



Evaluation of the International Market Access Program (Comprising the European Space Agency Contribution Program) of the Canadian Space Agency

For the period from April 2009 to December 2014

Project # 14/15 – 02-02

Prepared by the Audit and Evaluation Directorate

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Acronyms Used in the Report

ACNS	Altitude Control and Navigation System
APLS	Autonomous Planetary Landing System
ARLU	Annual Reference Level Update
ARTES	Advanced Research in Telecommunications Systems
ARV	Advanced Re-entry Vehicle
CCMEO	Canadian Centre for Mapping and Earth Observation
CNES	Centre national d'études spatiales
CRC	Communications Research Canada
CSA	Canadian Space Agency
DFATD	Department of Foreign Affairs, Trade and Development
DLR	Deutsches Zentrum für Luft
DSA	Deep Space Antenna
DVB-RCS	Direct Video Broadcast Technology
ECG	Evaluation Consultative Group
EGEP	European GNSS Evolution Programme
ELIPS	European Programme for Life and Physical Sciences
EO	Earth Observation
EOEP	Earth Observation Envelope Programme
ESA	European Space Agency
EU	European Union
FTE	Full-time Equivalent
GDP	Gross Domestic Product
GloNASS	Global Navigation Satellite System
GMES	Global Monitoring for Environment and Security
GNC	Guidance and Navigation Control
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GSTP	General Support Technology Programme
HME	Human Microgravity and Exploration
HQP	Highly Qualified Personnel
IMAP	International Market Access Program
ISRO	Indian Space Research Organization
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
JAXA	Japanese Aerospace Exploration Agency
LELR	Lunar Exploration Light Rover

MREP	Mars Robotic Exploration Preparation
MS	Member State
NASA	National Aeronautics and Space Agency
NRCan	Natural Resources Canada
OECD	Organisation for Economic Co-operation and Development
OGD	Other Government Department
OIC	Order in Council
O&M	Operations and Maintenance
PM	Performance Measurement
R&D	Research and Development
RFP	Request for Proposal
SAR	Synthetic Aperture Radar
SBAS	Space-based Augmentation System
SST	Space Science and Technology
STDP	Space Technology Development Program
TBS	Treasury Board Secretariat
TRL	Technology Readiness Level
TRP	Technology Research Programme
UK	United Kingdom

Executive Summary

Background

This report presents the findings of the Evaluation of the International Market Access Program (IMAP), comprising the European Space Agency (ESA) Contribution Program, administered by the Canadian Space Agency (CSA).

Formal Canada/ESA cooperation started in 1979 with the signing of the first Canada/ESA Cooperation Agreement, which has been renewed four times since then (in 1984, 1989, 2000 and 2012). The Canada/ESA Cooperation Agreement is an international treaty, i.e., an instrument bound under international law.

ESA is an international organization headquartered in Paris and is composed of 22 Member States (MS) and five Cooperating States, with Canada being the only non-European Cooperating State.

Through the Canada/ESA Cooperation Agreement, Canada benefits from the unique privilege of being the only non-Member State with direct participation in ESA programmes, thus allowing Canadian organizations to bid on tenders for ESA programmes in which Canada participates. Canada is also the only non-Member State involved in the decision-making process for ESA programmes.

The primary objective of Canada's cooperation with ESA is “enhancing the competitiveness of the Canadian space sector through the development of leading edge technologies and products.” More specifically, the objectives are to:

- Foster innovation and competitiveness by exposing Canadian space organizations to ESA programmes and activities dedicated to developing space technologies, applications and hardware;
- Maintain or increase the capability of the domestic space sector to successfully contribute to Canadian space endeavours by providing access to ESA space flight opportunities in order to demonstrate and qualify Canadian space technologies and hardware;
- Facilitate access to European public space markets as well as to global space public and private markets, when applicable; and,
- Acquire and maintain awareness of the directions of European space policies and of the European space technological, scientific, programmatic and commercial environments to feed the CSA strategic planning process.

In addition, Canadian participation in ESA programmes may:

- Facilitate the participation of Canadian scientists in ESA missions; and
- Facilitate access to ESA's data and/or infrastructure to academia and government departments/agencies.

The evaluation study was conducted between April 2014 and July 2015 on behalf of the CSA Audit and Evaluation Directorate by a consortium of firms led by Kelly Sears Consulting Group and covered the time period of April 2009 to December 2014. The evaluation is a requirement of the CSA five-year evaluation plan, which, in accordance with Treasury Board's Policy on Evaluation (2009) requiring that all federal programs be evaluated every five years. An Evaluation Consultative Group, consisting of representatives from the CSA guided the work of the consulting team.

The evaluation involved the following methods: a review of a considerable amount of documentation, files and literature; the conduct of 56 interviews with representatives from the CSA, companies with ESA contracts as well as companies without ESA contracts, other government departments, universities and industry associations; an online survey of the Canadian space industry (77 responses, consisting of 25 with ESA contracts and 52 without ESA contracts); and an economic impact assessment.

Conclusions and Recommendations

Relevance/Need

Canada holds a unique and privileged position as the only non-European country that has a cooperation agreement with ESA that allows direct participation in ESA optional programmes. Other countries, including Australia, South Africa, Israel and China have thus far unsuccessfully sought similar agreements with ESA. Evaluation findings indicate that the International Market Access Program responds to a number of needs within the Canadian space sector as well as in the researcher and data user communities in Canada.

Internationally, the space industry continues to be highly protectionist. Without the Canada/ESA Cooperation Agreement, Canadian companies would have little chance of winning public sector contracts in Europe unless they were able to set up operations there. Given that the public sector continues to be a critical market for the space industry around the world, the loss of the Canada/ESA Cooperation Agreement would have a negative impact on the Canadian space industry's opportunity to pursue space contracts in Europe. The Agreement enables Canadian companies to collaborate with European firms, helping them to build working relationships and to integrate their technologies with those of their European counterparts, thus putting them in a better position to pursue business around the world.

Canada's cooperation with ESA reflects the basic fact that countries must collaborate to undertake space missions due to their size, complexity and cost. Few countries have the financial and technological capacity to undertake missions completely on their own. International collaboration allows for the implementation of larger, more complex missions and the sharing of costs and risks.

The international space industry is highly R&D intensive. An important requirement of space R&D is the need to flight test technologies, which serves to increase their technology readiness level (TRL). Given the fact that Canada itself has launched few spacecraft in recent years (or plans to do so), Canadian companies seeking to increase the TRL of their products are highly dependent on opportunities outside of Canada – opportunities which are provided through ESA-led space missions. This allows companies to maintain their technological and competitive edge.

Canadian space scientists and some federal government organizations indicated that they rely on access to ESA data for scientific and modelling purposes. The loss (non-renewal) of the Canada/ESA Cooperation Agreement would not entirely curtail access since ESA data is increasingly open source; however, it would limit access to some data and background information on the data, and privileged access to the data. Some federal government organizations would need to purchase data for modelling purposes.

The loss of the Canada/ESA Cooperation Agreement also likely would have serious political implications. Canada has recently signed (but not yet ratified) the Canada-European Union (EU) Free Trade Agreement. In light of this, non-renewal of the Canada/ESA Cooperation Agreement post-2019 risks being seen as inconsistent. Should the longstanding working relationship between Canada and ESA end, it is unlikely that Canada would be given the opportunity to re-establish the Canada/ESA Cooperation Agreement at some point in the future.

The relationship between ESA and the EU is complex and Canada's signing of both the Canada/ESA Cooperation Agreement and Canada-EU Free Trade Agreement provides some clarity to Canada's relationships within the European space sector. In the past there have been challenges when ESA projects (which focus on technology development) were operationalized by the EU because Canada, as a non-EU country, was not included. Although the closer trade relationship with the EU may alleviate some tensions, there is evidence that Canadian officials will need to open discussions with the EU in tandem with ESA in negotiating the next Canada/ESA Cooperation Agreement prior to 2019 if Canada wishes to maximize access to both the ESA and EU space markets.

As the Canada/ESA Cooperation Agreement comes up for renewal, the CSA should encourage the Government of Canada to conduct discussions regarding renewal of the Canada/ESA Agreement in parallel with discussions with the EU about the Canada-EU Free Trade Agreement in order to ensure that the interests of the Canadian space sector are coordinated across the Canada/ESA Cooperation Agreement and the Canada-EU Free Trade Agreement.

Although the Free Trade Agreement will better position Canadian companies to bid on EU contracts, expanding their potential market and possibly facilitating work on operational contracts (e.g., operating ground stations), it will also serve to open the Canadian market to European companies. Although there are currently limited opportunities in Canada, even for Canadian firms, this may affect Canadian firms in the future should the Canadian government proceed with new space projects. There currently is limited awareness within the space sector of the full implications of the Canada-EU Free Trade Agreement.

Recommendation #1: The CSA should communicate the implications of the Canada-EU Free Trade Agreement to the Canadian space industry and encourage the industry to prepare in order to be better able to compete with European firms.

The Canada/ESA Cooperation Agreement aligns with federal priorities as indicated in the *Space Policy Framework* and the recently released *Science, Technology and Innovation Strategy*. As an international treaty, it is consistent with the role of the federal government to manage international relationships.

Achievement of Outcomes

Geo-Return

ESA uses the concept of geo-return in the awarding of contracts for both mandatory and optional programmes. In using geo-return, ESA aims to award contracts in proportion to each State's financial contribution. Based on ESA data, Canada achieved a fair overall geo-return (excluding the International Space Station (ISS) Exploitation programme) of 0.99 over the time period of 2000-2014¹. Although important, geo-return itself is not an appropriate stand-alone measure of the success of the Agreement since ESA periodically makes adjustments to ensure that all countries achieve a fair geo-return. Many programmes (such as most elements of the General Support Technology Programme (GSTP) and the Advanced Research in Telecommunications Systems (ARTES programme) provide for a guaranteed return of 1.0 at the conclusion of the programme.

Immediate Outcomes

There is evidence that the Agreement provides the CSA and other government departments (OGDs) with invaluable information and intelligence, some of which contributes to policy and decision-making. Examples include information on market trends, plans of other ESA Member States, and technological information. Most of this information is not published or publicly available. Canadian scientists who participate on ESA advisory groups and committees also obtain intelligence and background information on data which would otherwise not be available to them.

¹ In 2012, Council decided to exclude the ISS Exploitation programme from the geo-return statistics of the current period and to include it in the next period. Consequently, as of 2012, statistics are provided including and excluding that programme.

Although Canada contributes a very small proportion of ESA's total funding (0.83% of mandatory programmes and 0.55% of optional programmes) and does not participate in ESA's Science programme, there is evidence that Canadians are playing a meaningful role on ESA's scientific teams, particularly in the areas of Earth Observation and Human Microgravity and Exploration.

Intermediate Outcomes

Canadian space companies are forming alliances with European space organizations as a direct result of the Canada/ESA Cooperation Agreement. Most often the relationship is established through work on an initial contract for ESA and then solidifies as Canadian and European technologies are integrated. These working relationships may begin on ESA contracts and then continue on subsequent contracts beyond ESA. Given that Canada's contribution to ESA is not sufficiently large to allow Canadian firms to serve as primes, Canadian firms most often serve as sub-contractors to their European partners.

Canadian space companies provided numerous examples of where they have been able to increase the TRL of their technologies as a direct result of participation in ESA programmes. They emphasized that the opportunity to participate in these programmes is critical given the limited number of space projects currently underway or planned in Canada. In addition, participation in ESA programmes has also allowed some Canadian products and technologies to be space qualified – a prerequisite for commercial success.

There are essentially two types of users of space data that is made available by ESA missions: researchers (mainly in universities) who participate in scientific research projects and scientists (mainly in the federal government) who use ESA data for modelling purposes, e.g., weather forecasts and monitoring of sea-ice. There is evidence that Canadian scientists are accessing ESA data and that this data meets their needs. Although ESA data is increasingly "open access", Canadian scientists benefit from the Agreement because they have privileged access to all of the intelligence (i.e., background information to help in interpretation) concerning the data.

Ultimate Outcomes

There is good evidence that Canada's participation in the ESA Agreement is directly contributing to increasing the competitiveness of Canada's space industry. Although all ESA programmes in which Canada participates benefit at least part of Canada's industry, some ESA programmes and programme families are better structured to facilitate commercialization of technologies. The Canadian space sector is highly export-oriented and the European market represented 31% or \$497 million of the total of \$1.58 billion in Canadian space exports in 2012. Telecommunications revenues dominated the statistics for the Canadian space sector, representing 80% of total revenues. There is evidence that telecommunications and, to a lesser extent, Earth observation, are areas where the commercial potential is the highest.

In 2012, at the time of renewal of the current Canada/ESA Cooperation Agreement, the CSA reduced the funds set aside for future commitments to the Satellite Communications programme area at ESA, which resulted in an ongoing annual savings of \$1.13M for the government (approximately \$8M over the 8

years of the Agreement). However, the federal government recently committed, in Budget 2015, \$30 million over four years to ARTES. Although this announcement likely will be welcomed by Canadian industry, the industry had not planned for such a direction due to federal government decisions of 2012 to reduce investments in communications programmes. The absence of a clear long-term strategic direction in space for Canada makes it difficult for space companies to plan technology development and to invest in human resources in order to respond to international opportunities.

Recommendation #2: There is a need for the CSA and the federal government to establish a strategic direction for the Canadian space sector so that the industry can undertake long-term planning.

Although there is ample evidence that cooperation with ESA has contributed to increased competitiveness of Canadian companies, there is also evidence that the limited amount of funding is preventing Canadian companies from fully benefiting from the potential opportunities. Canadian companies are losing some of their competitive edge partly because of Canada's declining contribution to ESA in recent years. Specifically, a few interviewees reported that there have been instances where a Canadian company has a leading edge technology desired by ESA, however, due to Canada's limited funding as well as the implications of the geo-return policy, contracts have gone to Canada's European competitors who are then able to strengthen their expertise.

Recommendation #3: The CSA should examine its funding allocation to ESA programmes (for example, funding fewer programmes while focusing only on those that have demonstrated higher economic benefits). Such an examination should be conducted in relation to a long-term strategic direction for the Canadian space sector.

There have been few opportunities for Canadian organizations to participate in Canadian space endeavours in recent years. However, capacity developed with ESA could be put to use on Canadian or other international space endeavours.

Economic Benefits

Canadian organizations (including private sector companies, universities and OGDs) were awarded 182 contracts (including sub-contracts) under the Agreement between January 2009 and December 2013, valued at an estimated \$122.9 million². Although Canadian organizations have benefited from ESA contracts, these benefits are concentrated in a small number of organizations, with ten organizations accounting for 85% of the value of ESA contracts between 2009 and 2013. However, this mirrors the structure of the Canadian space industry which is dominated by a relatively small number of companies.

² Note that this figure does not represent the flow of funds since the signing of a contract is a commitment to pay sometime in the future.

There is good evidence that companies are benefiting from follow-on business. Companies surveyed for this evaluation reported attributable follow-on business worth 2.96 times the value of the ESA contracts they received.

The input-output model used for assessing the economic benefits of the \$114.2 million in ESA contracts obtained by Canadian private sector companies (i.e., excluding ESA contracts to universities and OGDs valued at \$8.7 million) between 2009 and 2013 yields total direct, indirect and induced economic benefits of \$447.9 million in GDP and 4,582 person years of employment.

Efficiency and Economy

There is strong evidence that Canada's participation with ESA is both economical and efficient. The total cost of the Agreement between 2009-10 and 2013-14 was \$149.7 million (including \$146.9 million in contributions to ESA and \$2.8 million for CSA salaries and overhead). In exchange Canadian organizations obtained an estimated \$122.9 million in ESA contracts as noted above. In other words, Canadian organizations were awarded contracts valued at 0.82 of every dollar spent on the program for the period from 2009-10 to 2013-14. When calculated for the period from 2004-05 to 2013-14, this ratio decreases to 0.71.

These results show a higher ratio than for the previous evaluation period (2000-2008) which reported a ratio of 0.68. However, if the calculations were repeated after excluding the \$26.5M contracts for data purchased under the Earth Observation programme family for third party mission contributions to Global Monitoring for Environment and Security (GMES), the ratios would be much closer to those obtained for the previous evaluation period (0.64 for 2009-10 to 2013-14 and 0.63 for 2004-05 to 2013-14).

No viable alternatives were identified by the evaluation that would provide the same level of economic, scientific and political benefits at the same or lower overall cost.

Program Delivery

Although the CSA has a well-articulated process for selecting which ESA programmes to participate in (which includes consulting with stakeholders), the evidence indicates that consultations with stakeholders have not occurred on a consistent basis, resulting in some dissatisfaction among stakeholders. There has been no formal consultation with stakeholders since 2012. The CSA has restricted consultation largely because of Canada's limited ability to invest in additional ESA programmes. Any consultation that does occur tends to be ad hoc, focusing on the major players rather than on the space sector as a whole.

Recommendation #4: There is a need for the CSA to undertake broader, formalized consultations with Canadian stakeholders (including industry, government and universities) regarding the selection of ESA programmes in which Canada participates.

Despite dissatisfaction with the consultation process, most stakeholders believe Canada is participating in the most appropriate ESA programmes. However, there is evidence that some of these programmes, although beneficial from a scientific research perspective and strongly supported by university researchers, may not be having strong industrial benefits in terms of return on investment. This is not to say that these programmes are not beneficial to researchers at Canadian universities and OGDs, rather, they do not align with the industrial benefits focus of the Agreement.

Recommendation #5: The CSA should assess the positioning of the Canada/ESA Cooperation Agreement (funded through the ESA Contribution Program) within its Program Alignment Architecture (PAA), and the CSA's overall suite of programs. It is possible that the Canada/ESA Cooperation Agreement aligns with more than one Sub-Program or Sub-Sub-Program. The CSA should also assess whether other of its activities or programs would fit under the International Market Access Program.

The lack of a fully-articulated plan for the Canadian space sector hinders longer-term planning and decision-making on the part of the CSA and the federal government about which programmes Canada should be investing in based on alignment with Canada's priorities. The evaluation also found evidence that this also hinders planning on the part of the Canadian space sector. There are no clearly articulated priorities at the federal level for the Canadian space sector to guide decisions about which ESA programmes Canada should focus on.

1 Introduction

This report presents the findings of the Evaluation of the International Market Access Program (IMAP), comprising the European Space Agency (ESA) Contribution Program, administered by the Canadian Space Agency (CSA). The evaluation was conducted on behalf of the CSA Audit and Evaluation Directorate by Kelly Sears Consulting Group in collaboration with Beechwood Consulting and Research Inc., BBMD Consulting Inc., and Hickling Arthurs Low Corp. between April 2014 and July 2015. The evaluation is a requirement of the CSA five-year evaluation plan and was conducted in accordance with the Treasury Board Secretariat (TBS)'s *Policy on Evaluation* (2009) requiring that all federal programs be evaluated every five years.

2 Background

This chapter provides a brief profile of the International Market Access Program (IMAP) comprising the ESA Contribution Program of the CSA.

2.1 Overview

Canada and ESA have been cooperating in space activities since the early 1970s. Formal Canada/ESA cooperation started in 1979 with the signing of the first Canada/ESA Cooperation Agreement, which has been renewed four times since then (in 1984, 1989, 2000 and 2012). The 2012-19 Canada/ESA Cooperation Agreement was approved by Cabinet in November 2010, signed at the ESA Council in December 2010 and ratified on March 28, 2012. The Agreement is an international treaty, i.e., an instrument bound under international law.

ESA is an international organization headquartered in Paris and is currently composed of 22 Member States (MS) and five Cooperating States, with Canada being the only non-European Cooperating State. ESA's mandate is *"to provide for and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their applications with a view to their being used for scientific purposes and for operational space applications systems"*.³

Through the Canada/ESA Cooperation Agreement, Canada benefits from the unique privilege of being the only non-Member State with direct participation in ESA programmes, thus allowing Canadian organizations to bid on tenders for ESA optional programmes and activities in which Canada participates. Canada is also the only non-Member State involved in the decision-making process of ESA programmes.

The Cooperation Agreement specifies, among other things, the following:

- Canada contributes annually to the ESA General Budget (excluding funds provided under "Technological Research"). Canada's contribution is 50% of what it would have been if it had been calculated on the basis used for the Member States of ESA.
- Canada contributes to the funding of ESA programmes in which it participates.
- Canada has the right to be represented at open meetings of the ESA Council and has the right to vote on questions relating to activities and programmes in which it participates. Canada has the right to be represented at meetings of ESA subsidiary and advisory bodies related to the activities and programmes in which it participates. Canada also has the right to be represented on the Programme Boards concerned with the programmes in which it participates and shall have the right to vote on issues relating to those programmes and activities.

