will be the size of a tennis court once deployed in outer space. Canada is providing the Fine Guidance Sensor (FGS) and the Near-Infra-Red Imager and Slitless Spectrometer (NIRISS). The FGS is integral to the attitude control system of the James Webb telescope,

	and consists of two fully redundant cameras that will report precise pointing information. Canadian expertise in this area was established previously with the successful fine error sensors for the former Far Ultraviolet Spectroscopic Explorer (FUSE) mission. Packaged with the FGS but functionally independent, the NIRISS covers the 0.7 to 5 micrometer spectral range. NIRISS provides a specialized capability for surveys of objects such as primeval galaxies, for the study of transiting planetary systems and for high-contrast imaging applications such as the detection of extra-solar planets. With COM DEV Canada as the prime contractor, the James Webb Space Telescope-FGS Major Crown Project consists of the design, development, testing and integration into the spacecraft, launching and commissioning of the FGS and NIRISS. By participating in this leading-edge international space exploration mission, the CSA is actively promoting Canadian scientific expertise and innovative, advanced space technologies. The National Research Council's Herzberg Astronomy and Astrophysics (NRC Herzberg) is a key Government of Canada (GoC) partner for activities related to the development of science instruments and distribution of telescope data. In return for its overall investment in the James Webb telescope, Canada will obtain a minimum of 5% of the time on this unique space telescope. Already, the news of Canada's involvement in this international space exploration mission is inspiring youth, educators and amateur astronomers, and rallying members of Canada's world-renowned astrophysics community.
Project outcomes	This MCP contributes to Program 1.2 Space Exploration which provides valuable Canadian science, signature technologies and qualified astronauts to international space exploration endeavours. It fosters the generation of knowledge as well as technological spin-offs that contribute to a higher quality of life for Canadians. This Program appeals to the science and technology communities. It is targeted mostly towards Canadian academia and international space exploration partnerships. Canadian industry also benefits from the work generated within this Program. The contribution of the MCP to

	the program objectives is measured through the Performance Measurement Framework (PMF) (Program Alignment Architecture (PAA) results and performance indicators). Program 1.2 Space Exploration Result #1: Expansion of advanced scientific knowledge acquired through space exploration endeavours. Performance Indicator #1: Number of peer-reviewed scientific publications, reports and conference proceedings using space exploration information and produced by researchers (sciences and technologies) in Canada. Result #2: Multiple use and applications of knowledge and know-how acquired through space exploration endeavours. Performance Indicator #1: Number of terrestrial applications of knowledge and know-how acquired through space exploration endeavours. Performance Indicator #2: Number of space re-utilizations of knowledge and know-how acquired through space exploration endeavours. Sub-Program 1.2.2 Exploration Missions and Technology Result #1: Technological know-how is acquired through Space Exploration endeavours (Astronomy and Planetary). Performance Indicator #1: Proportion of the CSA missions/solutions/instruments that met their mission performance requirements at acceptance review and/or at commissioning. Result #2: Canada maintains a strategic positioning which supports its capacity to influence space exploration missions and decision-making processes in key international space exploration forums.

	Performance Indicator #1: Number of CSA sponsored highly qualified personnel (HQP) nominated on the International Space Exploration decision bodies. Result #3: CSA's participation in space exploration missions provides access to scientific data about the Solar System and the Universe. Performance Indicator #1: Number of CSA's sponsored space astronomy and planetary missions providing data to Canadian scientific community.
Industrial benefits	Most of the direct industrial benefits from the construction of the Webb-FGS and NIRISS system will accrue to Ontario.
Sponsoring department	Canadian Space Agency (CSA)
Contracting authority	Public Services and Procurement Canada (PSPC)
Participating departments	NRC Herzberg Astronomy and Astrophysics Innovation, Science and Economic Development (ISED)
Prime contractor	- Honeywell Aerospace, Ottawa, Ontario
Major subcontractors	- Teledyne, USA - Corning Netoptix, USA - IMP Aerospace Avionics, Canada - ABB Bomem, Canada - MDA, Canada - INO, Canada - BMV, Canada - CDA Intercorp, USA - ESTL, Europe - Bach Research Corporation, USA

	- Materion, USA - Camcor, Canada
Project phase	Phase D – Implementation
Major milestones	Phase A: Requirement Definition (2004) Phase B: Preliminary Design (May 2005) Phase C: Detailed Design (September 2008) Phase D: Manufacturing/Assembly, Integration/Testing, Pre-launch preparations, Launch/System Commissioning (March 2021) Phase E: Operations (part of MCP) (2026)
Progress report and explanation of variances	In March 2004, Treasury Board granted Preliminary Project Approval for Phases B, C and D. In December 2006, before the completion of Phase C, detailed design of the FGS, the CSA requested increased expenditure authority to complete the project. In February 2007, the Treasury Board granted Effective Project Approval (EPA) and the project became a Major Crown Project (MCP). In March 2007, the first Critical Design Review (CDR) for the guidance function of the FGS revealed technical issues. During the preparation of the system-level CDR, new issues became apparent. The technical issues needed to be addressed. In December 2007, Treasury Board granted a revised EPA after project costs had raised significantly due to technical issues by the end of Phase C, the detailed design phase. In 2010, NASA discovered that the infrared detectors, extremely sensitive cameras capable of “seeing” light produced by heat, were showing signs of performance degradation due to a design fault. Following investigation, NASA concluded that all detectors, including the four procured by Canada, needed to be replaced. In effect, two years after their acceptance by the project, the detectors started to show the same degradation. NASA initiated an improvement project