³ http://www.esa.int/About_Us/Welcome_to_ESA/ESA_s_Purpose

- Regarding the geographical distribution of work related to the ESA activities and programmes in which Canada participates, ESA:
 - Ensures a fair industrial return to Canada for activities carried out under the General Budget, with the exception of the Technology Research Programme (TRP); and
 - For optional programmes, implements for Canada, the applicable rules developed for the various programmes and activities to the same extent as for the other participating States.

2.2 Program Objectives

The primary objective of Canada's cooperation with ESA is “enhancing the competitiveness of the Canadian space sector through the development of leading edge technologies and products.” More specifically, the objectives are to:

- Foster innovation and competitiveness by exposing Canadian space organizations to the ESA programmes and activities dedicated to developing space technologies, applications and hardware;
- Maintain or increase the capability of the domestic space sector to successfully contribute to Canadian space endeavours by providing access to ESA space flight opportunities in order to demonstrate and qualify Canadian space technologies and hardware;
- Facilitate access to European public space markets as well as global space public and private markets, when applicable; and,
- Acquire and maintain awareness of the directions of European space policies and of the European space technological, scientific, programmatic and commercial environments to feed the CSA strategic planning process.

In addition, Canadian participation in ESA programmes may:

- Facilitate the participation of Canadian scientists in ESA missions; and
- Facilitate access to ESA's data and/or infrastructure to academia and government departments/agencies.

2.3 Governance, Roles and Responsibilities

2.3.1 ESA Programme Governance

The implementation of the Canada/ESA Cooperation Agreement involves mainly the Department of Foreign Affairs, Trade and Development Canada (DFATD), the CSA and ESA.

Canada, in its dealings with ESA, is represented by Canadian delegates nominated to the various ESA Programme Boards and other ESA subordinate bodies. All current Canadian delegates on ESA boards and committees are from the CSA, with the exception of the Counsellor (European Space Affairs) who is based in Paris and acts as the permanent Canadian delegate to ESA and, as such, represents Canada on all boards and committees and reports to DFATD.

On the Canadian side, one of the first steps in the implementation of the Canada/ESA Cooperation Agreement was the selection and approval of ESA programmes and activities in which Canada would participate. This process is briefly described below, followed by a brief description of those involved in the overall delivery of the Agreement.

2.3.2 Roles and Responsibilities

The Minister of Foreign Affairs, with the assistance of the Minister of Industry, obtains the required approvals and authorities through Orders in Council (OICs) related to the Canada/ESA arrangements and their subsequent amendments.

The Minister of Industry, who is responsible through the CSA for implementing the Canada/ESA Cooperation Agreement and related arrangements, usually represents Canada at Ministerial ESA Council meetings.

The President of the CSA is usually the Head of the Canadian delegation at ESA; he usually represents Canada at ESA Council meetings and signs Programme Arrangements.

The Policy Branch of the CSA usually represents Canada at ESA Council and International Relations committee meetings.

The Space Science and Technology (SST) Branch of the CSA fulfils the following responsibilities:

- Coordinates ESA programme budgets and payments to ESA;
- Usually represents Canada at the ESA Council, Industrial Policy Committee and Administrative and Finance Committee Meetings;

- Identifies, with the support of other branches at the CSA, delegates to represent Canada on relevant ESA Programme Boards and other ESA subordinate bodies (such as committees, working and advisory groups);
- Identifies opportunities, along with the Canadian delegates on ESA's Programme Boards and representatives from other branches at the CSA, for participation in new programmes, organizes consultations with industry and other government departments (OGD), and prepares Programme Approval Submissions for presentation to the CSA Executive Committee; and,
- Prepares documents required by DFATD for the Order in Council (OIC) submissions on Programme Declarations and Canada/ESA Arrangements, with the support of the Policy Branch.

The SST Branch also performs the following program management tasks, with the support of the Canadian delegates to ESA:

- Positioning Canadian industries with ESA (e.g., monitoring ESA opportunities for Canadian industries, briefing on ESA opportunities to Canadian industries, positioning of interested and competent Canadian organizations to successfully bid on ESA's contracts, and promotion of those organizations to ESA);
- Preparing recommendations to ESA identifying which specific activities Canada is willing to support under a given programme (a procedure applicable to some programmes);
- Monitoring implementation of the ESA activities and optional programmes in which Canada contributes by participating in ESA Programme Boards and horizontal committees with Canadian delegates whose roles and responsibilities are to ensure effective representation of Canada's interests with ESA; and
- Monitoring Canadian performance arising from the ESA optional programmes in which Canada contributes (e.g. industrial returns, ESA procurement and contracts).

The Canada Centre for Mapping and Earth Observation (CCMEO) and the Communications Research Centre (CRC), which are respectively part of Natural Resources Canada (NRCan) and Industry Canada, may send experts delegated to ESA's Programme Boards at the CSA's request. DFATD is involved in meetings where relevant.

The Counsellor (European Space Affairs) in Paris, who is a DFATD representative, acts as a permanent Canadian delegate on the ESA Council and on all subordinate bodies.

2.3.3 Governance of ESA

The ESA Council, composed of representatives of the Member States, is ESA's governing body that provides the basic policy guidelines within which the European space program is developed. Reporting to the Council are the Working Groups, Plenary Subordinate Bodies and Programme Boards. The Council appoints a Director General who is the Chief Executive Officer responsible for the management of ESA, and for the implementation of its policies and programs in accordance with the directives issued by the Council. Pursuant to the Canada/ESA Cooperation Agreement, Canada has the right to be represented in Council and relevant subordinate bodies.

ESA is responsible for managing the delivery of its activities and programmes, including the procurement process. As a result of this procurement process, ESA may award contracts to Canadian organizations (mostly industry, but may also include universities and federal departments or agencies) to develop the technologies, systems or components required by the ESA programmes and activities in which Canada participates. The entire procurement process (e.g., planning and preparation of invitations to tender; release of invitations to tender; reception, evaluation and selection of proposals; award of contracts; and debriefing to unsuccessful bidders) is managed by ESA. The contracts are awarded in conformity with the industrial and procurement policies of ESA. The ongoing administration of contracts to Canadian organizations is also an ESA responsibility.

In accordance with the Canada/ESA Cooperation Agreement, Canada is entitled to receive the same level of reporting received by ESA Member States regarding contracts awarded by ESA to Canadian organizations. The contract reports consist of the list of contracts awarded (or commitments within a contract) to Canadian organizations with the following information: name of the company (organization), contract title, approximate date during which the contract was awarded, amount of the contract, weighting coefficient (between 0 and 1, 0 for contracts with no technological content and 1 for contracts with technological content) and programme under which the contract is awarded.

In accordance with the ESA convention, cumulative geo-return statistics are published quarterly. These statistics provide the individual programme and overall geo-return coefficient for all Member States and Canada. However, these statistics have not been published consistently in the past four years due to ongoing financial and procurement reforms within the ESA.

There is no contractual relationship between the CSA and Canadian organizations being awarded contracts by ESA – as such, the contractors have no contractual or reporting obligation to the CSA.

ESA's Industrial Policy ensures that all Member States participate in an equitable and effective manner in implementing the ESA programmes, while exploiting the advantages of free competitive bidding. One of its main elements relates to geographical distribution or fair return in ESA procurement. The Canada/ESA Cooperation Agreement includes guarantees with regards to Canada's industrial return.

2.4 Resource Allocation

The total spending to implement the Canada/ESA Cooperation Agreement from 2009-10 through 2013-14 is presented in Table 1 (as of September 2014).

Table 1: Actual Program Spending, 2009-10 to 2013-14 (\$000's)

	2009-10	2010-11	2011-12	2012-13	2013-14	Total
Contributions to ESA						
General Budget	7,480	7,245	7,748	7,601	8,528	38,601
Payments for Over Return		4,715	4,894			9,609
Optional Programmes	22,954	21,520	22,434	15,678	16,093	98,680
Total Contributions to ESA	30,434	33,480	35,076	23,279	24,621	146,890
CSA Management of ESA Agreement						
Operations and Maintenance (O&M)	346	179	175	98	75	873
Salaries	440	419	358	312	350	1,879
Total CSA Mgmt.	786	598	533	410	425	2,752
Total Program Spending	31,220	34,078	35,609	23,689	25,046	149,642

Source: CSA ESAPA database, September 2014.

*Due to rounding, amounts may not sum exactly to totals.

The salary figures include the salaries of employees directly involved in the implementation of the Cooperation Agreement (currently 3 full-time equivalents (FTEs)) but exclude resources from other CSA branches (currently approximately 0.5 FTE) who act as ESA Programme Board delegates. The figures also exclude resources not directly involved in program delivery (Policy Directorate involvement to oversee the Cooperation Agreement and CSA senior management attendance at ESA Council meetings).

The actual payments to ESA in 2012-13 and 2013-14, which are part of the current evaluation period, as well as the estimated outstanding commitments to ESA are presented in Table 2.

Table 2: Payments and Commitments to ESA versus Authority for the 2012-19 Canada/ESA Cooperation Agreement* (\$'000s)

	Actuals		Outstanding Commitments							Total	
	Duration of Existing Cooperation Agreement								Future FYs		
	2012-13		2013- 14	2014- 15	2015- 16	2016- 17	2017- 18	2018- 19			2019-20
	ESA 2012	ESA 2013									
General Budget	5,215	2,386	8,528	9,966	12,172	12,503	12,874	12,874	6,308		82,825
Optional Programmes	11,517	4,162	16,093	18,291	13,297	12,783	10,981	7,856	5,413	7,014	107,406
(A) Contributions to ESA (Actuals and Commitments)	16,732	6,547	24,621	28,257	25,469	25,286	23,854	20,729	11,721	7,014	190,231
	23,279										
									Authority	ARLU 13-14 reprofiling	REV. Auth.
(B) Authority									193,776	10,363	204,139
C = (B – A) Estimated Remaining Authority											13,908

Source: CSA ESAPA database, September 2014.

*Values do not take into account an additional \$30 million committed to ARTES in the 2015 Federal Budget.

**Due to rounding, amounts may not sum exactly to totals.

It is important to distinguish between the contribution funds allocated to the International Market Access Program in the CSA's level of reference and the authorities to make commitments to ESA.

The authority obtained in September 2012 was based on the financial table included in the approval documents obtained in December 2010. This authority (\$204.14M) includes payment to the ESA General Budget for the duration of the agreement (i.e., until the end of 2019), all outstanding commitments in optional programmes made during previous agreements, and all new commitments to optional programmes made during the current agreement.

The program's Performance Measurement (PM) Strategy notes that due to some reallocation of funds to the International Market Access Program in past years, there is a difference between the budget allocated from 2012-13 to 2019-20 (\$208.94M) and the authority (\$204.14M). Total payments to ESA from April 2012 and outstanding commitments cannot exceed the authority.

Estimated commitments are based on the following assumptions:

- Exchange rates (conversion from euros to Canadian dollars): 1.55 in 2014-15, 1.6 in 2015-16, 1.65 in 2016-17 and 1.7 in subsequent years;
- Inflation: 0.9% per year;
- 20% risk margin for the Global Monitoring for the Environment and Security (GMES) Space Component Programme;
- Gross Domestic Product (GDP) rates of 4.8% (normalized at 4.58%) to calculate the General Budget after 2014; and,
- Stable level of resources for ESA.

It should be noted that some of the current commitments to ESA for optional programmes go beyond the duration of the agreement. These commitments have to be taken into account when ensuring the authority is not exceeded. On the other hand, payments to ESA for the General Budget beyond the current agreement do not have to be taken into account and are not included in Table 3. Based on these assumptions the estimated amount of unused authority (as of September 2014) is \$13.9M (\$204.14M – \$190.23M).

Given the legally-binding nature of the commitments to ESA, in addition to the authority, an OIC is required to sign new arrangements and to commit funds to ESA optional programmes. At the occasion of the 2012 Ministerial Council, OICs were approved to resign seven of the existing arrangements (thus making existing commitments legally binding) and allowed the CSA to make additional commitments to six of those ESA optional programmes up to \$99.8M including outstanding commitments at the date of the OIC approval (November 2012). Actual payments and outstanding commitments (using the same assumptions as in Table 2) in those six Programmes are presented in Table 3.

Table 3: Spending and Commitments to ESA Subject to OIC Authority (\$'000s)*

	Actuals	Outstanding Commitments								Total
	2012-13 (from Nov.1)	2013- 14	2014- 15	2015- 16	2016- 17	2017- 18	2018- 19	2019- 20	Future FYs	
Optional Programmes Subject to OIC Authority	4,158	16,066	18,244	13,272	12,768	10,977	7,856	5,339	6,829	95,508
										REV Auth.
B) OIC Authority										99,800
C = (B – A) Estimated Remaining OIC Authority										4,292

Source: CSA ESAPA database, September 2014.

The above values reflect scenario 199 in ESAPA. This scenario reflects the actual exchange rate for the payment in October 2014. A risk value of 20% was considered for ARTES 21 and GMES Space Component.

The exchange rates reflected in scenario 199 are: 2015 – 1.50; 2016 – 1.55; 2017 – 1.60; and 2018 – 1.65.

*Due to rounding, amounts may not sum exactly to totals.

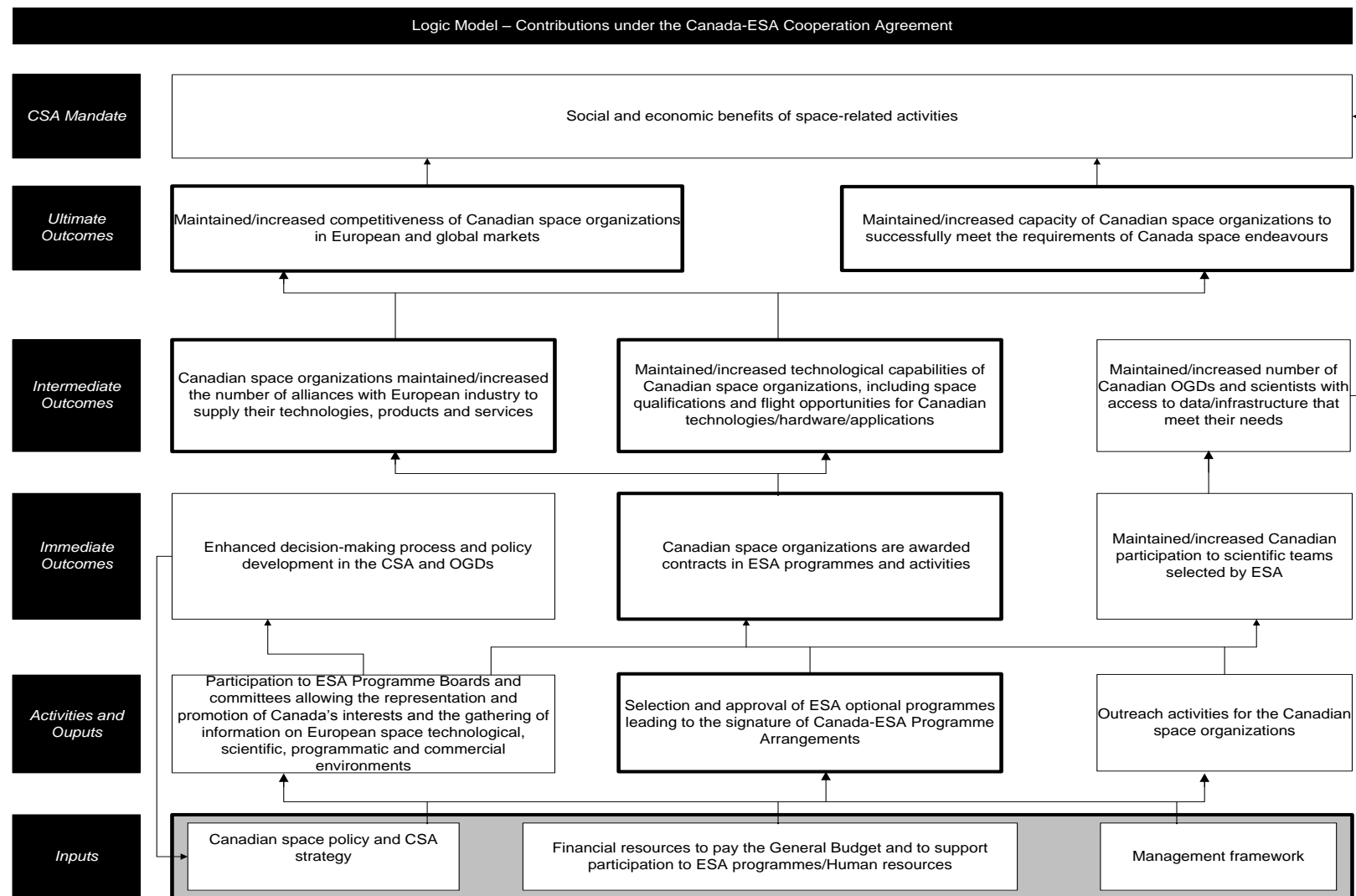
**Values do not take into account an additional \$30 million committed to ARTES in the 2015 Federal Budget.

With the assumptions mentioned previously, the estimated amount of unused OIC authority is \$4.292M (as of September 2014).

2.5 Program Theory

The International Market Access Program logic model and narrative were taken from the PM Strategy developed by the International Market Access Program management prior to the evaluation. The logic model, presented in Figure 1, identifies the linkages, or the causal connections, from the activities through associated outputs to the sequence of expected outcomes. A short explanatory text describes what each box of the logic model implies. It is to be noted that bolded boxes in the logic model identify the core components of the program. The logic model narrative is included in Appendix B.

Figure 1: Logic Model for the International Market Access Program



2.6 ESA Programmes in which Canada Participates

Table 4 summarizes programmes in which Canada participates under the ESA Agreement. All but the General Budget are optional. Within ESA's mandatory activities, funded through the General Budget, Canada does not participate in the Technology Research Programme (TRP). The scientific programme is a mandatory activity for Member States, but not for Canada.

Table 4: Description of ESA Programmes with Canadian Participation (2009-10 to 2013-14)

Programme Family	ESA Programme	Programme Description
Earth Observation	EOEP	EOEP comprises two main components: the Earth Explorer Component (which includes the definition, development, launch and operations of Earth Explorer missions and covers both the platform and payload, as well as the associated ground segment) and the Development and Exploitation Component (which covers preparatory activities for Earth Explorer and Earth Watch; instrument pre-development for user-driven candidates for Earth Explorer and Earth Watch type missions; definition of Earth Watch type missions and the preparation of dedicated programme proposals for optional Earth Watch type programmes; and Mission Exploitation).
	European Earth Watch (Infoterra/TerraSAR)	The Earth Watch element of ESA's Living Planet Programme comprises a science and research element, which is designed to facilitate the delivery of Earth observation data for use in operational services. Earth Watch includes the well-established meteorological missions with the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat). In addition, the Copernicus Sentinel missions, which form part of the Copernicus Space Component, will collect robust, long-term climate-relevant datasets. Together with other satellites, their combined data archives will be used to produce Essential Climate Variables for climate monitoring, modeling and prediction.
	GMES Space Component	Global Monitoring for Environment and Security (GMES) establishes service infrastructure that will use space-based Earth observation data to generate information for policy makers and other users relating to the environmental and climate change issues. The GMES Space Component develops the required space segment infrastructure (i.e., satellites and the receiving stations) to generate the Earth observation data required by GMES users and also includes the operations of all satellite and ground segment infrastructure providing the required data streams.
	POEM-1 (ENVISAT)	ENVISAT was the largest satellite built for EO, and it provided data on the Earth's atmospheres, oceans, land and ice. Canada participated in the design, construction and deployment of ENVISAT.
Space Exploration	AURORA (European Space Exploration Programme)	The Aurora Programme defines a European strategy for the exploration of the solar system over the next 30 years, including manned expeditions to the Moon, Mars, to asteroids and even beyond. Canada

Programme Family	ESA Programme	Programme Description
		participates in all elements of that Programme, namely: the preparatory activities, the Core Programme, Exomars and the Mars Robotic Exploration Preparation (MREP) Programme.
	ISS DEV (Euro. Transp. & Human Expl. Prep. Prog.)	Canada participates in the following components of this Programme: <ul style="list-style-type: none"> ▪ European Transportation Phase A studies (Advanced Re-entry Vehicle - ARV); ▪ Lunar Lander Activities; and ▪ Early activities Component.
Navigation	GALILEO PROGRAM	Galileo will be Europe's own global navigation satellite system, providing highly accurate, guaranteed global positioning service under civilian control. It will be interoperable with GPS and GLONASS, the two other global satellite navigation systems.
	GNSS	The European GNSS Evolution Programme's (EGEP) primary aim is to undertake research and development in and verification of technologies relating to regional space-based augmentation systems (SBAS) and global navigation satellite systems (GNSS). EGEP also provides a framework for scientific research enabled by GNSS, which spans a wide range of disciplines, from atmosphere and climate modeling through time and space references to fundamental physics.
Satellite Communications	ARTES	Advanced Research in Telecommunications Systems (ARTES) has two major aims: to develop technologies to be used in future satellite communication and navigation programmes, and to help develop new markets so as to improve the competitiveness of the industry on the commercial market. These goals are broadly defined and permit the ARTES programme to evolve with the rapidly changing needs of the field.
Microgravity	ELIPS	The European Programme for Life and Physical Sciences in Space (ELIPS) programme promotes life and physical sciences and applications using the European Columbus module on the International Space Station.
General Technologies	GSTP	The GSTP develops technologies for space applications, and raise it to a proper readiness level for future ESA missions. Canadian organizations have developed innovative spacecraft attitude control software and fiber-optic based monitoring of spacecraft temperature and pressure.
General Budget /mandatory activities	General Budget (except TRP)	Activities carried out under the General Budget are 'mandatory'; they include the ESA's basic activities (studies on future projects, technology research, shared technical investments, information systems and training programmes). Canada does not contribute nor benefit from the Technology Research Programme.

Table 5 summarizes the CSA's contribution to each ESA programme in which Canada participated between 2009-10 and 2013-14. ESA's total budget in 2014 was 4,102.1 million euros.

Table 5: Canada's Contributions to ESA Programmes (2009-10 to 2013-14) (\$'000s)

Programme Family	2009-10	2010-11	2011-12	2012-13	2013-14	Total
Earth Observation	6,865	7,024	7,220	5,255	7,260	33,625
Space Exploration	5,978	6,775	4,783	3,832	3,191	24,557
Navigation	4,280	452	314	234	26	5,307
Satellite Communications	3,352	5,546	8,425	4,669	3,604	25,596
Microgravity	1,954	1,025	1,451	1,205	1,596	7,231
General Technologies	525	699	241	483	416	2,364
General Budget/ mandatory activities	7,480	7,245	7,748	7,601	8,528	38,601
Payments for Over Return		4,715	4,894			9,609
Total:	30,434	33,480	35,076	23,279	24,621	146,890

Source: CSA ESAPA database, September 2014.

*Due to rounding, amounts may not sum exactly to totals.

As part of the 2012 Strategic and Operating Review, the CSA examined options for savings in program areas where federal support or intervention was believed to be less needed. As a result of the review, the satellite communications sector was targeted for savings since this segment of the space sector was believed to be mature, commercially successful and globally competitive. Consequently, the CSA reduced the funds set aside for future commitments to the Satellite Communications programme area at ESA, which resulted in an ongoing annual savings of \$1.13M for the government (approximately \$8M over the 8 years of the Agreement). The CSA and Industry Canada's perspectives on the satellite communications sector have since evolved, and currently there is a sense that the sector requires ongoing support from the federal government, which is being provided through other programs, such as the Space Technology Development Program (STDP). In order to reflect the priorities identified in Canada's Space Policy Framework (2014), the CSA announced new contributions of 1.8M euros to ARTES (the main ESA satellite communications programme in which Canada participates) at occasion of the latest Ministerial ESA Council meeting held in December 2014. Federal Budget 2015 also committed to increasing the funding to ARTES by \$30 million over four years, beginning in fiscal 2016-17.

Canada's ranking as of 2012 in terms of its contribution to ESA's budget is presented in Table 6. Overall, Canada's percentage contribution to ESA's overall budget for both mandatory and optional programmes has decreased since 2008. In other words, Canada's overall contribution, and thus influence within ESA, is diminishing over time.

Table 6: Contributions to ESA Programmes by ESA Member States (2008⁴-12⁵)

Country	% of total mandatory programmes		% of total optional programmes	
	2008	2012	2008	2012
Germany	21.86%	19.97%	22.12%	27.74%
France	15.50%	15.46%	25.51%	28.51%
Italy	12.85%	11.69%	14.63%	12.24%
UK	17.71%	15.61%	8.70%	5.88%
Belgium	2.74%	2.72%	6.72%	6.91%
Spain	7.33%	8.42%	5.98%	3.83%
Switzerland	3.42%	2.90%	3.66%	3.81%
Netherlands	4.48%	4.59%	3.91%	1.41%
Sweden	2.58%	2.58%	2.15%	2.24%
Norway	2.06%	2.41%	1.74%	2.09%
Austria	2.24%	2.19%	1.06%	1.67%
Poland		2.57%		0.05%
Denmark	1.76%	1.75%	0.73%	0.69%
Finland	1.40%	1.41%	0.44%	0.38%
Greece	0.87%	1.06%	0.34%	0.03%
Luxembourg	0.11%	0.22%	0.57%	0.62%
Portugal	1.20%	1.22%	0.52%	0.32%
Romania		1.00%		0.17%
Czech Republic		1.00%		0.34%
Ireland	1.11%	1.22%	0.36%	0.31%
Canada	0.77%	0.83%	0.85%	0.55%
Hungary				0.09%
Estonia				0.06%
Slovenia				0.06%

In 2012, Canada paid 0.83% of the expenses for all of ESA's total mandatory activities (including those to which Canada does not contribute). This percentage can be calculated as follows: Canada paid 5,833,108 euros out of the total costs of ESA mandatory programmes which amount to 701.2 billion euros (Basic Activities: 221.5 billion euros plus the Scientific Programme: 479.7 billion euros)⁶. It should

⁴ *Summative Evaluation of the 2000-2009 Canada/ESA Cooperation Agreement, Final Report*. Prepared for the Canadian Space Agency by Goss Gilroy Inc. February 22, 2010.

⁵ ESA Annual Report 2012, <http://esamultimedia.esa.int/multimedia/publications/Annual-Report-2012/>

⁶ 2012 budget ESA/AF(2011)7, rev. 1

be noted that Member States contribute to all mandatory activities while Canada only contributes to the General Budget (basic activities) less the amounts for the Technology Research Programme (Canada does not contribute to ESA's Scientific Programme).

When only considering mandatory activities to which Canada contributes (i.e., General Budget less the amounts for the Technology Research Programme), Canada's contribution rate was 3.90% in 2012. In 2012, Canada paid 0.55% of ESA total expenses for all optional programmes⁷.

2.7 Prior Evaluations of the Program

A summative evaluation of the 2000-2009 Canada/ESA Cooperation Agreement was completed in February 2010. The objectives were to assess rationale and relevance, the extent to which the Agreement was successful in meeting its objectives, and its cost-effectiveness. This evaluation found that the Agreement continued to be relevant and that it was successful in meeting its objectives despite some challenges in delivery. The evaluation made five recommendations, which were accepted by the CSA Executive Committee:

1. CSA should seek renewal of the Agreement for an additional ten-year period; if feasible additional resources should be allocated to the new Agreement either from an increase in the allocation of Government of Canada resources or through a reallocation from other CSA programs.
2. Clarify the role of ESA within the long-term space plan in order to guide industry on Canadian priorities in space, including ESA participation.
3. Develop and publicize a more coherent set of policies & programs for supporting organizations in the sector and developing new entrants.
4. Develop a coherent plan for communicating targeted ESA industrial opportunities.
5. Continue to monitor the impacts, if any, of the 2007 European Space Policy and EU trends on Canada and, if necessary, take steps to mitigate any adverse effects. The CSA along with Foreign Affairs and International Trade Canada should also undertake a policy review of Canada's role in ESA, given the changes occurring in Europe as a result of the 2007 European Space Policy.

⁷ ESA Annual Report 2012, <http://esamultimedia.esa.int/multimedia/publications/Annual-Report-2012/>

3 Evaluation Approach and Methods

3.1 Purpose, Evaluation Issues and Scope

The Evaluation of the CSA's International Market Access Program is in keeping with the requirements stipulated in the Policy on Evaluation and the *Financial Administration Act*. The evaluation report was required to be approved by September 2015, as scheduled in the CSA's Evaluation Plan 2015-16 to 2019-20.

The current cooperation agreement between the CSA and ESA ends in 2019. In anticipation of its expiry, the CSA and the Government of Canada will need to begin the process of reviewing whether or not to renew the agreement. This evaluation will provide input into the decision-making process.

The evaluation addresses the time period since the completion of the previous summative evaluation of the Canada/ESA Cooperation Agreement 2000-2009, i.e., from April 2009 to December 2014. ESA data is available for most but not all this entire period: data on contracts is available from 2009 to 2013 while geo-return data covers the period up to December 2014.

The evaluation focuses on the five core issues identified in the TBS's Directive on the Evaluation Function (2009), which includes issues of relevance (continuing need, alignment with federal government priorities, alignment with federal roles and responsibilities) and performance (achievement of expected outcomes, demonstration of efficiency and economy). The specific questions addressed by the evaluation are listed below.

Relevance

1. To what extent is there a continued need for the International Market Access Program? (i.e., do the policy, programmatic, and industrial conditions that led the CSA to enter into a Cooperation Agreement with ESA still exist today?)
2. Is the International Market Access Program aligned with the CSA and federal government priorities?
3. Is the International Market Access Program consistent with federal roles and responsibilities?

Performance

4. To what extent has the International Market Access Program achieved its immediate outcomes? Does achievement of immediate outcomes vary by ESA programme in which Canada participates?
5. To what extent has the International Market Access Program achieved its intermediate outcomes? Does achievement of intermediate outcomes vary by ESA programme in which Canada participates?

6. To what extent has the International Market Access Program achieved its ultimate outcomes? Does achievement of ultimate outcomes vary by ESA programme in which Canada participates?
7. What have been the social and economic benefits of the ESA Agreement to Canada (revenues, employment)?
8. Have there been any unexpected outcomes (positive or negative) as a result of the International Market Access Program?
9. Is the International Market Access Program producing its outputs and outcomes in the most efficient manner?
10. Are there alternative, more efficient or effective ways of delivering the results of the International Market Access Program?
11. Are there any opportunities for improving the overall economy of the International Market Access Program?

Program Delivery

12. To what extent have the International Market Access Program consultations for the selection of ESA programmes been effective?
13. To what extent has the International Market Access Program effectively communicated with its stakeholders?
14. To what extent have recommendations from the previous (2010) evaluation of the International Market Access Program been implemented?

3.2 Approach and Methods

3.2.1 Approach

The evaluation team worked closely with an Evaluation Consultative Group (ECG). Members of the ECG included CSA managers and staff as well as representatives from the Audit and Evaluation Directorate. The evaluation team sought input and feedback from the ECG on key deliverables for the evaluation including: project work plan; evaluation plan; interview guides; survey questionnaire; presentation of preliminary findings; and the draft and final reports. The ECG also provided names of individuals to be interviewed.

3.2.2 Data Sources

Given that the first Canada/ESA Cooperation Agreement was signed more than 35 years ago, the International Market Access Program is well established. The focus of this evaluation was on the relevance and performance of the International Market Access Program and as such is considered a summative evaluation according to the TBS definition.

In the terminology of evaluation research methodology, the design chosen was a basic non-experimental design, whereby the evaluation team assessed the extent to which the program delivered on its objectives over the time period being evaluated (April 2009 to December 2014). Although the

program has received data related to the geo-return to Canada from its inception, the PM Strategy was only finalized in September 2014 and so only very limited performance data was available.

According to the latest CSA's Departmental Evaluation Plan 2015-16 to 2019-20, the level of risk of the program is high when combining its risk severity score and materiality score. Taking into consideration the level of risk and the need to consult with program stakeholders, the evaluation used interviews, a survey of organizations that had received ESA contracts as well as those that had not, and a document and file review as data sources. The evaluation design and the data sources made it possible to gather data for each evaluation question from multiple lines of evidence.

3.2.2.1 Document Review

A review of existing documentation that relates to the Agreement was undertaken to help address all evaluation issues of relevance, effectiveness, efficiency, and economy. A number of documents were provided by the Project Authority and other members of the ECG and these documents were reviewed as part of the process of developing the work plan, evaluation matrix and evaluation plan. Additional documents were identified by the research team through an Internet search. All documents were reviewed systematically, using a template based on the evaluation matrix, during the data collection phase of the evaluation. The list of all documents reviewed for this evaluation is presented in Appendix A.

Although no challenges were encountered during the document review, it must be noted that a few documents received were marked as confidential and could not be quoted. Although these documents provided important context to the evaluation team in interpreting the findings, the information contained in the documents could not, in many cases, be used in the report. This challenge was mitigated through the use of other documents and interviews.

3.2.2.2 Key Informant Interviews

The selection of interviewees was focused on individuals who were the most familiar with the Canada/ESA Cooperation Agreement and who were well placed to respond to the evaluation questions – i.e., selection of key informant interviewees was purposeful. The interviewees were identified by members of the ECG.

In all, 56 key informant interviews were completed, as summarized in Table 7. Of the individuals identified for the key informant interviews, some could not be completed because they were unavailable during the interview period, because they were no longer with the organization, or because they felt someone else within the organization was better placed to respond to the interview questions (in which case these individuals were contacted instead). In a number of cases we did not receive a response despite numerous attempts via email and/or telephone.

Table 7: Key Informant Interviews by Category

Category of Interviewee	Number of Interviews Completed
CSA senior management, delegates to ESA and IMAP managers (current and former)	15
Other federal government departments (Environment Canada, Natural Resources Canada, Industry Canada)	9
Universities	9
ESA representatives	2
Companies with ESA contracts (2009-13)	16 (with 18 individuals)
Companies without ESA contracts (2009-13)	4
Industry association	1
Total	56

Interviews were conducted in the preferred official language of the interviewee. Interviews ranged in length from approximately 20 minutes to slightly over 60 minutes, averaging about 45 minutes.

A key limitation of the interview findings is that the majority of interviewees have a vested interest in the Canada/ESA Cooperation Agreement and its continuation. However, the findings from the key informant interviews have been triangulated with findings from other lines of evidence to the extent possible.

With respect to analysis, the specific roles and responsibilities of each interviewee meant that the interviewees were not in a position to respond to all questions posed, even though the guides had been tailored to each of the broad category of interviewee. Furthermore, in the case of clients the need to keep corporate information confidential and the qualitative nature of key informant interview data meant that reporting interview findings using counts of interviewees (i.e. how many said what) is neither relevant nor appropriate.

3.2.2.3 Survey of the Canadian Space Industry

An online survey was conducted of companies in the Canadian space industry.⁸ The target populations for the survey consisted of two groups: companies that had participated in ESA projects (via contracts or sub-contracts) and those that had not. For the first group, all companies were included that had been involved in ESA projects between 2009 and 2013 or during the previous five years (2004 to 2008). The reason for including the earlier time period is that we were interested in finding out about the follow-on

⁸ Originally the intention was to also survey universities that had received ESA contracts, but due to the relatively small numbers involved, the decision was made to conduct interviews with representatives of several universities instead (see the section on key informant interviews).

business that results from ESA contracts, recognizing that there can be a considerable lag between the completion of an ESA project and capitalizing on this experience to obtain follow-on business.

ESA maintains a database of contracts⁹ awarded to companies in all Member States in order to track geo-return. ESA provides the CSA with detailed data on each contract awarded to a Canadian company (as well as to government departments and universities), including the company name, the ESA programme, the contract title, the year of contract award and the contract value. This ESA contracts database included 72 companies with contracts between 2004 and 2008 and 58 with contracts between 2009 and 2013, with a high degree of overlap between the two sets of companies. Starting with this list, we carried out web research to determine if each company still existed and, if so, to find a contact email address (typically for the company president). In several cases, the company was no longer in business (or had been acquired by another company); the company was foreign with no obvious Canadian presence; or, an email address was not available on the company's website. After deleting such companies, we were left with a total of 53 companies that had usable email addresses. In a few cases, we obtained multiple email addresses for the company (for each of its divisions), which increased the total number of records to 58.

In order to develop a list of space companies that had not obtained ESA contracts, we used several sources, including the list of companies surveyed by the CSA annually as part of its space sector survey; the CSA online directory of space companies; and, the companies registered with the ESA EMITS system, which is the registry of companies interested in doing business with ESA.

In the end, the total population consisted of 254 records with email addresses: 58 companies (or divisions) that had obtained ESA contracts between 2004 and 2013 and 196 that had not.¹⁰

CSA administered the online survey. It was launched on February 25, 2015 with an introductory email message sent to all targeted respondents, signed by the Chief of CSA's Audit and Evaluation Directorate, which explained the purpose of the evaluation and the survey. The plan was to keep the survey window open for about three weeks, i.e., until March 13, 2015.

CSA sent out two email reminders to non-respondents. The evaluation team also contacted by email and telephone all of the companies that were interviewed in order to encourage response, as these companies represented the majority of ESA contracts. In order to maximize the response rate, the survey window was extended to March 30, 2015.

⁹ The ESA database includes both contracts and sub-contracts. For the purpose of this report, we use the term "contracts", since our interviews with companies revealed that they generally don't make a distinction between the two.

¹⁰ Several companies that were not in the ESA contracts database indicated in the survey that they had been involved with ESA projects in the past. Further research revealed that Canadian companies can get involved with ESA in ways other than through the Canada/ESA Cooperation Agreement. For example, one had received a contract directly with a European prime (i.e., outside of the Agreement) while another was involved in the James Webb Telescope, which is led by NASA but supported by ESA.

In the end a total of 77 responses were received, consisting of 25 that had obtained ESA contracts and 52 that had not (the total of 77 responses represented 75 companies, as one company provided separate responses for its three divisions). Of the total of 254 survey invitations sent out via email, 12 emails bounced back, resulting in a response rate of 32%. We believe this is a robust response rate given the survey sought detailed financial information which may have been sensitive and/or time consuming for some respondents to collate and provide, plus most companies that had not obtained ESA contracts over the years would have had little interest in responding. The distribution of responses by primary space-related activity is presented in Table 8.

Table 8: Primary Space-Related Activities of Respondents (n=77)

Activity	% of Respondents
Earth Observation	52
Telecommunications	30
Navigation	17
Space segment technology	29
Ground segment technology	21
Science	22
Microgravity	3
Exploration	22

Source: Survey of the Canadian Space Industry, 2015.

Since the primary objective of the survey was to collect data on the follow-on business resulting from ESA contracts, we were hoping to achieve good coverage of the companies that had participated in ESA programmes. The 25 responses from companies with ESA contracts account for a high dollar volume of contracts. Of the total of \$114.2 million in ESA contract awarded to Canadian companies from 2009 to 2013¹¹, the companies that completed the survey accounted for \$104.9 million, or 92%. This high level of coverage is due to the fact that most of the companies that had obtained the majority of ESA contract dollars were interviewed, which provided an opportunity to encourage them to also complete the survey.

¹¹ Note this excludes the value of contracts awarded to universities and OGDs.

3.2.2.4 *Economic Impact Assessment*

The economic impact of the ESA Agreement over the period 2009-13¹² results from two sources: i) the direct value of work funded by ESA that is performed by Canadian companies¹³, and ii) the spinoff work that those companies obtain as a result of the increased capabilities, connections, and reputation they acquire from their ESA work.

The value of work funded by ESA is tracked by ESA and known accurately. The value of spinoff work was estimated using the results of the survey conducted for this evaluation. Companies were asked to estimate the value of spinoff revenues resulting from their ESA work over three time periods: 2003 to 2008, 2009 to 2014, and 2015 to 2020. This extended period was used because it can take some time before spinoff benefits are realized.

It is recognized that even if the ESA work made a difference in the company's subsequent business opportunities, some fraction of those opportunities should logically be attributable to other programs, funding sources, organizations or stimulants. To the extent these other sources can be identified, they should share in the allocation of impacts and benefits associated with the ESA work. Therefore, companies were also asked to estimate how much of the value of their spinoff estimates should be attributed to their ESA work. The product of the estimated spinoffs and the attribution factor is the attributable ESA spinoff revenues.

The ratio of the ESA work to attributable ESA spinoff revenues is the spinoff multiplier. This multiplier was then used to calculate the spinoffs for the study period of 2009 to 2013. A number of factors influence the accuracy of the spinoff multiplier estimate. The greatest problem is the ability of respondents to estimate the revenue, past and future, resulting from their ESA work, and in particular the attribution factor. However, working in favour of the estimate is the excellent survey response rate (described above in the survey section), with 92% of the value of the ESA work during the evaluation period represented in the responses.