	with Teledyne Scientific & Imaging LLC to address the design issue causing the degradation. In 2011–12, work continued on hardware and software development. COMDEV Canada worked on the Proto Flight Model (PFM) which successfully completed a very stringent environmental test campaign during which the instrument was subjected to cryogenic temperatures over a period of 80 continuous days. Teledyne Scientific & Imaging LLC completed the detector design improvements and, pursuant to testing successfully addressed the degradation issues. NASA then initiated the procurement process for new detectors for the James Webb telescope Mission; the acquisition of the detectors for the FGS/NIRISS was under the responsibility of the CSA. The FGS Engineering Test Unit (ETU) was integrated into the NASA Goddard Space Flight Center (GSFC) test set-up and underwent system-level testing with the other science instrument engineering units. The integration test onto the Integrated Science Instrument Module (ISIM) of the James Webb telescope was successfully conducted. A technical issue surfaced with a component, the Tunable Filter Instrument (TFI), which triggered the need for a change in the design approach and led to the design and development of the Near-Infrared Imager and Slitless Spectrograph (NIRISS). This new instrument relied on existing components of the old TFI but used a different approach to cover the light spectrum required for the science mission. On July 30, 2012, the PFM FGS/NIRISS was delivered to NASA GSFC. On November 15, 2012, the PFM FGS/NIRISS was officially accepted by NASA following the successful completion of post-delivery functional tests. The FGS/NIRISS was the first instrument officially accepted by NASA as part of the James Webb Space Telescope project. As to the procurement of the four new detectors for FGS/NIRISS, the CSA and NASA agreed on cost sharing: NASA would manage the procurement with Teledyne Scientific & Imaging LLC until the

	detectors are completed at which point they would be procured off-the-shelf by the CSA (through PWGSC). In August 2013, NASA initiated a cryogenic test campaign with the Integrated Science Instrument Module (ISIM). The test was completed in November 2013, and the FGS/NIRISS performed as expected. The second cryogenic test campaign was conducted in 2014–15 as the integration and test activities at NASA with ISIM continued. As well, in 2014, the FGS/NIRISS detectors were replaced after the completion of the second cryogenic test campaign. The launch date for the James Webb telescope is currently planned for May 2020. In 2007, when the project obtained Treasury Board approval for the revised EPA, the anticipated mission launch date was May 2013. Following a re-planning exercise conducted by NASA, the launch date was slipped to October 2018, extending the project life by 5.5 years. There was an associated cost increase in the mission's integration and test phase, due to NASA having originally underestimated the work needed for this phase. The scope of work remaining to be completed for this project is as follows: Although the flight instrument has now been delivered, the project is still in the implementation phase where support must be provided for the integration of the FGS/NIRISS to the spacecraft, for the launch activities and for the spacecraft commissioning activities. With all the integration and test activities at NASA having been delayed and the duration of these activities revised under the NASA replan, the CSA and COM DEV are required to provide direct engineering post-delivery support to NASA for FGS/NIRISS and to the James Webb mission commissioning activities from 2014 up until March 2021. Official mission operations will commence after the completion of the telescope's commissioning, six months after its launch. The James Webb telescope operations centre will be located in the Space Telescope Institute in Baltimore, Maryland, in the United States. Canadian scientists will be on location to directly support the

	operations of the FGS and NIRISS throughout the mission's operations. The operations will also be supported by engineering staff in order to be able to address technical issues if and when they occur to ensure the functionality of Canada's instruments. Ultimately this remaining scope of work and the extension of the mission schedule resulted in cost increases that could not be absorbed by the 2007 project authorities. As well, PWGSC needed contractual authorities for acquiring the new detectors under a sole-source contract with a US supplier. As a result, the CSA prepared a new submission to Treasury Board addressing the issues above. The submission was approved in February 2014. Treasury Board granted a revised EPA of $169.9 million (excluding taxes). In January 2016, NASA completed the third and final cryogenic test campaign of ISIM at NASA's GSFC. During this test campaign, the FGS/NIRISS performed as expected, thus successfully closing the final performance verification of Canada's contribution to the James Webb Space Telescope. In March 2016, NASA entered the next level of spacecraft integration and testing with the joining of ISIM and the Optical Telescope Element to form the OTIS (Optical Telescope element and Integrated Science instrument module). In 2016–17, the Integrated Science Instrument Module (ISIM) was integrated with the Optical Telescope and the new assembly (nicknamed OTIS, which stands for Optical Telescope and Science Instruments) underwent a series of rigorous environmental testing, comprised of ambient functional, vibration and acoustic testing, at NASA Goddard Space Flight Center in Maryland. The FGS/NIRISS team has supported these tests and prepared for the OTIS cryogenic tests planned for the summer of 2017. In May 2017 the OTIS module was shipped to the NASA Johnson Space Center where it went through a series of cryogenic vacuum tests designed to ensure the telescope functioned as expected in an extremely cold, airless environment akin to that of space. These tests, which lasted about 100 days, were completed successfully in November 2017, with flawless performance from the Canadian instruments FGS and NIRISS. In February 2018 the OTIS was shipped

	to Northrop Grumman Aerospace Systems (NGAS) in California, where it will be integrated with the spacecraft element to form the complete James Webb Telescope Observatory. Although the OTIS module testing was completed successfully and on schedule, in 2017–18 the James Webb Space Telescope mission saw significant delays. On September 28, 2017, NASA announced that the launch planned for October 2018 was delayed until the spring of 2019, due to a combination of some integration activities on the spacecraft bus and sunshield at NGAS taking longer than planned and the integration of lessons learned from earlier testing. Then, after an independent assessment of the remaining integration and test tasks, on March 27, 2018, NASA announced a further launch delay to approximately May 2020. A more specific launch time frame will be defined by an independent review board which will provide an assessment to the US Congress in the summer of 2018.