Revenues, however, are not equivalent to economic impact. On the one hand, factors such as imports of materials act to leak some of revenues out of the economy, reducing the impacts. On the other hand, purchases of goods and services by the space companies and their employees act to magnify the impacts and spread them through the rest of the economy (called indirect and induced impacts). An input-output economic model was used to calculate these effects.

¹² As noted previously, the time period of the evaluation as per TBS requirements five years from the last evaluation – April 2009 to December 2014. However, the ESA and Federal Government of Canada fiscal years do not align with ESA's fiscal year running from January to December and the federal fiscal year running from April to March. The evaluation has used ESA data for January 2009 to December 2013.

¹³ This work may be directly for ESA or as a subcontractor to another organization that holds an ESA contract.

Input-output tables describe the dollar value flows of commodities between industry, persons, government, and foreigners. An input-output model is developed by converting a set of input-output tables into input-output matrixes and vectors, and then using matrix algebra to define the model's algorithm. The model's vectors are changed (initial shock) and the algorithm computes the economic impact on industries. An economic impact using an input-output model can be disaggregated into three effects: direct effects, indirect effects, and induced effects:

- Direct Effects – The industrial change that occurs resulting from the initial shock (in this case, the value of the ESA work in Canada). The initial shock is broken down between the region's production, international imports, taxes, and inter-regional imports.
- Indirect Effects – The resulting industrial change from the increase in inputs required to produce the commodities of the directly affected industries. This is an iterative calculation since each supplying industry will also require inputs, and so on. At each iteration, 'leakages' are removed from the region in the form of taxes and international and inter-regional imports.
- Induced Effects – Direct and indirect effects generate labour income for households (i.e., wages and salaries), which can either be saved or used to purchase consumer products. Saving is a leakage to the flow of income in the economy. Spending this income will create more demand for both domestic and international commodities, which in turn will generate more industrial production and labour income. This cycle continues until the leakages erode the flow of income to zero.

The direct, indirect and induced effects can be translated using fixed ratios into other economic indicators, including: employment, GDP, labour income, and taxes:

- GDP: The value added of the goods and services produced.
- Employment: Results for employment are based on FTE after adjustments for part-time and seasonal workers.
- Labour Income: Wages and salaries are recorded on a gross basis, before deductions for taxes.
- Taxes: Taxes include components paid to federal, provincial, and municipal levels of government.

To calculate the results contained here, the input-output model of Policy Models Corporation¹⁴ was used.

¹⁴ For brief background on the models see <http://policymodels.com>

3.3 Limitations

Most interviewees have a vested interest in the Agreement. With the exception of interviewees from companies that had not obtained ESA contracts over the years, all interviewees had an interest in the continuation of the Agreement. This limitation has been mitigated by requiring interviewees to explain their perspectives and provide examples where appropriate. In terms of the overall report, the findings from the key informant interviews were triangulated with findings from other data sources (survey, document review, ESA data, financial data and economic analysis).

There is only limited data available for the various ESA programme families. Where available we have provided quantitative data disaggregated by programme family. For qualitative information, we have, where applicable, provided information for certain programme families.

Beyond the data provided to the CSA by ESA, there was little additional performance measurement data available. The program has only recently developed its PM Strategy (September 2014) and it has not yet been fully operationalized. As a result, the data presented in this report generally does not reflect trends (e.g., increased or maintained) because there is no comparator.

4 Results

This chapter presents evaluation findings related to the relevance and performance of the International Market Access Program.

4.1 Relevance

The relevance of the International Market Access Program was evaluated with regard to: 1) the extent to which there is a continued need for the program to support the Canadian space industry; 2) the linkages between program objectives and federal priorities; and, 3) the role and responsibilities for the federal government in facilitating market access by the Canadian space sector to ESA contracts.

4.1.1 Continued Need for the Program

4.1.1.1 Current and Anticipated Need for the Program

Based on the information obtained through the various lines of evidence, there is an ongoing need to support the Canadian space industry via the Canada/ESA Cooperation Agreement. The Agreement responds well to the current and anticipated needs of the Canadian space sector. It does this by facilitating access to the European public sector space market and supporting the research and development (R&D) needs of Canadian space organizations by providing industry the opportunity to develop, refine and “fly” their technologies. The program also aligns with a need for space data for research and applications for scientists and OGDs.

The Canadian space sector is an integral part of Canada’s economy and plays an important role in our society. Canada’s space industry provides about 8,000 highly skilled jobs and contributes \$3.33 billion to Canada’s economy each year.¹⁵ A competitive and innovative Canadian space sector is important for continued job creation and the growth of infrastructure for a knowledge-based economy.¹⁶ The skills the industry requires are those of an advanced, knowledge-based economy. The jobs it creates are demanding and rewarding. And the profits it generates domestically and through international sales and partnership is a significant benefit to the national economy.¹⁷

According to the Organisation for Economic Co-operation and Development (OECD), the space sector remains an R&D intensive, leading edge sector and a source of innovation, as demonstrated by recent case studies conducted by the OECD, one of which was Canadian. The Canadian case study, based on survey results from the space industry (including aerospace), concluded that in 2012 space manufacturing was close to six times more R&D intensive than total manufacturing. The study found

¹⁵ Canadian Space Policy Framework, Canadian Space Agency, February 7, 2014.

¹⁶ Ibid.

¹⁷ Ibid.

that the space sector outperformed other key R&D sectors such as pharmaceuticals, automobile and parts manufacturing.¹⁸

Some interviewees noted that the space sector tends to be highly protectionist, particularly for public sector contracts, and a few further noted that the US market in particular has become more challenging in recent years as a direct result of “buy American” policies and the International Traffic in Arms Regulations (ITAR), making access to the European market all the more critical for the Canadian space sector. The protectionist nature of the space sector means that without the ESA Agreement, Canadian firms would have very limited access to the European market.

In all countries, the role of government remains essential as a source of initial funding for public space R&D as well as a major anchor customer for many space products and services.¹⁹ When Canada signed the first Agreement with ESA in the 1970s, only a small number of countries had the capacity to build and launch a spacecraft. There are now an increasing number of countries and corporate players across a wide range of industrial sectors engaged in space-related activities, and this is expected to continue over the coming years. Despite the global economic downturn, institutional funding for space remained stable in 2013 on a global scale, with increased budgets in several OECD countries and emerging economies.²⁰

Representatives from universities and private sector companies with ESA contracts noted that the size, complexity and cost of space projects/missions are such that no one country can realistically undertake many of them on its own. Being able to collaborate with ESA allows the Canadian space sector to participate in large-scale projects that Canada could not afford to undertake on its own. The Agreement is seen as providing a mechanism and structure for collaboration on large-scale space projects. The OECD echoes this perspective, noting that joint institutional programs provide an excellent way to develop and use national expertise and scientific capabilities, while sharing financial burdens in large-scale projects that would have been impossible to launch individually.²¹ The Aerospace Review also noted the importance of international collaboration in space projects remarking that collaboration allows for the sharing of the risks, costs and benefits of developing, manufacturing and operating space assets.²²

Through participation in ESA programmes, Canadian organizations have the opportunity to be involved in the development of advanced space-borne instruments and sub-systems and user-oriented applications. It ensures Canadian access to ESA space data and positions Canadian industry and scientists to participate in future European space, scientific and technological developments related to

¹⁸ OECD, Space Economy at a Glance, 2014.

¹⁹ Ibid.

²⁰ Ibid.

²¹ Ibid.

²² Industry Canada, Aerospace Review Volume 2: Reaching Higher: Canada’s Interests and Future in Space, November 2012.

planetary exploration and life and physical science programmes. For example, through participation in the ESA ARTES programme, the Canadian space industry will continue to be involved in developing new satellite technologies, equipment and applications.²³

Canadian companies interviewed reported that opportunities to flight test and/or space qualify their technologies are critical to their R&D process and overall commercial success. Given the limited number of opportunities to flight test or space qualify their technologies on Canadian missions, they stated that it is highly beneficial to have the opportunity to participate in ESA-led missions.

Interviewees representing OGDs, specifically data users, noted the need for access to ESA data. They also noted that while ESA data will increasingly be available to everyone (i.e., whether their country is a member of ESA or not) at no cost, Canadian government scientists highly value the privileges associated with Canada's membership, e.g., they have the opportunity to influence mission requirements (e.g., to ensure an Earth observation satellite's footprint covers Canada) and have early access to data and models.

Most interviewees stated that the needs for the program have not diminished over time while a few interviewees reported that the needs have increased in recent years as a result of increased protectionism in the space sector, the decreased number of CSA space missions and increased activity in the area of space research.

4.1.1.2 Potential Impact of Non-Renewal of the Canada/ESA Cooperation Agreement

Interviewees generally agreed that the loss (or non-renewal) of the Canada/ESA Cooperation Agreement would be detrimental to the Canadian space sector. Canada is seen as having a privileged relationship with ESA – one that other non-European countries have sought (unsuccessfully to date).

Interviewees agreed that there would be a loss of business and research opportunities as a result of loss of Canada's privileged access to the European market. Without the Agreement, Canadian organizations would no longer be eligible to bid on ESA contracts, build working relationships with their ESA partners, and develop longer-term opportunities in Europe. For example, one company estimates that approximately 60 to 70% of its annual revenues depend on ESA. Loss of access to ESA projects would also, according to interviewees, result in a loss of flight opportunities for Canadian technologies and thus further erode the competitiveness of Canadian space technologies and products.

In addition to the business impacts resulting from the loss of the Canada/ESA Cooperation Agreement, interviewees representing universities and OGDs predicted the loss of research and data sharing. For example, one university representative believes that the loss of the Agreement would mean that his

²³ CSA 2013-14 Report on Plans and Priorities.

university would lose its investment in SWARM²⁴ made over the past ten years. OGDs that are dependent on ESA data only available for purchase (i.e., not available via open source) predict they would be forced to pay for the data or have less privileged access.

Non-renewal of the Agreement would, according to CSA representatives, have political implications with respect to Canada's relationship with Europe. Ending three decades of collaboration with ESA could be seen as somewhat inconsistent with the recent signing of the Canada-EU Free Trade Agreement (note this agreement has not yet been ratified). In addition, interviewees agreed that should Canada not renew its Agreement with ESA then it would lose any possibility of negotiating a similar agreement in the future.

4.1.1.3 Anticipated Impact of the Canada-EU Free Trade Agreement

Although the Canada-EU Free Trade Agreement has not yet been ratified, there is evidence that it will affect the Canadian space sector. Canadian firms will be able to bid on EU space contracts, however, EU firms will also be able to bid on Canadian space projects. ESA is not part of the EU and so is not bound by the Free Trade Agreement in terms of procurement policy. However, in the context of the evolving relationship between the EU and ESA, the Free Trade Agreement may serve to provide more clarity to the position of Canada within the EU and ESA relationship.

The European space environment is complex. ESA follows the European Space Policy, jointly prepared by the European Commission and ESA, and endorsed by the Space Council (joint EU-ESA body) in 2007. The ESA Council at the Ministerial Level, which usually meets every three years, contributes to the implementation of the policy. During this Council, ministers from Member States decide which projects will be funded and how.

The increasing cooperation between the EU and ESA in European programmes has led to complex issues related to the coexistence of different contract award principles between the two organizations. ESA programmes are based on a redistribution model where Member States achieve an adequate return on their investments. This geo-return principle has been instrumental in motivating European countries to invest in ESA programmes, but conflicts with the EU's open competition principles. In a resolution adopted in November 2012, the ministers of ESA Member States requested further evolution of ESA to provide efficient management of EU-funded programmes under EU-rule (i.e., without geographic return)

²⁴ Swarm is ESA's first constellation of satellites to advance our understanding of how Earth works. Harnessing European and Canadian technological excellence, the three Swarm satellites will measure precisely the magnetic signals that stem from Earth's core, mantle, crust and oceans, as well as its ionosphere and magnetosphere. http://www.esa.int/Our_Activities/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers/Swarm/ESA_s_magnetic_field_mission_Swarm

and give a clear mandate to the ESA director general to ensure coherence and coordination between the respective processes on both the ESA and EU sides.²⁵

A few interviewees, including representatives of companies with ESA contracts and the CSA, anticipate that the Canada-EU Free Trade Agreement may be beneficial for the Canadian space sector because the Canadian industry is focused on both developing and building technologies as well as downstream products and services. Thus the combination of the Canada/ESA Cooperation Agreement and the Canada-EU Free Trade Agreement might position Canadian companies to both develop technologies for ESA and to undertake activities such as managing ground stations. However, as noted above, it is also critical to recognize that while Canadian companies will be better positioned to compete for work in the EU market, EU companies will also be competing for contracts in the Canadian market. Based on responses to interview questions, in which some company representatives indicated that they were not sure of the likely impacts of the Canada-EU Free Trade Agreement, there is evidence from the key informant interviews that many companies are not fully aware of the implications of the Canada-EU Free Trade Agreement.

Currently 50% of spacecraft and associated components are duty free between Canada and the EU. If ratified, this percentage will increase to 98% within seven years of ratification. As a result, almost all spacecraft and associated components bought and sold between Canada and the EU will be duty free. This will open the EU market to Canadian organizations but will also open the Canadian market to EU organizations, thereby increasing competition overall.

4.1.2 Alignment with Federal Priorities

The evidence indicates that the International Market Access Program aligns with federal government priorities.

The stated objectives of the International Market Access Program align well with two of the four spending areas of the Government of Canada.²⁶ The strategic outcome of the Government of Canada under the Economic Affairs spending envelope is “an innovative and knowledge-based economy: Program activities aim to prepare Canada for future challenges by investing in innovative research and development and in specialized education and training”. The International Affairs outcome is “a prosperous Canada through global commerce: Program activities aim to promote and sustain international trade and investment for Canada and Canadian businesses through the promotion of Canadian goods and services abroad, the negotiation of international trade agreements, and the regulation of Canadian products to meet international market requirements”.

The International Market Access Program’s stated objective is “facilitating foreign market access by the Canadian space industry through negotiating, implementing and managing special international

²⁵ EuroConsult, Profiles of Government Space Programs, 2014.

²⁶ Descriptors for Government of Canada Outcome Areas, Treasury Board of Canada Secretariat, 2014-07-11.

arrangements.” In return for CSA monetary contributions to ESA under the Canada/ESA Cooperation Agreement, Canadian industry obtains some of the contracts awarded by ESA, thus penetrating a market that would otherwise be limited to Europeans.²⁷ Through the involvement of Canadian organizations’ participation in ESA programmes, the International Market Access Program supports an innovative and knowledge based economy and a prosperous Canada through global commerce.

Representatives from the CSA and OGDs agreed that the program aligns with federal government priorities as contained in the Space Policy Framework. Specific elements of the Space Policy Framework with which the program aligns are positioning the private sector at the forefront of space activities; progress through partnerships; and excellence in key capabilities.

Although there was agreement that the International Market Access Program aligns well with the Space Policy Framework, a few CSA representatives noted that the alignment is better for some ESA programmes in which Canada participates than others. Specifically, one interviewee noted that there is good alignment for Satellite Communications and to a lesser extent Earth Observation because Canada has significant strengths in these areas and a history of commercializing technologies in these areas. The ELIPS programme has had challenges in meeting the geo-return target despite Canada’s demonstrated technical and industrial strengths in the relevant niche areas.

The International Market Access Program also aligns with the recently released Science, Technology and Innovation Strategy (2014). The Strategy contains three pillars, one of which is innovation. The innovation pillar fosters business innovation “in building synergies with Canada’s research capacities and in using its skilled and innovative workforce.” The Strategy encourages businesses to work with partners and the need to enhance Canada’s access to global markets. The program aligns with this pillar through its objectives linking to Canadian scientists’ participation in European space projects, accessing data made available through ESA and opening the European space market to Canadian organizations.

Some interviewees made the linkage to R&D and technological development by noting that participation in ESA provides Canadian firms with increased opportunity to flight test their technologies. Flight testing of technologies is a critical step in the commercialization process for space technologies.

4.1.3 Alignment with Federal Roles and Responsibilities

The *Canadian Space Agency Act (1990)* states under Articles 5(3)(c) and 5(3)(d) that “In carrying out its objects, the Agency may: (c) make grants and contributions in support of programs or projects relating to scientific or industrial space research and development and the application of space technology, including projects designed to develop, test, evaluate or apply new or improved processes, products, systems or information relating to space science and technology with a view to determining the commercial potential of that science and technology, but not including any programs or projects relating

²⁷ CSA Report on Plans and Priorities, 2014-2015.

solely to the commercial exploitation of space science or technology; and, (d) cooperate with the space and space-related agencies of other countries in the peaceful use and development of space.”²⁸ The International Market Access Program aligns with the responsibilities of the CSA as reflected in the Act – the program is a contribution program, focused on the space sector, involving a partnership with an international partner and intended to develop the Canadian space sector.

The Canada/ESA Cooperation Agreement has international treaty status and is thus the responsibility of the federal government.

4.2 Performance

This section addresses the evaluation questions related to performance including the achievement of outcomes and economy and efficiency.

4.2.1 Canada’s Geo-Return with ESA

One important element of ESA’s industrial policy is ensuring that all Member States participate in an equitable manner, having regard to their financial contribution, in implementing ESA’s activities and programmes. To achieve that, ESA uses the concept of geo-return in the awarding of contracts. For both the mandatory and optional programmes, ESA aims to award contracts in proportion to each State’s financial contribution. The overall return coefficient is calculated in accordance with the ESA Council Resolution ESA (98)92 Regulation 5, which states that:

The overall return coefficient per Member State shall be calculated by totalling the weighted value of all contracts placed with industry and organizations of that State under each of the Agency’s programmes (or “overall value of contracts”) and then comparing that value with the sum of ideal values (or “overall ideal value”²⁹) for the same programmes for that State.

It should be noted that the return coefficients are cumulative values computed for a given period. The current period covers all contracts awarded since 2000 and until December 2014, but excludes contracts for programmes phases and elements announced at the 2012 Ministerial Council. There are also other exclusions in the current statistics, the most important being the GMES Space Component programme, and the ISS Exploitation programme. All programmes excluded from the current period will be included in the next period.

²⁸ Canadian Space Agency Act, 1990.

²⁹ The ideal value of contracts for a State for a given programme is the sum of all contracts awarded to industry and organizations of all participating States of that programme multiplied by the State’s normalized contribution rate for that programme. The normalized contribution rate used are those in force at the date of calculation of the return coefficient, adjusted to total 100% in cases where the scale of contributions is less or exceeds that figure. Those percentage contributions can be found in the programme declarations in force at the time of calculation.

Canada's participation in ESA programmes is legally binding and ESA's obligation under the industrial policy is to provide a fair overall return over the duration of the programmes. The ESA convention stipulates that the ideal value for the overall return coefficient of a Member State shall always be 1. The convention also states that formal reviews must be done every five years, and that Council shall set a minimum overall return coefficient for each review period. When a Member State's overall coefficient is below that minimum, ESA must take proactive measures to correct the imbalances.

The minimum overall return coefficient set by Council for the 2000-2014 period was 0.96.

As Canada is a Cooperating State and not a full member, the Agreement contains provisions with respect to the industrial return for Canada. The Agreement stipulates that for optional programmes, Canada is entitled to the same treatment as participating States. For the ESA General Budget, Canada is entitled to a "fair industrial return". This last clause was added in 2000 at Canada's request, since Canada was, at the time, under return due mainly to its poor performance in activities financed by the General Budget. At the time, ESA had already taken actions to correct Canada's return: the main action was the award of a contract to a Canadian company to build the first Deep Space Antenna (DSA). This company later obtained contracts to build the second and third antennas, which contributed to Canada's situation of over-return in 2009, at the beginning of the negotiations for the renewal of the agreement. ESA insisted that Canada take actions to bring Canada's return to a more reasonable level. The conclusions of negotiations were that Canada had to make a payment of 7 million euros to ESA.³⁰

Table 9 summarizes Canada's overall return coefficient for 2012 to 2014. Canada's coefficient is well within the minimum set by Council for the current period, and very close to the ideal value of 1.0.

Table 9: Canada's Overall Return Coefficient for 2012 to 2014 (Excluding the ISS Exploitation Programme)

	2012	2013	2014
Overall return coefficient	0.98	0.96	0.99

Source: ESA data.

According to background information provided by the CSA, the statistics on geo-return generally include recharges (when a contract originally accounted for the General Budget is then recharged to a given programme). For example, a significant portion of the ESA contracts awarded to a Canadian company were recharged to the scientific programme (which is mandatory but in which Canada does not participate) or other optional programmes in which Canada does not participate (for example European participation in the International Space Station (ISS) and ISS Exploitation programmes).

³⁰ Note this appears as a large increase in Canada's contribution to the General Budget in Table 1 for 2010-11 and 2011-12 (Financial data).

Background explanations provided by the CSA also note that in 2012, Council decided to exclude the ISS Exploitation programme from the geo-return statistics of the current period and to include them in the next period.³¹ Consequently, as of 2012, statistics are provided including and excluding that programme. Although Canada does not participate in the ISS Exploitation programme, approximately 7 million euros in contracts awarded to Canadian organizations under the General Budget have been recharged to the two main ISS programmes (the other is ISS Participation). This is why removing the ISS Exploitation programme from the statistics has an impact on Canada's overall return. These significant recharges to the two ISS programmes also have the effect of artificially increasing the return coefficient in the Human Space Flight family of programmes, while decreasing the return coefficient for the General Budget/mandatory activities family.

It is also important to note that for many programmes (such as most elements of GSTP and ARTES), the legal documents (declaration or implementing rules) include a guaranteed return of 1.0 at the conclusion of the programme. This means that a retroactive adjustment of contributions (additional contribution or reimbursement of contribution) will be performed at the end of the programme so that all participating States achieve a return coefficient of 1.0. For these programmes, the ideal value is set to the value of contracts awarded, to avoid creating temporary imbalances that would eventually be corrected at the end of the programme. This is why so many of the programmes have a geo-return coefficient of 1.0.

It is also worth noting that Canada's return coefficient for the General Budget is very low, however, CSA interviewees report that this is acceptable for mandatory activities. Mandatory activities include the basic activities of the General Budget, the Technology Research Programme (TRP) and the Science programme. Canada does not participate in the TRP or the Science programme and so the ideal value of contracts for Canada under these programme areas is zero. Since a large portion of the DSA contracts have been recharged to the Scientific programme (over 10 million euros since 2000), the CSA usually considers the return coefficient for mandatory activities to assess whether Canada is achieving a fair industrial return under the General Budget.

Canada's geo-return overall and by programme family and programme in which Canada participates for 2003 to 2014 is presented in Appendix C.

4.2.2 Achievement of Immediate Outcomes

This section presents evaluation findings related to the achievement of immediate outcomes, specifically:

- Enhanced decision-making process and policy development in the CSA and OGDs; and
- Maintained or increased Canadian participation to scientific teams selected by ESA.

³¹ As reflected in documents ESA/C(2012)124 and ESA/IPC(2012)40,rev.3.

Findings for a third immediate outcome, Canadian space organizations are awarded contracts in ESA programmes and activities, is addressed below in section 4.2.5.1.

4.2.2.1 Enhanced Decision-Making

There was near consensus among CSA and OGD representatives interviewed that Canada's participation in ESA Programme Boards and horizontal committees provides the CSA and OGDs with invaluable information and intelligence. Specifically, CSA interviewees indicated that Canada's participation on ESA boards and committees (i.e., decisional boards and committees) provides Canada with information on market trends, plans of ESA Member States, and technological information, among other things. Much of the information obtained is not public or published information and would thus be unavailable otherwise. Similarly, Canadian scientists who participate on ESA's scientific advisory groups and committees obtain intelligence or background information concerning ESA data which aids in the understanding and interpretation of the data.

Interviewees representing the CSA and OGDs agreed that the intelligence reports obtained through Canada's participation on ESA boards and committees are useful in decision-making and policy development. By being part of ESA boards and committees, Canada is aware of the priorities and strategic directions of ESA Member States and thus able to coordinate its international positions. OGDs representatives indicated that although they find the information useful, not all found the information relevant to decision making.

In addition to intelligence reports, a few CSA representatives reported that ESA is also a source of information on project management and contracting. For example, the CSA has access to information on best practices and lessons learned related to project management. The CSA is also able to obtain information on the costing of some projects/contracts which it can use to improve cost estimates when issuing its own Requests for Proposals (RFPs).

Although some CSA representatives noted the difficulty in linking or attributing a specific decision to information, intelligence or reports obtained through participation in ESA, the majority of interviewees noted the important contribution made by this information. A few CSA representatives were able to provide specific examples where ESA intelligence contributed to decision-making. For example:

- The United Kingdom (UK) has been actively developing its space policy and space industry in recent years. During the Thatcher era funding for space in the UK was seriously curtailed and the industry is now being rebuilt. The UK is very focused on specific areas, including satellite communications, navigation and downstream technologies which are also of interest to Canada. The close working relationship and network built between Canada and the UK through participation in ESA is facilitating the exchange of information.

- The CSA is using research produced for ESA on the return on investment from space science. The research is not publicly available and so without participation in ESA, Canada would not have access to this and would have to pay for its own research.
- Information contributes to building bilateral relationships by providing the CSA/Government of Canada with information on what other space agencies would like to do as well as what they are able to do.

4.2.2.2 Canadians Participating on ESA Scientific Teams

There is evidence from the review of documentation and key informant interviews that Canadian scientists are participating on ESA scientific teams and are making a contribution. However, it should be noted that Canada contributes a very small percentage of total funding to ESA and to ESA programmes and so it is unrealistic to expect Canadians scientists to play a deciding role in ESA projects. It should be further noted that Canada does not participate in ESA's Science programme.

Canadian universities have a small, but internationally-recognized cadre of space scientists who are contributing to Earth observation, planetary exploration, space astronomy, and understanding of the universe. Canadian space universities have expertise in planetary exploration and modeling, analogue field science, data analysis and science instrument development.³²

According to CSA, OGD and university interviewees, Canadian scientists are well represented on the scientific teams selected by ESA for specific ESA programmes, including those in which Canada participates (i.e., optional programmes to which Canada contributes financially) and those in which it does not participate. There are few scientists involved in GSTP and Satellite Communications and a larger number involved in Earth Observation and Human Microgravity and Exploration (HME). According to interviewees familiar with EO and HME, Canadian scientists are well represented on the teams, relative to Canada's funding to the programmes. It is worthwhile noting that ESA does not fund scientists who participate on its science teams; instead, they are funded by their respective national organizations (e.g., universities, granting councils, research institutes), while ESA provides the platform, data, etc.

There was agreement among CSA, OGDs and university representatives interviewed that Canadian scientists are making meaningful contributions to ESA scientific teams relative to Canada's financial contribution. For example, there are Canadian scientists on the landing site selection committee for ExoMars, and the Canadian scientists involved are considered by the university representatives interviewed to be of a very high calibre. Another example cited by interviewees is Canada's contributions to the SWARM mission through a Canadian scientist.

A list of ESA science teams with Canadian members is provided in Appendix D.

³² Aerospace Review, *Space Working Group Report*, September 2012.

4.2.3 Achievement of Intermediate Outcomes

This section presents evaluation findings related to the achievement of intermediate outcomes as depicted in the logic model, specifically:

- Canadian space organizations maintained/increased the number of alliances with European industry to supply their technologies, products and services;
- Maintained/increased technological capabilities of Canadian space organizations, including space qualification and flight opportunities for Canadian technologies/hardware/applications; and
- Maintained/increased number of Canadian OGDs and scientists with access to data/infrastructure that meet their needs.

4.2.3.1 Alliances with European Industry

There is evidence from the survey of organizations with ESA contracts and key informant interviews that Canadian space organizations have formed alliances with the European space industry to supply their technologies, products and services. These relationships have been formed and have evolved over a number of years, i.e., these alliances have not necessarily been formed during the 2009-2014 period.

There was agreement among interviewees representing the CSA, universities and private sector companies with ESA contracts that Canadian organizations have teamed up with European partners on ESA contracts. Although sometimes the Canadian organization is the lead, most often Canadian organizations are subcontractors.

There was agreement among interviewees representing the CSA, universities and companies with ESA contracts that in most cases once the working relationship is established on one project, the relationship is carried over into other projects for ESA or other clients. CSA representatives interviewed noted some differences across the ESA programme families in terms of Canadian organizations' relationships with European companies.

For the Satellite Communications and Space Exploration programme families, interviewees reported that Canadian companies' ability to partner with European firms allows for the integration of Canadian technologies and products with those of European firms. This has led to long-term collaborative relationships. A few interviewees noted that Canadian companies tend to have critical technologies that are of interest to European primes. Once the technologies are integrated, the relationships tend to become long term. A few representatives from companies with ESA contracts reported that sometimes European firms approach Canadian firms because of their unique expertise.

For Earth Observation programmes, a few Canadian firms have set up offices (or are in the process of doing so) in the UK and this has allowed them to bid on UK projects (outside of the Canada/ESA Cooperation Agreement). According to one CSA representative much of the "brainwork" is still being

done in Canada. However this interviewee noted that there is a risk of technologies being exported to the UK and that these companies might effectively become European companies.

The survey of companies with ESA contracts asked what benefits, if any, had resulted from their involvement in ESA projects. Each potential benefit was rated on a scale from 1 to 5, where 1 is “very small” benefit” and 5 is “very large” benefit. The results are presented in Table 10.

Overall, the majority of companies that had obtained ESA contracts stated that their involvement in ESA projects had helped them to form new alliances/partnerships (second item in Table 10). 71% of respondents rated this benefit as large (4 or 5 on the 5-point scale).

Table 10: Rating of Benefits from Participating in ESA Projects

Benefits	Mean Rating (1 to 5)	% Agree (4 or 5)	% Disagree (1 or 2)	n
Addition of new skills and capacities	4.2	79%	13%	24
Formation of new alliances/partnerships	4.1	71%	4%	24
Development of new technologies or systems	3.9	79%	17%	24
Development of new products and services	3.8	67%	13%	24
Access to new markets in Europe	3.3	50%	38%	24
Access to new markets outside of Europe	2.6	30%	65%	23

Source: Survey of the Canadian Space Industry, 2015.

Evidence from the key informant interviews indicates that in general Canadian organizations serve as subcontractors and rarely as primes (although on occasion a Canadian company may be the prime for a major component of a satellite, for example, and will have subcontracts with supplier companies around the world). Much of this is because Canada does not contribute a sufficient amount of funding to ESA to allow Canadian firms to bid on large projects where they would act as prime contractors.

4.2.3.2 Increased Technological Capacity

There is evidence from the key informant interviews and from performance measurement information collected by the program team that participation in the Canada/ESA Cooperation Agreement has provided Canadian space organizations with the opportunity to maintain their technological capability. This is seen by interviewees as particularly important given the limited opportunities to flight test technologies within Canada.

Interviewees representing the CSA, universities and companies with ESA contracts were able to provide specific examples of Canadian technologies/products supported through ESA programmes that have resulted in an increased TRL. There is strong evidence from the interviews that participation in ESA is serving to increase the TRL of Canadian space products and technologies. Examples include:

- Development of an infrared detector with Rutherford Appleton Laboratories in the UK. The Canadian company did the quality assurance and quality control aspects. It is currently at TRL 6 and will be on the Earth Explorer Launch in 2018, moving it to TRL 7.
- For the ExoMars Rover, a Canadian company building certain components for the rover will achieve TRL 9 when the mission reaches Mars in 2019 and the rover becomes operational.
- A Canadian company work related to ENVISAT, which is a satellite orbiting the Earth that ESA has lost contact with. Interviewees report that this satellite will eventually crash into the Earth. This company has obtained study contracts with ESA ("e.Deorbit"), whereby an orbiter would go up and "grab" ENVISAT and bring it back to low altitude, to dump it safely into the ocean. Although this company played a relatively small role on this project, this work has allowed this company to reach TRL 4-5.

A definition of the various levels of technology readiness may be found in Appendix E.

Interviewees representing companies with ESA contracts were able to provide specific examples of new products or services generated as a result of ESA contracts. University representatives, although able to provide examples of the increased technological and human capacity that have resulted from their participation in ESA, were less able to provide examples of new products or services. Specific examples of new products or services generated as a result of ESA contracts provided by interviewees include:

- Infrared detector was initially funded through ESA GSTP programme, then the CSA provided funding under the STDP program and the product was bought by the Argentinian Space Agency and is currently in orbit.
- Altitude Control and Navigation System (ACNS). The ACNS software was first validated in orbit on the ESA autonomous satellite PROBA-1 launched in October 2001. The second generation of the ACNS software is performing its Sun observation mission since the PROBA-2 launch in November 2009. Following the success of PROBA-1 and PROBA-2, different versions of the autonomous ACNS software are being developed, among them, the Guidance and Navigation Control (GNC) software for the PROBA-V and PROBA-3 missions, two ESA technology-demonstration missions, as well as for the Sentinel-3 mission, a major operational mission.
- Autonomous Planetary Landing System (APLS). The APLS software developed for the ESA and the CSA makes it possible for a space probe to recognize and avoid obstacles on the surface of a celestial body and to safely land on a secure site with high accuracy. APLS is currently used in the design of the Mars Sample Return mission, the NEXT Lunar Lander mission and the Lunar Exploration Light Rover (LELR).
- A company has developed a "network of sensors", which are being applied on the current contract with the German Aerospace Center.
- Development of deep space antennas which has led to the development of design-related expertise, multi-band antennas, and has led to contracts outside of ESA, such as with Indian Space Research Organization (ISRO). This company has also obtained work with the Chinese

Space Agency to help them with the design of deep space antennas, e.g., how to design the antenna to withstand an earthquake.

There was agreement among interviewees representing universities and companies with ESA contracts on the importance of having the opportunity to space qualify the organization's technologies. As explained by one interviewee, putting a company's products into space is very prestigious and good advertising. A few interviewees noted that the opportunity to space qualify their products in Canada is extremely limited because of the limited investment on the part of the CSA into space missions. According to the performance targets set by the program, four Canadian components/technologies flew on ESA missions by the end of 2013-14 compared to a target of five over the duration of the Agreement (to December 2019). The four components/technologies flew on three different missions (Alphasat, PROBA-2 and SWARM), and involved three companies and one university.

There was agreement among representatives from companies with ESA contracts and universities that participation in ESA contracts is an important mechanism for increasing their technological capacity. University and company representatives were able to provide specific examples of how their technological capacity has been increased as a result of work undertaken for ESA. Specific examples provided include:

- Prior to their first involvement in ESA projects, the company was an optical instruments company with no involvement in the space sector. Their ability to participate in ESA projects under the Agreement was the key factor that allowed the company to develop a space capability and to provide services to other space agencies like the National Aeronautics and Space Administration (NASA – United States), the Japanese Aerospace Exploration Agency (JAXA – Japan), the Centre national d'études spatiales (CNES – France), and the Deutsches Zentrum für Luft (DLR – Germany), etc.
- Work done in developing NEST and the Sentinel-1 toolbox has enhanced the company's technical capacity and allowed them to win work with multiple Canadian federal agencies (Agriculture Canada, Forestry, etc.).
- The ENVISAT-related work has enabled a Canadian company to build on the Canadarm and Dextre technologies.
- The ExoMars work has enabled a Canadian company to build its capability in rover systems, which could have applications in future space missions and terrestrial systems.

4.2.3.3 Access to Data by Canadian Scientists and OGDs

There is evidence from the key informant interviews that Canadian scientists are accessing ESA data and that the data is meeting their needs.

There are essentially two types of users of ESA data: researchers (mostly university scientists) who participate in scientific research projects; and scientists (mostly in federal government departments)

who use ESA data for modelling. For example, one interviewee explained that Canada's participation in the Human Space Flight and Microgravity programme was stimulated by researchers: ESA has access to missions and projects that are of interest to Canadian researchers. As an example of using ESA data for modelling, Environment Canada interviewees noted that the data is used to develop more accurate forecasting models for weather prediction.

Interviewees representing the CSA, universities and OGDs agreed that participation in ESA has enabled Canadian scientists and OGDs to access space data (both for research purposes and as input for modelling and forecasting) from ESA programmes, with the exception of the Satellite Communications programme family which tends not to generate data for use in scientific research or other applications. For example, the OECD notes that meteorology was the first scientific discipline to use space capabilities in the 1960s, and today satellites provide observations of the state of the atmosphere and ocean surface for the preparation of weather analyses, forecasts, advisories and warnings, for climate monitoring and environmental activities. Currently approximately three quarters of the data used in numerical weather prediction models depend on satellite measurements.³³

Although ESA is increasingly making its data available to all (i.e., open source), thus making participation in ESA less critical in terms of access to ESA data, a few interviewees who are users of data reported that participation in ESA allows for privileged access to the data. This is particularly true for users of scientific data, where Canadian participation in ESA allows Canadian scientists access to the data as well as the background information to help in interpreting the data.

Representatives from the CSA, universities and government organizations were able to provide examples of scientific teams and government departments that have benefited from access to ESA space data and infrastructure. Examples include:

- Data from ESA's SWARM project are the basis for scientific projects being pursued by at least six researchers at a Canadian university, including students, postdoctoral researchers and faculty.
- The Canadian Ice Service is the primary user of data via C Band and Synthetic Aperture Radar (SAR), as the technology is particularly good at detecting/measuring ice. This has been a huge benefit, saving millions of dollars because otherwise the data would need to be collected by aircraft covering thousands of square kilometers.

4.2.4 Achievement of Ultimate Outcomes

This section presents evaluation findings related to the achievement of ultimate outcomes as depicted in the logic model, specifically:

- Maintained/increased competitiveness of Canadian space organizations in European and global space markets; and

³³ OECD, Space Economy at a Glance, 2014.

- Maintained/increased capacity of Canadian space organizations to successfully meet the requirements of Canadian space endeavors.

4.2.4.1 Increased Competitiveness

Although there is evidence that Canada's participation in ESA programmes has contributed to increasing the competitiveness of the Canadian space sector, there is also evidence that some ESA programmes provide more potential to benefit from commercial opportunities. Satellite communications and Earth observation technologies have been particularly strong areas for Canadian organizations and there is evidence that participation in ESA has contributed to increasing or maintaining competitiveness. The ability to partner and integrate Canadian technologies into European technologies has been critical. Although the International Market Access Program has been successful at contributing to the increased competitiveness of Canadian organizations, particularly in the European market, there is also evidence that the program could have achieved more success with additional funding.

The exact number of Canadian companies that export space-related goods to Europe is not available. According to the ESA contracts database, 50 companies, 15 universities and 5 government organizations were awarded ESA contracts between 2009 and 2013.³⁴ This compares to 71 companies, 14 universities, and 7 government organizations that were awarded contracts in the previous five-year period (2004 to 2008). As a result it may be concluded that fewer companies were awarded contracts over the 2009 to 2013 time period relative to 2004 to 2008; however, this does not reflect the overall size of the contracts or the economic impacts resulting from the contracts. Also, some companies may have merged. In any event, the number of contracts is a weak indicator of success.

The European market represented 31% or \$497 million of the total of \$1.58 billion in Canadian space exports in 2012.³⁵ Table 11 summarizes the value of Canadian space sector exports to Europe from 2002 to 2012. Although the global space sector is growing and the most recent statistics in the *State of the Canadian Space Sector* (2012) indicate that the Canadian space sector is relatively healthy with revenues of \$3.327 billion in 2012, these statistics reflect major variations in the growth of the various segments of the industry. According to the Aerospace Review's Space Working Group report (2012), telecommunication's revenues dominate the statistics in the Canadian space sector, accounting for 80% of the sector's revenues and which have increased by 24% over the previous five years. As noted in the Space Working Group's report:

It is important to note that these statistics are dominated by the growing communications satellite services and applications sector, which grew by almost 16% in 2010. The strength of this segment masks a worrying trend in other segments of the space industry. For instance, while the

³⁴ Note the distinction between the number of organizations that were awarded contracts versus the number of organizations that held contracts – the number of organizations that held contracts over the time period is greater since this include contracts issued in previous time periods.

³⁵ CSA, *State of the Canadian Space Sector*, 2012.

services and applications segment has experienced growth in the past five years of 67%, the space segment has only grown by 1%, the research segment by 8% and the ground segment has contracted by 4%.³⁶

Table 11: Value of Canadian Space Sector Exports, Total and Europe (2003-12) (\$ millions)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Europe	269	432	401	323	283	399	408	525	544	497
Total Exports	798	1,208	1,245	1,099	993	1,405	1,491	1,703	1,665	1,584

Source: CSA, *State of the Canadian Space Sector* 2012.

The majority of representatives from the CSA and companies with ESA contracts stated that the Agreement has contributed to identifying new business opportunities and new markets for Canadian organizations. However, some CSA representatives noted that this is truer for some ESA programmes than others.

CSA representatives familiar with Human Microgravity and Exploration (HME) noted that there is not much transferability or commercial potential in the short term, however in the longer term technologies are often transferable to other applications. For example, they noted that the health and life sciences projects that are the focus of the CSA's involvement with ESA have some terrestrial applications in healthcare and thus may eventually become business opportunities for the companies involved. The Space Working Group report (2012) reflects this perspective, noting that space exploration remains a heavily government-driven market, even though many of the state-of-the-art technologies demanded by space exploration are subsequently commercially deployed in other domains both in space and terrestrially.

Canadian Earth observation companies are seen by CSA representatives as being highly competitive internationally. For example, one key technological area of expertise has been in SAR, which has been used in RADARSAT-1 and RADARSAT-2 and is being further developed for the RADARSAT Constellation Mission (RCM) – a technology that was also used in ESA's ERS programme. Companies working in the area of Earth observation are able to sell data commercially and are increasingly providing operational services to the oil and gas industry, commercial shipping, and other resource and environmental customers.³⁷ In 2012 the EO sector represented 19% of the revenues generated by the Canadian space sector.³⁸

³⁶ Aerospace Review, *Space Working Group Report*, September 2012. Accessed on line at: [http://aerospacereview.ca/eic/site/060.nsf/vwapj/5-Space_Working_Group_Report-Sept12-Final-eng.pdf/\\$file/5-Space_Working_Group_Report-Sept12-Final-eng.pdf](http://aerospacereview.ca/eic/site/060.nsf/vwapj/5-Space_Working_Group_Report-Sept12-Final-eng.pdf/$file/5-Space_Working_Group_Report-Sept12-Final-eng.pdf)

³⁷ Aerospace Review, *Space Working Group Report*, September 2012.

³⁸ CSA, *State of the Canadian Space Sector*, 2012.

The satellite communications segment is the most established and commercially-oriented within the space sector, representing 81% of the total revenues generated by the sector.³⁹ However, the Space Working Group Report (2012) notes that the Canadian satellite communications industry is faced with a growing disparity in the global marketplace as international competitors are often better supported by government funding for technology development, risk sharing investments, first-user policies and through more business-friendly regulatory regimes. The issue of other countries providing more financial support to their satellite communications industries was also noted by a few interviewees from the CSA and from companies with ESA contracts. It appears that this has been recently recognized by the federal government, as the 2015 Federal Budget announced \$30M in funding to ARTES over 4 years starting in fiscal year 2016-17 to assist in the commercialization of satellite communications technologies.

Representatives from companies with ESA contracts reported that new business opportunities have been identified in a range of countries including Britain, Belgium, France, Germany, the United States, Canada, China, Vietnam and Japan as well as Latin America and Africa.

Although there is evidence that at least some ESA programmes in which Canada participates have contributed to increased competitiveness of Canadian organizations, there is also evidence that inadequate funding is limiting the ability of Canadian organizations to fully benefit from the opportunities presented by the Agreement. This was noted by CSA representatives and companies with ESA contracts. A few interviewees reported that there have been instances where a Canadian company has the leading-edge technology desired by ESA, however because Canada's funding is limited and because of the geo-return policy, contracts have gone to Canada's European competitors which are then able to build up their expertise relative to Canada. A few interviewees argued that Canada is losing its leading edge, in part because of Canada's declining contribution to ESA.

Canada's contribution to ESA has been decreasing over time while that of some other countries, increasingly seen as strong competitors with Canada, has been increasing. For example, previously the UK invested an average of £170 million a year in ESA and this is slated to rise to an average of £240 million over the period from 2013-14 to 2017-18. Like Canada, the UK space sector has been focused on satellite communications and Earth observation. As noted earlier, the increased investment by the UK has been a factor in prompting some Canadian space companies to establish operations over there.

4.2.4.2 Increased Capacity for Canadian Space Endeavours

Interviewees representing universities and private sector companies with ESA contracts generally agreed that there have been few opportunities to position Canadian space organizations to participate in Canadian space endeavours since there have been very few Canadian missions in recent years. However, CSA and company representatives were able to provide specific examples of instances where

³⁹ Ibid.

participation in ESA programmes positioned Canadian space organization to participate in Canadian space endeavors:

- A company developed a few products for ESA building on robotics and on-orbit servicing – so when the CSA used stimulus funding to develop the next generation Canadarm a lot of what this company had developed for these other (non-CSA projects) was integrated into the CSA project.
- Early investments in SAR, which made Canada a world leader in this technology, enabled Canada to develop RADARSAT. The first investments in SAR developments were made as part of participation in ESA. In the 1980s and 1990s, there was ERS-1 and ERS-2, which were ESA satellites. ERS-1 was launched in 1991. The expertise gained through ESA collaboration was instrumental for RADARSAT-1, which was launched in 1995. The technologies that were developed were then transferred into ENVISAT ASAR and RADARSAT-2, which has continued to the latest Sentinel-1 and the Canadian RCM. These developments enabled a Canadian company to maintain its leadership in SAR processor technology.
- Direct Video Broadcast technology (DVB-RCS) was heavily supported through the ESA Programme. The company which developed this technology has won a number of ESA contracts in recent years. The company has used this technology in other projects in Canada and around the world. The technology is particularly useful to users living in remote communities.

4.2.5 Economic Benefits of the Program

4.2.5.1 Canadian Organizations Awarded ESA Contracts

Although there is clear evidence that Canadian organizations are obtaining ESA contracts and that Canada is benefiting in proportion to its contribution to ESA, as illustrated by Canada's overall return coefficient, the benefits are not broadly dispersed across the Canadian space sector.

According to ESA data provided to Canada, a total of 182 contracts (including sub-contracts) were awarded to Canadian organizations over the time period of the evaluation (2009-13), of which 12 are duplicated in two programme families.⁴⁰ The total weighted value of the contracts was \$102.1 million and the unweighted value was \$122.9 million. We note that ESA's fiscal year and thus data provided to Canada is based on a calendar year (January 1 to December 31) while the CSA data is based on the federal government fiscal year (April 1 to March 31).

The value of contracts summarized in Table 12 does not reflect the actual flow of funds to Canadian organizations between 2009 and 2013, it represents the value of contracts awarded, i.e., a contractual commitment to pay for work undertaken for ESA by Canadian organizations between 2009 and 2013. As such, the work, and thus the flow of payments may be staggered over a number of years and extends beyond 2013. Negative values arise when there are contract amendments (i.e., to decrease the contract

⁴⁰ Canadian Space Agency. (2014). Canada-ESA Cooperation Agreement Commitments from 2009 to 2013, List of ESA Contracts to Canada, 2009-13.

value), re-charging of the contract to another activity, subcontracting of work to another company or when the contract is cancelled.

Table 12: Value and Number of ESA Contracts, by Programme Family, 2009-13

Programme Family	Estimated Value of contracts-un-weighted (\$)	Estimated Value of contracts-weighted (\$)	Value of contracts-un-weighted (Euro)	Value of contracts-weighted (Euro)	Number of contracts
Earth Observation	61,725,677	41,685,648	43,616,697	28,574,550	75
Space Exploration	14,827,079	14,827,079	10,998,857	10,998,857	18
Navigation	(3,065,991)	(3,065,991)	(2,287,875)	(2,287,875)	7
Satellite Communications	10,385,352	10,385,352	6,856,548	6,856,548	30
Microgravity	2,254,304	2,254,304	1,578,613	1,578,613	6
General Technologies	2,051,542	2,051,542	1,402,815	1,402,815	12
General Budget / mandatory activities	33,046,057	32,287,630	21,684,531	21,136,533	40
Other**	1,719,678	1,697,057	1,259,124	1,242,264	6
Total:	122,943,698	102,122,621	85,109,310	69,502,305	194

Source: Canadian Space Agency. (2014). Canada-ESA Cooperation Agreement Commitments from 2009 to 2013, List of ESA Contracts to Canada, 2009-13.

*Due to rounding, amounts may not sum exactly to totals.

**Exchange rates used for conversion of Canadian dollars to Euros are: 2009 – 1.58550; 2010 – 1.36610; 2011 – 1.37670; 2012 – 1.28500; and 2013 – 1.36810 (www.bankofcanada.ca/rates/exchange/annual-average-exchange-rates/).

***Included contracts received under the Launchers and Science programme families, programmes in which Canada does not participate.

While it is clear that Canadian space organizations have benefited from ESA contracts over the past five years (2009-13), the contracts have largely benefited a small number of companies. The top five organizations with respect to the value of ESA contracts over the past five years account for 75% of the total value of ESA contracts obtained by Canadian organizations. Similarly, the top ten organizations account for 85% of the total value of ESA contracts obtained.

It should be noted that a significant portion of the contracts awarded under the Earth Observation programme family were for the purchase of data for third party mission contributions to GMES. Such contracts amount to \$26.5M unweighted, and \$6.9M weighted. The GMES Space component is a programme cofunded by ESA and the EU which included purchase of data from third party missions. All contracts under this programme were awarded by ESA and will be included in the next geo-return statistics period, even if part of the funding comes from the EU.

4.2.5.2 Follow-on Business

According to CSA delegates to ESA, the value of follow-on business to Canadian space companies from their involvement in ESA projects tends to vary by programme. For satellite communications, for example, the return on investment has historically been very positive, but this has changed in recent years. According to interviewees familiar with this ESA programme area, there is considerable demand for Canadian products and services within ESA and the only limiting factor is the amount of funding provided by Canada – which was cut in 2012. There is evidence from the interviews that this may have longer-term implications for the satellite communications sector in Canada because other countries are winning contracts with ESA which previously might have gone to Canadian companies. This means that while other countries are building up their technological capacity and commercial track record, Canadian companies are losing their competitive advantage.

The survey of companies with ESA contracts asked companies to estimate the value of follow-on business resulting from their involvement in ESA projects over the years. Recognizing that many factors (in addition to the ESA contracts) influence a company's success in obtaining follow-on business, they were asked to estimate the percentage of this follow-on business attributable to their ESA programme involvement.

Based on the survey results, companies earned attributable follow-on business that is worth 2.96 times the value of their ESA contracts.⁴¹ This means that the \$114.2 million of private-sector ESA contracts over the 2009 to 2013 timeframe examined by this evaluation will result in \$338.4 million of attributable follow-on business into the future.

4.2.5.3 Direct, Indirect and Induced Impacts

Direct Funding Economic Impact

The value of the direct work is closely monitored by ESA and constrained by ESA's geo-return requirements – in other words, the value of work awarded to Canadian organizations is determined by

⁴¹ This study has found that each dollar of ESA contracts has resulted, on average, in an additional 2.96 dollars of attributable follow-on business for Canadian companies. The resulting multiplier can be calculated in two ways: 1. If the ESA contracts are considered to be a cost to Canada of achieving the follow-on business, the multiplier is 2.96 (Follow-on Business [\$338.4M]/ESA Contracts [\$114.2M]). 2. If the ESA contracts are to be considered as a benefit on top of the follow-on business, the multiplier is 3.96 (Follow-on Business [\$338.4M + ESA Contracts [\$114.2M]]/ESA Contracts [\$114.2M]). Some previous studies have used the second approach. However, the first approach was preferred for the current evaluation in order to calculate the spinoff impacts of the Canada/ESA Cooperation Agreement.

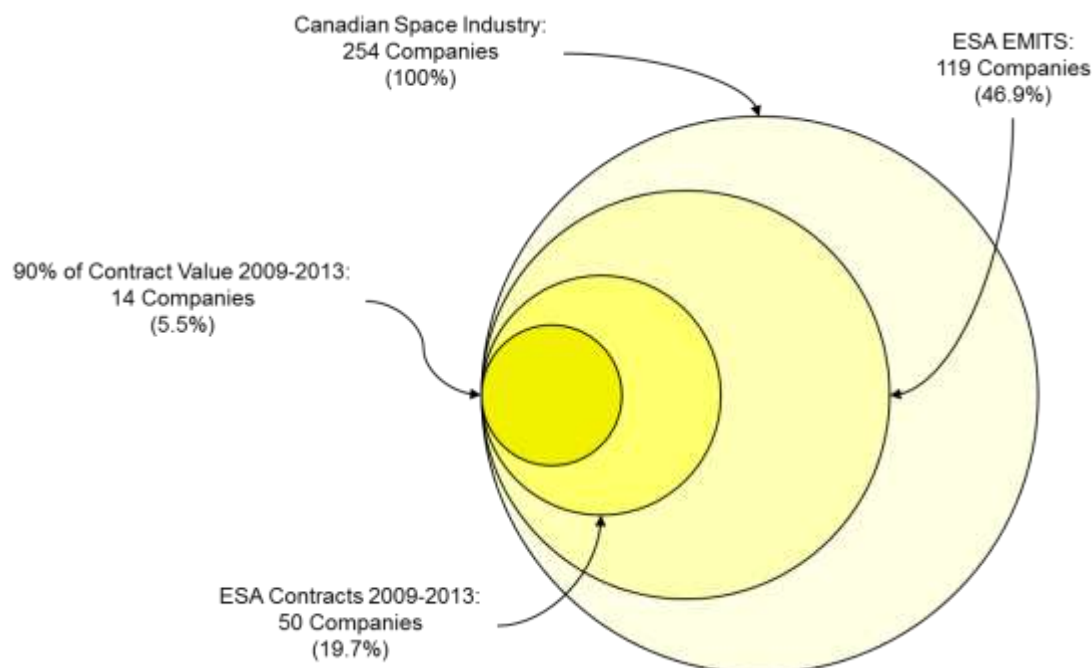
the contribution the Canadian government makes to ESA. Over the period 2000-2014, Canada's geo-return has been 0.996.⁴²

As noted above Canadian companies received \$114.2 million in work from ESA⁴³ between January 2009 and December 2013. Using the input-output economic model, the \$114.2 million in revenue from ESA contracts is estimated to have contributed \$44.4 million to Canada's GDP and 324 person years of employment over 2009 to 2013.

However, receipt of that money was highly concentrated – 14 companies account for 90% of the value of the work. Figure 2 shows the breakdown of who benefited.

⁴² ESA, *Canada: Industrial Involvement in ESA Programmes, situation at end of December 2014*. Provided to evaluation team by ESA representative, March 2015.

⁴³ Government departments and academic institutions also received funding.

Figure 2: Few Canadian Space Companies Participate in ESA Work

This evaluation identified 254 companies involved in the Canadian space sector (largest circle). However, for a variety of reasons not all of these companies are in a position to take advantage of ESA opportunities. The survey conducted for this evaluation found that most companies (82%) were aware of ESA and the opportunity to bid on contracts (63 of the 77 respondents to this question). Of those who were aware of ESA, 6% had participated in bidding on ESA contracts in the past (40 of the 63 respondents to this question). When asked why they had not bid on ESA contracts in the past (n=23), responses were as follows (multiple responses were permitted):

- My company's capabilities are different from the programme areas supported by ESA (30%) (n=7)
- My company has other priorities (35%) (n=8)
- We do not believe we would be competitive (13%) (n=3)
- Other (44%) (n=10).

Responses in the "other" category varied, but a number of companies were new and as a result had not yet pursued ESA opportunities.

One measure of awareness of and interested in pursuing ESA work is the number of companies that have registered with ESA's EMITS registry. A total of 119 companies (46.9%) have registered with EMITS (second circle). (Note this figure is based on our analysis of the companies listed on the online EMITS registry.)

Over the study period, 50 companies (19.7%) have participated in ESA work (third circle). However, the top 14 companies (5.5%) account for over 90% of the value of that work (fourth circle).

Based on the results of the study survey, it is evident that companies that participate in ESA work differ, on average, from the rest of the Canadian space industry.⁴⁴

First, companies with ESA funding tend to be larger (Figure 3). Based on the average number of employees, they are much larger (218 versus 22 employees), but this measure is skewed by a small number of very large firms. However, even the median number of employees is much larger (25 versus 8 employees). This size difference probably accounts for the rest of the differences between companies with and without ESA funding.

Figure 3: Companies with ESA Funding are Larger



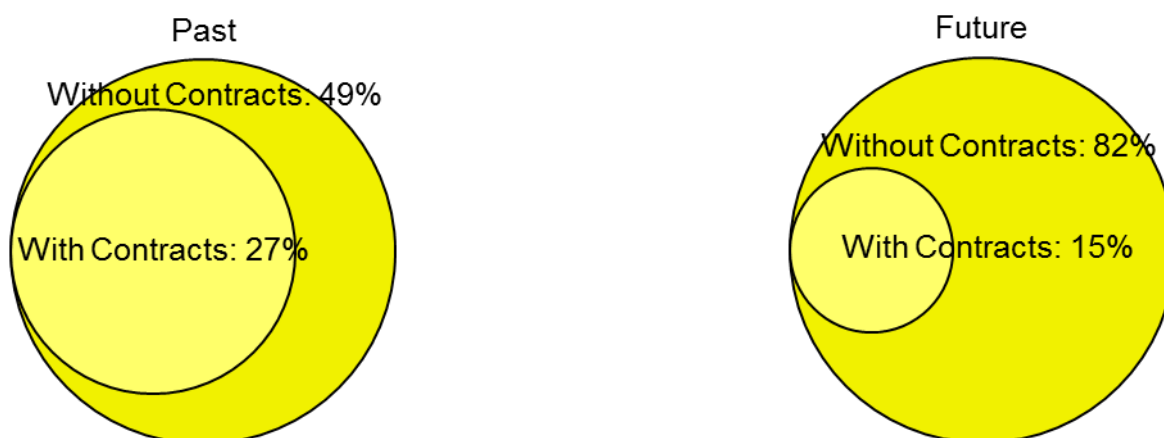
Second, companies with ESA funding tend to be more diversified as measured by the number of areas in which the company participates (Figure 4).⁴⁵ This difference is not dramatic (2.3 versus 1.7 areas out of eight), and it is to be expected that larger companies would be more diversified.

⁴⁴ It must be remembered that correlation does not mean causation. In other words these differences are not believed to be the result of, or necessary for, companies receiving ESA funding.

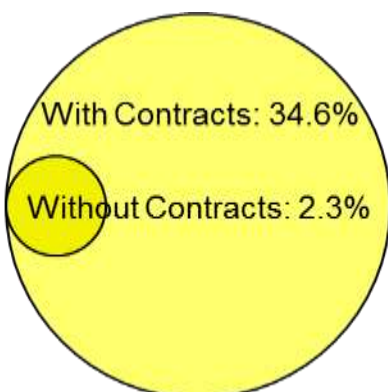
⁴⁵ Earth Observation, Telecommunications, Navigation, Space Segment Technology, Ground Segment Technology, Science, Microgravity, Exploration.

Figure 4: Companies with ESA Funding are More Diversified

Third, companies with ESA funding tend to grow more slowly (Figure 5). Over the last six years, the number of employees at companies with ESA funding grew 27%, compared to 49% for companies without ESA funding. Expectations of companies without ESA funding are that their number of employees will grow 82% in the next six years, compared to 15% for companies with ESA funding. Again, this difference can be attributed to the difference in average company size between the two groups. Larger, more mature companies tend to grow more slowly. Also, small, entrepreneurial companies tend to have overly optimistic views of the future.

Figure 5: Companies with ESA Funding Grow More Slowly

Finally, companies with ESA funding tend to do more business in Europe (Figure 6). This difference is significant. Companies with ESA funding obtain 34.6% of their revenues from Europe, compared to just 2.3% for companies without ESA funding. This effect may be explained partially by the size difference, as larger firms are more likely to export. However, it is probable that some of the effect is due to the connections that companies make in Europe as a result of their work on ESA projects.

Figure 6: Companies with ESA Funding do More Business in Europe

Spinoff Economic Impact

Using the spinoff multiplier of 2.96 calculated above in section 4.2.5.2, the ESA contracts revenue of \$114.2 million was translated into subsequent attributable spinoff revenues of \$338.4 million. Using the input-output economic model, the spinoff revenue can be calculated to have contributed \$131.5 million to Canada's GDP and 959 person years of employment.

Indirect and Induced Economic Impacts

As described above, both the direct ESA funding and spinoff impacts have related indirect and induced impacts resulting from the follow-on economic activity of suppliers and employees. Using the input-output economic model, this indirect and induced economic activity can be calculated to have contributed \$272.0 million to Canada's GDP and 3,299 person years of employment.

Summary

Tables 13, 14 and 15 summarize the economic impacts obtained in this analysis between 2009 and 2013.

Table 13: Indirect Economic Impacts of ESA Funding and Spinoff Benefits (2009-13)

	Funding Impacts	Spinoff Impacts	Total Impacts
Revenues	\$114,247,919	\$338,402,336	\$452,650,255
GDP	\$44,401,840	\$131,518,251	\$175,920,091
Employment	324	959	1,283

Table 14: Indirect and Induced Economic Impacts of ESA Funding and Spinoff Benefits (2009-13)

	Funding Impacts	Spinoff Impacts	Total Impacts
Revenues	\$138,079,472	\$408,991,397	\$547,070,870
GDP	\$68,647,080	\$203,332,650	\$271,979,730
Employment	833	2,466	3,299

Table 15: Total Economic Impacts of ESA Funding and Spinoff Benefits (2009-13)

	Funding Impacts	Spinoff Impacts	Total Impacts
Revenues	\$252,327,391	\$747,393,733	\$999,721,125
GDP	\$113,048,920	\$334,850,901	\$447,899,821
Employment	1,157	3,426	4,582

Breakdown by Area

Table 16 provides a breakdown of funding and spinoff impacts by programme area. The funding breakdown has been calculated over the period 2004-13 for private sector organizations using the ESA allocation among programme families. Projects funded in the 'General' category were reallocated to other categories where this made sense. The funding left in the 'General' category is mostly for studies of generic nature, such as economic impact analyses. The spinoff impacts cover the period 2009-20 for those companies that participated in the survey conducted for this evaluation (which represent approximately 90% of the funding in the 2009-13 period) based on their indication of the areas in which they are involved.

Table 16: Breakdown of Funding and Spinoff Impacts by Area

	Funding	Spinoff Impacts
Earth Observation	49.2%	40.5%
Telecommunications	17.0%	31.5%
Navigation	5.5%	0.3%
Space Segment Technology	3.6%	1.6%
Ground Segment Technology	12.3%	1.9%
Science	1.6%	0.6%
Microgravity	0.8%	0.1%
Exploration	9.6%	23.0%
General	0.6%	0.3%

4.2.6 Unexpected Outcomes

Most interviewees did not identify any unexpected outcomes.

A few CSA representatives noted the increased number of countries participating in ESA as an important issue for Canada. On the one hand, the increased number of countries means a larger market for Canadian technologies and services, and thus an increased need for the Canada/ESA Cooperation Agreement. On the other hand, the larger number of countries risks diminishing Canada's influence and voice within ESA. This risks being compounded by the steadily decreasing level of funding for the program by the CSA.

Finally, CSA representatives identified an outcome which may be interpreted positively or negatively depending on how the situation evolves. As noted earlier, a few Canadian companies are opening offices in Europe, specifically in the UK. However one of the motivating factors for these companies is reported to be the lack of public sector contract opportunities at the CSA and the growth of the space program in the UK. In order to obtain contracts with the UK companies need to undertake the work in the UK and this means that Canada may be losing capacity and Highly Qualified Personnel (HQPs) to the UK. So in some sense this is a positive outcome because these companies have successfully expanded their market as a direct result of ESA but it may not be entirely positive in the long term because Canada may be losing some of its most successful companies to the UK.

4.2.7 Demonstration of Efficiency and Economy

This section assesses whether the International Market Access Program has been able to generate outputs and achieve its outcomes in an economic and efficient manner. The TBS Directive on the Evaluation Function defines the demonstration of efficiency and economy as the "assessment of resource utilization in relation to the production of outputs and progress towards expected outcomes." In general, the analysis of efficiency requires assessing relationships between inputs and outputs and/or outcomes, and the assessment of economy concerns the extent to which best use is made of resource inputs to achieve intended outcomes.

We address economy and efficiency by assessing:

- Whether the program is producing its outputs and outcomes in the most efficient manner;
- Whether there are alternative, more efficient or effective ways of delivering the results; and
- Whether there are opportunities for improving the overall economy of the International Market Access Program.

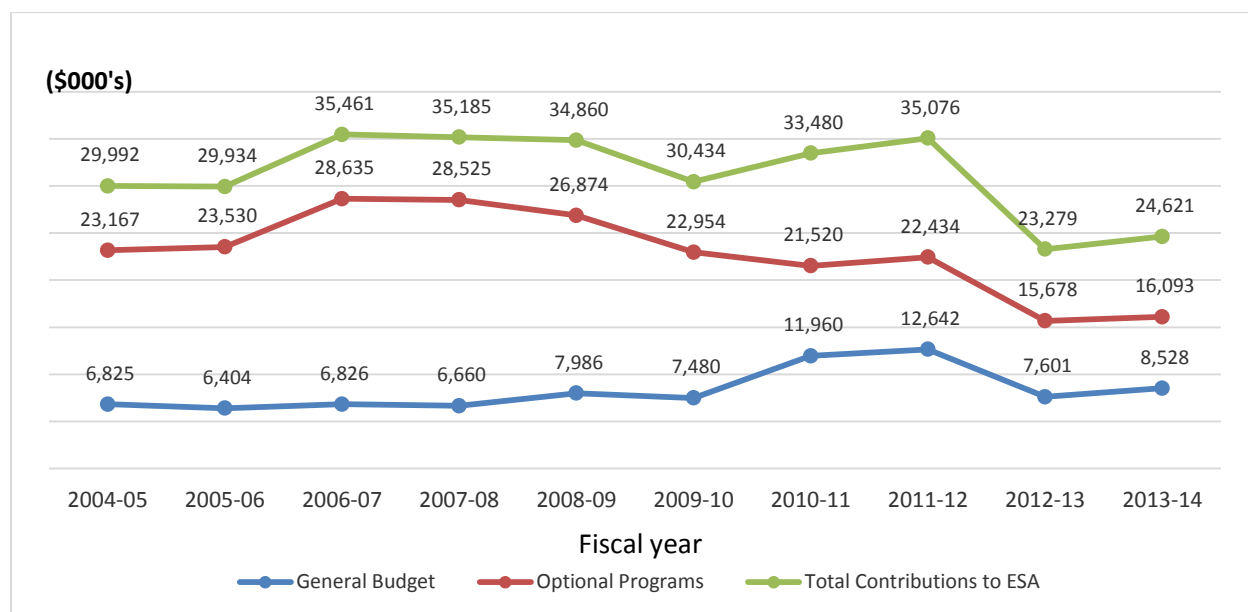
4.2.7.1 Economy and Efficiency

Overall, the evidence indicates that Canada's participation in the Canada/ESA Cooperation Agreement is both economical and efficient. In terms of economy, the cost of Canada's contribution to ESA from 2009-10 to 2013-14 was \$149.7 million, which consists of \$146.9 million in contribution to ESA's General Budget and optional programmes plus CSA overhead costs of \$2.8 million. In return, the Canadian space sector received \$122.9 million in contract awards between 2009 and 2013. We consider this to be a very reasonable investment. Efficiency is measured by comparing the costs incurred by Canada in participating in the Agreement to the benefits obtained to the Canadian space industry, which is measured by the value of contracts obtained from ESA along with the value of follow-on business. As outlined earlier, the overall multiplier of 2.96, has led us to conclude that the Agreement is also very efficient.

In order to examine the operational economy of the Agreement, we examined the CSA's investment in the Agreement, which consists of three components: 1) the contribution to ESA's overhead at both the general level as well as for each mandatory and optional programme in which Canada participates; 2) the contribution to direct program expenditures (optional programmes chosen by Canada); and, 3) the CSA's overhead costs devoted to managing the Agreement.

Canada's contribution to ESA's General Budget over the period from 2009-10 to 2013-14 amounted to \$48.2⁴⁶ million or 32.8% of Canada's total contribution to ESA (\$146.9 million). CSA interviewees noted that the proportion of Canada's contribution to ESA going towards the General Budget is increasing over time. This is due to the decline in Canada's annual contribution together with the steadily increasing amount mandated for the General Budget which is tied to Canada's GDP and ESA total expenses under the General Budget. Since Canada's economy has been relatively healthy in recent years, reflected by an increasing GDP, this has caused an increase in Canada's contribution to the General Budget. This situation is illustrated in the Figure 7 – where the two lines representing Canada's total contribution to ESA and ESA's General Budget are converging over time.

⁴⁶ See Table 1: Actual Spending (2009-10 to 2013-14).

Figure 7: Trends in Canada's Contributions to ESA (\$'000s) – 2004-05 to 2013-14

Source: CSA ESAPA data, September 2014.

*Canada's contribution to the General Budget includes payments for over return.

Many interviewees from the CSA have the impression that very little of the General Budget directly benefits Canadian companies as measured through the volume of contracts obtained from ESA. However this is not entirely accurate. Of the \$48.2 million that Canada contributed towards ESA's General Budget between 2009-10 and 2013-14, \$33.0 million (unweighted) in contracts were awarded to Canadian organizations.⁴⁷ Thus \$15.2 million of the contribution to the General Budget was not returned to Canada via contracts to Canadian organizations over the time period. It is, however true that the contracts issued to organizations under the General Budget may not always align with the priorities of the federal government/CSA (e.g., development of a specific technology or sector within the space industry). In contrast, contracts issued under the optional programmes are selected by Canada to target specific technologies or sectors.

It is worth noting that Canada has a privileged situation with respect to its contribution to ESA General Budget. As a Cooperating State, Canada's contribution is 50% of what it would have been if it had been calculated on the basis used for the Member States of ESA.

Canada contributes to ESA's overhead through specific overhead components included in each optional programme budget. The proportion of each ESA programme budget which goes towards overhead varies by programme and programme family and ranges from a low of 20% for GSTP to 29% for Earth

⁴⁷ A large portion of those contracts are for the three Deep Space Antennas purchased by ESA to a Canadian company. Without these contracts Canada's return for the General Budget would be much lower and CSA management do not anticipate that a fourth Deep Space Antenna will be purchased by ESA.

Observation programmes. All participating countries pay the same percentage of overhead for programmes in which they participate. The contributions to overhead for specific programmes are included in the total contributions (i.e., they are reflected in Canada's total contribution of \$146.9 million). Note that it is beyond the scope of the present evaluation to assess whether the overhead costs incurred by the ESA in managing its programmes were reasonable. The overhead charged by ESA for each programme family is summarized below in Table 17.

Table 17: ESA Overhead by Programme Family

Programme Family	Overhead (%) ⁴⁸
Earth Observation	29
Space Exploration	24
Navigation ⁴⁹	18
Satellite Communication	21
Microgravity	21
GSTP	20

Source: ESA Programme Declarations.

In addition to the overhead paid to ESA through a portion of Canada's contributions to the General Budget and ESA programme overhead, there is overhead associated with managing the Canada/ESA Cooperation Agreement by the CSA. Overhead costs at the CSA for managing the program include 3 FTEs and other overhead costs (O&M) amounting to \$2.8 million from 2009-10 to 2013-14.⁵⁰ The roles fulfilled by these 3 FTEs within the CSA are described above in section 2.3.2 (Roles and Responsibilities).

Given total contributions to ESA of \$146.9 million and CSA overhead costs of \$2.8 million, the total cost of the program to Canada was \$149.7 million over the five-year period of 2009-10 to 2013-14. The total value of contracts awarded to Canadian organizations over the same time period was \$122.9 million. This corresponds to an estimated overhead cost of \$26.8 million or 18%. We note that this estimate does not represent the exact value of overhead over this time period because although contracts were issued between 2009 and 2013, the funds flowing from these contracts will occur sometime in the future as work on the projects gets underway (i.e., there is a lag between the time the contracts are issued and when funds flow to Canadian organizations). ESA does not provide data to the CSA on the flow of funds to Canadian organizations. However, for some contracts awarded before 2009, funds will flow during the 2009-2013 period. Assuming the magnitude of both is similar, the estimate should be adequate. Our calculations for 2009-10 to 2013-14 are summarized in Table 18, and Table 19 summarizes the same calculation for 2004 to 2013.

⁴⁸ Overhead calculated as 1-Development Costs/Total Expenditures indicated in ESA Program Declarations.

⁴⁹ Excludes Galileo.

⁵⁰ These costs are detailed in Table 1.

Table 18: Summary of Overhead Estimate - 2009-10 to 2013-14 (\$'000s)⁵¹

Total Contributions under Agreement	146.9
Program Overhead (CSA Salaries and O&M)	2.8
Total (i.e. total cost of the program)	149.7
Total Contracts to Canadian Organizations	122.9
Total Estimated Overhead	26.8
Ratio of Value of Contracts to Canadian organizations to Total Program Cost	.82

Table 19: Summary of Overhead Estimate - 2004-05 to 2013-14 (\$'000s)

Total Contributions under Agreement	312.3
Program Overhead (CSA Salaries and O&M) ⁵²	5.5
Total (i.e. total cost of the program)	317.8
Total Contracts to Canadian Organizations	225.6
Total Estimated Overhead	92.2
Ratio of Value of Contract to Canadian organizations to Total Program Cost	.71

These results show a much higher ratio than for the previous evaluation period (2000-2008) which reported a ratio 0.68. If the calculations of table 17 and 18 were repeated after excluding the \$26.5M contracts for data purchase (see section 4.2.5.1), the ratios would be much closer to those obtained for the previous evaluation period (0.64 for 2009-10 to 2013-14 and 0.63 for 2004-05 to 2013-14).

4.2.7.2 Alternatives

Overall, there are three potential alternatives to the Canada/ESA Cooperation Agreement: 1) funding of Canadian space projects/programs; 2) bilateral agreements; and 3) multilateral agreements among multiple countries (such as the ISS Agreement with the United States, Russia, ESA and Japan). Based on the evaluation findings, none of these three alternatives would provide the same level of benefits to Canada and to the Canadian space sector.

There was agreement among a large majority of interviewees that there is no other viable alternative to the International Market Access Program which would provide the same or similar benefits. Although a

⁵¹ The same calculation, excluding the \$26.5 million in data purchase contracts from ESA in 2011-13, results in a ratio of Value of Contracts to Canadian organizations to total program cost of .64 (based on total contracts to Canadian organizations of 96.4 million (i.e., \$122.9 million less \$26.5 million).

⁵² These costs exclude CSA salaries and O&M for the fiscal year 2004-05.

few interviewees proposed alternatives, these were quickly discounted by the interviewees as not providing the same level of positive impacts as the International Market Access Program. A few CSA representatives suggested bilateral agreements, such as increased ties with NASA, but these were dismissed as providing Canada with less influence over the projects and less value in terms of the industrial benefits relative to the Canada/ESA Cooperation Agreement. The Agreement opens the European market to Canadian organizations while a bilateral agreement would provide access to a single country's market. Multiple bilateral agreements would need to be negotiated and maintained in order to achieve broad market access for Canadian space products and services.

A few interviewees from the CSA and industry identified increased participation in the EU's *Horizon 2020* program as a possible alternative. However this option was also dismissed by these interviewees as not having the potential for providing the same level of industrial benefits to Canada compared to the Canada/ESA Cooperation Agreement.

A few interviewees suggested direct funding to industry and OGDs; again, this option also was dismissed. Direct funding to industry would not ensure access to the European market – Canada has privileged access to the European public sector market as a direct result of the Canada/ESA Cooperation Agreement. In addition, direct funding to industry would not provide the same level of access to ESA data and background information on ESA data, nor would Canada obtain the intelligence and information available to ESA Member and Cooperating States.

4.3 Program Delivery

4.3.1 Effectiveness of Consultations with Stakeholders

Although CSA has a well-articulated process for selecting which ESA programmes to participate in, which includes consultations with stakeholders, the evidence indicates that such consultations have not occurred on a consistent basis to the satisfaction of stakeholders. There has been no formal consultation with stakeholders since 2012. The CSA has restricted consultation largely because of Canada's limited ability to invest in additional ESA programmes. Any consultation that does occur tends to be ad hoc, focusing on the major players rather than on the space sector as a whole.

As mentioned previously, there is evidence from key informant interviews of a need to assess the number and nature of the programmes in which Canada participates. In terms of the number of programmes, given the limited resources available, Canada may be participating in too many ESA programmes, i.e., spreading financial resources too thinly. According to interviewees representing industry and the CSA, this has had the effect of limiting the size of contracts that Canadian organizations may benefit from as well as limiting the number of contracts that may go to Canadian firms within an ESA programme. A more focused approach to developing and/or maintaining the competencies of Canadian space organizations might be necessary.

The lack of a fully articulated plan for the Canadian space industry (i.e., Space Strategy) along with corresponding funding reflecting the Strategy (i.e., priorities for the space sector) also hinders longer-term planning and decision-making about which ESA programmes are most clearly aligned with Canada's priorities. The lack of an ability to plan is noted in a recent report by Euroconsult which concludes that, "Canada has focused its program on the development of niche technologies; however with no long-term plan in place, the national program and industry players have suffered from a lack of guidance for strategic decision-making."⁵³

In terms of the types of ESA programmes that Canada is participating in, there is evidence that some of these programmes, although beneficial from a scientific research perspective and strongly supported by university researchers, may not be having strong industrial benefits in terms of the return on investment. This is not to say that these programmes are not beneficial to Canada or Canadians, however they do not align with the industrial benefits focus of the Agreement.

Opportunities for Member States or Canada to join ESA optional programmes or to make significant additional contributions to on-going/existing programmes usually occur during Council meetings at the ESA Ministerial level, which take place approximately every three or four years. However, some countries, including Canada, often make additional contributions in the interim.

According to the International Market Access Program's PM Strategy, the selection of ESA programmes in which Canada will participate is based on the following key criteria:

- Funding availability (taking into consideration additional long term commitments which may stem from the initial investment in a programme).
- Alignment with the Canadian Space Program.
- Contract opportunities with potential for building and maintaining the capacity and/or opening of new markets for the Canadian space sector and program risks.

In addition, strong consideration is given to programmes which could facilitate the participation of Canadian scientists in ESA's missions and/or facilitate access to ESA's data and/or infrastructures meeting the needs of academia and government departments and agencies.

Programme selection follows the decision-making process described below:

- The Canadian delegation participates in the activities of the ESA programmes preparatory and planning process.

⁵³ Euroconsult, Profiles of Government Space Programs, 2014.

- The CSA consults with Canadian stakeholders (e.g., industries, universities, not-for-profit organizations, and OGDs) during the ESA programme preparatory and planning process, as appropriate.
- The SST Branch of the CSA prepares Programme Approval Submissions recommending Canada's participation in ESA programmes (including the financial parameters of Canada's participation) and presents them to the CSA's Executive Committee.
- The CSA Executive Committee selects the ESA programmes, and determines the financial parameters of Canada's participation to the said programmes, ensuring that they are affordable within the CSA's reference levels. These are then presented to the Governor in Council (through OICs) for final approval, in order to obtain the authority to legally commit Canada to those programmes.

Canada's participation in an ESA optional programme is conditional on the unanimous approval of the Member States funding this programme. Upon this approval, a specific Canada/ESA Arrangement defines the terms and conditions of Canadian participation in the optional programme. The Arrangement refers to the ESA Programme Declaration that details the rights and obligations of the participants, describes the objectives and contents of the optional programme, and establishes the financial contributions of participants. Once concluded, each Arrangement will form an international treaty between ESA and Canada on participation in an optional programme.

Based on interviews conducted with representatives from the CSA, OGDs, universities and private sector companies (with and without ESA contracts), it is clear that the CSA has not undertaken large-scale, focused consultations on the selection of ESA programmes. CSA representatives interviewed recognize this but noted that consultations on the selection of ESA programmes have been adequate given the limited amount of funding available. A few CSA representatives explained that the limited amount of funding available has made the CSA cautious about large-scale consultations which may create false expectations on the part of industry.

The perspectives of university representatives, OGDs and companies reflect the lack of large-scale consultation and provide some indication that consultations are ad hoc, focusing on the key players rather than the space sector as a whole. Although most interviewees indicated they had not been consulted, a few indicated that the CSA has communicated and consulted with them about ESA.

Despite the general dissatisfaction with the consultations on the selection of ESA programme, a few interviewees recognize the challenges faced by the CSA. As noted by one company representatives, "...it is difficult for the CSA to select the best programmes taking into consideration the limited funds available, the interests of different parts of the industry."

Most interviewees representing OGD and universities stated that their organizations' interests are well represented by the International Market Access Program. However the opinions of companies with ESA

contracts were split, with those who believe their interests are not well represented generally focused on the satellite communications industry. Those from the satellite communications sector noted that there is no support for their sector and their capability in relation to other countries is declining as a result.

Most interviewees stated that Canada is participating in the most appropriate ESA programmes. Not surprisingly, opinions depended on whether the organization's key areas of interest were reflected in the selection of ESA programmes in which Canada participates. For example, private sector companies with ESA contracts who did not believe Canada was participating in the most appropriate programmes indicated they would like to see Canada involved in more satellite communications and human space flight programmes.

Companies that had obtained ESA contracts were asked to rate each of the ESA programme families in terms of creating business opportunities for their companies. The highest-rated programme family is Earth Observation, followed by General Technologies. The lowest-rated programme family is Microgravity, followed by Navigation. These results are summarized in Table 20.

Table 20: Ratings of Contributions to Business Opportunities by ESA Programme Family

Type of Benefit	Mean Rating (1 to 5)	% Large Benefit (4 or 5)	% Small Benefit (1 or 2)	n
Earth Observation	3.8	71%	33%	21
General Technologies	3.2	50%	50%	16
Space Exploration	2.9	44%	56%	16
Satellite Communications	2.7	37%	53%	19
Navigation	1.9	6%	63%	16
Microgravity	1.3	0%	92%	13

Source: Survey of the Canadian Space Industry, 2015.

A few CSA representatives suggested that Canada may be participating in too many ESA programmes relative to the funding available. There is a need for the CSA to focus its funding on the ESA programmes that are the most beneficial from the perspective of industrial development. These CSA interviewees suggested that funding for space exploration and microgravity may not align with the objective of developing the space industry because the products and technologies developed are so specialized and thus much more difficult to commercialize relative to other areas such as satellite communications. However based on the survey results shown in Table 20, of the companies that had obtained ESA contracts, just under one-half (44%) indicated that space exploration has provided a large benefit in terms of contributing to business opportunities.

4.3.2 Effectiveness of Communication with Stakeholders

The majority of interviewees representing universities, OGDs, and companies with and without ESA contracts do not look to the CSA to communicate contract opportunities with ESA. CSA representatives interviewed indicated that it is not the responsibility of the CSA to communicate ESA contract opportunities; this is done by ESA which manages the entire contracting process. ESA uses EMITS which lists all RFPs issued. Each RFP lists the invitation to tender which includes the list of eligible countries.

There is evidence from the key informant interviews that not all organizations are aware of the existence of EMITS. The survey of space industry companies revealed that of the companies that had not obtained ESA contracts, about one-quarter (27%) were not aware of ESA and the opportunity for Canadian companies to bid on contracts. Also, of those who were aware of ESA (and had not had any contracts), 50% had registered with EMITS.

One CSA interviewee noted that although all companies are able to access ESA's RFPs on EMITS, there is often a lot of background information that companies, particularly smaller companies or companies that have not worked with ESA before will not be aware of which will put them at a disadvantage when bidding on ESA contracts. This issue was noted by one representative from a company with an ESA contract. This interviewee explained that in terms of opportunities, the CSA does provide information on existing, posted opportunities; however, other companies get advance notice of opportunities and that allows them to position themselves in anticipation of these opportunities. This interviewee suggested that Canada needs to provide some advance intelligence. However, some interviewees representing companies and the CSA noted that companies are sometimes able to obtain intelligence from sources other than the CSA, i.e., they receive information about invitations to tender before they are published. There is little the International Market Access Program can do to avoid this since it does not manage the RFP process within ESA.

All companies that had been involved in ESA projects in the past were asked whether they had experienced any challenges in attempting to realize business opportunities resulting from this work. Table 21 summarizes the results. The main challenge relates to a lack of funding to develop new products or services (52% agreed with this statement), followed by difficulties in accessing markets (48% agreed), and strong competition (34% agreed).

Table 21: Ratings of Challenges in Attempting to Realize Business Opportunities from ESA Projects

Challenge	Mean Rating (1 to 5)	% Agree (4 or 5)	% Disagree (1 or 2)	n
We lack funding to develop new products or services	3.5	52%	24%	33
We have difficulties in accessing markets	3.1	48%	36%	31
We face strong competition	3.1	34%	38%	32
We lack market acceptance for our new products or services	2.8	27%	43%	30
We lack the necessary skilled resources	2.0	13%	69%	32

Source: Survey of the Canadian Space Industry, 2015.

Only interviewees representing private sector companies identified challenges in trying to access ESA contracts.

- ESA managers tend to be very risk adverse and place accountability with the private companies contracted, sometimes without adequate funding or tendencies for “scope creep.” The CSA may want to consider having the CSA experts involved with Canadian companies in ESA projects as oversight.
- One of the challenges of participating in ESA projects relates to the nature of their funding. Since they receive funds from a number of ESA countries and Canada, projects often need to involve fairly large teams from multiple countries, which makes them very complex.
- The ESA bidding process is onerous due to the amount of detail required in submissions relative to the size of the project.
- The requirement from ESA to disclose overhead rates, profit margins, etc.
- Difficulty in establishing relationships with ESA firms in trying to partner for opportunities. The company attends the major events (IGARSS, Living Planet, etc.) but it is still challenging given the geographic distance.
- The CSA provides no help in working with ESA, e.g., to explain how geo-return works.

Respondents to the survey were also given the opportunity to list other challenges. The main challenge (identified by 5 out of the 12 respondents who listed another challenge) relates to a lack of sufficient government funding for Canada’s space sector. As noted by one respondent,

Other government agencies within ESA are supporting their industry substantially. Canada however, does not seem to support its space industry to the same extent. We have developed unique and substantial technology but due to government priorities the Canadian space industry is rapidly falling behind other countries in the world. Canada was a world power in satellite communications but this is being rapidly eroded.

4.3.3 Implementation of Previous Recommendations

This section provides an update on the extent to which the International Market Access Program management has responded to the recommendations from the previous evaluation completed in 2010. This update is based on CSA's on-going follow-up on the management action plan in response to the recommendations and comments by CSA representatives interviewed for this evaluation.

Recommendation 1: CSA should seek renewal of the Agreement for an additional 10-year period. If feasible, additional resources should be allocated to the Agreement either from an increase in the allocation of Government of Canada resources or through a reallocation from other CSA programs.

The Canada/ESA Cooperation Agreement was renewed. However, additional resources were not allocated.

Recommendation 2: Clarify the role of ESA within the long-term space plan in order to guide industry on Canadian priorities in space, including ESA participation.

The action associated with this recommendation was beyond the control of the International Market Access Program management as there was no clear timeline for the release of an updated long-term space plan. However, the Government of Canada released the Canadian Space Policy Framework in February 2014, which is a comprehensive approach to Canada's future in space. The Canada/ESA Cooperation Agreement is in line with the Canadian Space Policy Framework with regards to the core principles of 1) Positioning the Private Sector at the Forefront of Space Activities, 2) Progress through Partnerships, and 3) Excellence in key capabilities.

Recommendation 3: Develop and publicize a more coherent set of policies & programs for supporting organizations in the sector and developing new entrants.

In the years following the publication of the last summative evaluation (2010), progress was made to consult, develop and communicate more coherent programmatic directions and policies with the space sector and new entrants. Following consultations with industry and OGDs throughout 2012, a few programmatic scenarios were proposed to the CSA Executive Committee in anticipation of the 2012 ESA Ministerial held in December 2012. This recommendation also called for the development of a coherent plan of action for communicating targeted ESA industrial opportunities to Canadian companies. The ESA management team has updated the ESA section of the CSA website to include relevant information and web links that could be useful to potential Canadian bidders and new entrants.

Recommendation 4: Develop a coherent plan for communicating targeted ESA industrial opportunities

The recommendation to support potential Canadian bidders included an action item that pertains to the development of a Guide for Canadian ESA delegates. In order to ensure that Canadian delegates have easy access to relevant information relating to the ESA procurement process and understand their role

on ESA Programme Boards, a draft guide has been developed and has been through a consultation process with the delegates. Amendments to the guide were made based on these consultations and approval and distribution to Canadian ESA delegates is anticipated for the current fiscal year.

Recommendation 5: Continue to monitor the impacts, if any, of the 2007 European Space Policy and EU trends on Canada and, if necessary, take steps to mitigate any adverse effects. The CSA along with Foreign Affairs and International Trade Canada should also undertake a policy review of Canada's role in ESA, given the changes occurring in Europe as a result of the 2007 European Space Policy.

There has been regular and continuous monitoring of the impacts the European Space Policy may have on Canada's participation in European space activities since the publication of the previous summative evaluation in 2010. The CSA's Policy Branch was actively involved in the development of various Canada-EU agreements and program files that have an impact on Canada-Europe space relations. The actions taken to implement this recommendation have resulted in practices, policies and initiatives that are now integrated in CSA's policy and corporate functions.

5 Conclusions and Recommendations

5.1 Relevance

Canada holds a unique and privileged position as the only non-European country that has a cooperation agreement with ESA that allows direct participation in ESA optional programmes. Other countries, including Australia, South Africa, Israel and China have thus far unsuccessfully sought similar agreements with ESA. Evaluation findings indicate that the International Market Access Program responds to a number of needs within the Canadian space sector as well as in the researcher and data user communities in Canada.

Internationally, the space industry continues to be highly protectionist. Without the Canada/ESA Cooperation Agreement, Canadian companies would have little chance of winning public sector contracts in Europe without establishing offices there. Given that the public sector continues to be a critical market for the space industry around the world, the loss of the Canada/ESA Cooperation Agreement would have a negative impact on the Canadian space industry's opportunity to pursue space contracts in Europe. The Agreement enables Canadian companies to collaborate with European firms, helping them to build working relationships and to integrate their technologies with those of their European counterparts, thus putting them in a better position to pursue business around the world.

Canada's cooperation with ESA reflects the basic fact that countries must collaborate to undertake space missions due to their size, complexity and cost. Few countries have the financial and technological capacity to undertake missions completely on their own. International collaboration allows for the implementation of larger, more complex missions and the sharing of costs and risks.

The international space industry is highly R&D intensive. An important requirement of space R&D is the need to flight test technologies, which serves to increase their TRL. Given the fact that Canada itself has launched few spacecraft in recent years (or plans to do so), Canadian companies seeking to increase the TRL of their products are highly dependent on opportunities outside of Canada – opportunities which are provided through ESA-led space missions. This allows companies to maintain their technological and competitive edge.

Canadian space scientists and some federal government organizations rely on access to ESA data for scientific and modelling purposes. The loss (non-renewal) of the Canada/ESA Cooperation Agreement would not entirely curtail access since ESA data is increasingly open source; however, it would limit access to some data and background information on the data. Some federal government organizations would need to purchase data for modelling purposes.

The loss of the Canada/ESA Cooperation Agreement would likely have serious political implications. Canada has recently signed (but not yet ratified) the Canada-EU Free Trade Agreement. In light of this, non-renewal of the Canada/ESA Cooperation Agreement post-2019 risks being seen as inconsistent. Should the longstanding working relationship between Canada and ESA end, it is unlikely that Canada would be given the opportunity to re-establish the Canada/ESA Cooperation Agreement at some point in the future.

The relationship between ESA and the EU is complex and Canada's signing of both the Canada/ESA Cooperation Agreement and Canada-EU Free Trade Agreement provides some clarity to Canada's relationships within the European space sector. In the past there have been challenges when ESA projects (which focus on technology development) were operationalized by the EU because Canada, as a non-EU country was not included. Although the closer trade relationship with the EU may alleviate some tensions, there is evidence that Canadian officials will need to open discussions with the EU in tandem with ESA in negotiating the next Canada/ESA Cooperation Agreement prior to 2019 if Canada wishes to maximize access to both the ESA and EU space markets.

As the Canada/ESA Cooperation Agreement comes up for renewal, the CSA should encourage the Government of Canada to conduct discussions regarding renewal of the Canada/ESA Agreement in parallel with discussions with the EU about the Canada-EU Free Trade Agreement in order to ensure that the interests of the Canadian space sector are coordinated across the Canada/ESA Cooperation Agreement and the Canada-EU Free Trade Agreement.

Although the Free Trade Agreement will better position Canadian companies to bid on EU contracts, expanding their potential market and possibly facilitating work on operational contracts (e.g., operating ground stations), it will also serve to open the Canadian market to European companies. Although there are currently limited opportunities in Canada, even for Canadian firms, this may affect Canadian firms in the future should the Canadian government proceed with new space projects. There currently is limited awareness within the space sector of the full implications of the Canada-EU Free Trade Agreement.

Recommendation #1: The CSA should communicate the implications of the Canada-EU Free Trade Agreement to the Canadian space industry and encourage the industry to prepare in order to be better able to compete with European firms.

The Canada/ESA Cooperation Agreement aligns with federal priorities as indicated in the *Space Policy Framework* and the recently released *Science, Technology and Innovation Strategy*. As an international treaty, it is consistent with the role of the federal government to manage international relationships.

5.2 Performance

5.2.1 Geo-Return

ESA uses the concept of geo-return in the awarding of contracts for both mandatory and optional programmes. Based on ESA data, Canada achieved a fair overall geo-return (excluding the ISS Exploitation programme) of 0.99 over the period 2000-2014. Although important, geo-return itself is not an appropriate stand-alone measure of the success of the Agreement since ESA periodically makes adjustments to ensure that all countries achieve a fair geo-return. Many programmes (such as most elements of GSTP and ARTES) include a guaranteed return of 1.0 at the conclusion of the programme.

5.2.2 Immediate Outcomes

There is evidence that the Agreement provides the CSA and OGDs with invaluable information and intelligence, some of which contributes to policy and decision-making. Examples include information on market trends, plans of other ESA Member States, and technological information. Most of this information is not published or publicly available. Canadian scientists who participate on ESA advisory groups and committees also obtain intelligence and background information on data which would otherwise not be available to them. The program provides the CSA and OGDs with information and intelligence, the value of which cannot be quantified.

Although Canada contributes a very small proportion of ESA's total funding (0.83% of mandatory programmes and 0.55% of optional programmes), and does not participate in ESA's Science programme, there is evidence that Canadians are playing a meaningful role on ESA's scientific teams, particularly in the areas of Earth Observation and Human Microgravity and Exploration.

5.2.3 Intermediate Outcomes

Canadian space companies are forming alliances with European space organizations as a direct result of the Canada/ESA Cooperation Agreement. Most often the relationship is established through work on an initial contract for ESA and then continues as Canadian and European technologies are integrated and working relationships are solidified. These working relationships extend to both ESA and non-ESA contracts. Given that Canada's contribution to ESA is not sufficiently large to allow Canadian firms to serve as primes, Canadian firms most often serve as sub-contractors to their European partners.

Canadian space companies provided numerous examples of where they have been able to increase the TRL of their technologies as a direct result of participation in ESA programmes. They emphasized that the opportunity to participate in these programmes is critical given the limited number of space projects currently underway or planned in Canada. In addition to increasing the TRL, participation in ESA programmes has also allowed some Canadian products and technologies to be space qualified, a prerequisite for commercial success.

There are essentially two types of users of space data that is made available by ESA missions: researchers (mostly in universities) who participate in scientific research projects and scientists (mostly in the federal government) who use ESA data for modelling purposes, such as weather forecasts and monitoring of sea-ice. There is evidence that Canadian scientists are accessing ESA data and that this data meets their needs. Although ESA data is increasingly “open access”, Canadian scientists benefit from the Agreement because they have privileged access to all of the intelligence (i.e., background information to help in interpretation) concerning the data.

5.2.4 Ultimate Outcomes

There is good evidence that Canada’s participation in the ESA Agreement is directly contributing to increasing the competitiveness of Canada’s space industry. Although all ESA programmes in which Canada participates benefit at least part of Canada’s industry, some ESA programmes and programme families are better structured to facilitate commercialization of technologies. The Canadian space sector is highly export-oriented and the European market represented 31% or \$497 million of the total \$1.58 billion in Canadian space exports in 2012. Telecommunications revenues dominated the statistics for the Canadian space sector, representing 80% of total revenues. There is evidence that telecommunications and, to a lesser extent, earth observation, are areas where the commercial potential is the highest.

In 2012, at the time of renewal of the current Canada/ESA Cooperation Agreement, the CSA reduced the funds set aside for future commitments to the Satellite Communications programme area at ESA, which resulted in an ongoing annual savings of \$1.13M for the government (approximately \$8M over the 8 years of the Agreement). However, the federal government recently committed, in Budget 2015, \$30 million over four years to ARTES. Although this announcement likely will be welcomed by Canadian industry, the industry had not planned for such a direction due to federal government decisions of 2012 to reduce investments in communications programmes. The absence of a clear long-term strategic direction in space for Canada makes it difficult for space companies to plan technology development and to invest in human resources in order to respond to international opportunities.

Recommendation #2: There is a need for the CSA and the federal government to establish a strategic direction for the Canadian space sector so that the industry can undertake long-term planning.

Although there is ample evidence that cooperation with ESA has contributed to increased competitiveness of Canadian companies, there is also evidence that the limited amount of funding is preventing Canadian companies from fully benefiting from the potential opportunities. Canadian

companies are losing some of their competitive edge partly because of Canada's declining contribution to ESA in recent years. Specifically, a few interviewees reported that there have been instances where a Canadian company has the leading edge technology desired by ESA; however because Canada's funding is limited and because of the geo-return policy, contracts have gone to Canada's European competitors which are then able to build up their expertise relative to Canada.

Recommendation #3: The CSA should examine its funding allocation to ESA programmes (for example, funding fewer programmes while focusing only on those that have demonstrated higher economic benefits). Such an examination should be conducted in relation to a long-term strategic direction for the Canadian space sector.

There have been few opportunities for Canadian organizations to participate in Canadian space endeavours in recent years. However, capacity developed with ESA could be put to use on Canadian or other international space endeavours.

5.2.5 Economic Benefits

Canadian organizations (including private sector companies, universities and OGDs) were awarded 182 contracts (including sub-contracts) under the Agreement between January 2009 and December 2013, valued at an estimated \$122.9 million⁵⁴. Although Canadian organizations have benefited from ESA contracts, these benefits are concentrated in a small number of organizations, with ten organizations accounting for 85% of the value of ESA contracts between 2009 and 2013. However, this mirrors the structure of the Canadian space industry which is dominated by a relatively small number of companies.

There is good evidence that companies are benefiting from follow-on business. Companies surveyed for this evaluation reported attributable follow-on business worth 2.96 times the value of the ESA contracts they received.

The input-output model used for assessing the economic benefits of the \$114.2 million in ESA contracts obtained by Canadian private sector companies (i.e., excluding ESA contracts to universities and OGDs) between 2009 and 2013 yields total direct, indirect and induced economic benefits of \$447.9 million in GDP and 4,582 person years of employment.

5.3 Efficiency and Economy

There is strong evidence that Canada's participation with ESA is both economical and efficient. The total cost of the Agreement between 2009-10 and 2013-14 was \$149.7 million (including \$146.9 million in contributions to ESA and \$2.8 million for CSA salaries and overhead). In exchange Canadian organizations obtained an estimated \$122.9 million in ESA contracts as noted above. In other words,

⁵⁴ Note that this figure does not represent the flow of funds since the signing of a contract is a commitment to pay sometime in the future.

Canadian organizations were awarded contracts valued at 0.82 of every dollar spent on the program for the period from 2009 to 2013. When calculated for the period from 2004-05 to 2013-14, this ratio decreases to 0.71.

These results show a higher ratio than for the previous evaluation period (2000-2008) which reported a ratio of 0.68. However, if the calculations were repeated after excluding the \$26.5M contracts for data purchased under the Earth Observation programme family for third party mission contributions to Global Monitoring for Environment and Security (GMES), the ratios would be much closer to those obtained for the previous evaluation period (0.64 for 2009-10 to 2013-14 and 0.63 for 2004-05 to 2013-14).

No viable alternatives were identified by the evaluation that would provide the same level of economic, scientific and political benefits at the same or lower overall cost.

5.4 Program Delivery

Although the CSA has a well-articulated process for selecting which ESA programmes to participate in, which includes consulting with stakeholders, the evidence indicates that consultations with stakeholders have not occurred on a consistent basis to the satisfaction of stakeholders. There has been no formal consultation with stakeholders since 2012. The CSA has restricted consultation largely because of Canada's limited ability to invest in additional ESA programmes. Any consultation that does occur tends to be ad hoc, focusing on the major players rather than on the space sector as a whole.

Recommendation #4: There is a need for the CSA to undertake broader, formalized consultations for the selection of ESA programmes in which Canada participates with Canadian stakeholders, including industry, universities and OGDs.

Despite dissatisfaction with the consultation process, most stakeholders feel Canada is participating in the most appropriate ESA programmes. However, there is evidence that some of these programmes, although beneficial from a scientific research perspective and strongly supported by university researchers, may not be having strong industrial benefits in terms of the return on investment. This is not to say that these programmes are not beneficial to researchers at Canadian universities and OGDs, rather, they do not align with the industrial benefits focus of the Agreement.

Recommendation #5: The CSA should assess the positioning of the Canada/ESA Cooperation Agreement (funded through the ESA Contribution Program) within its Program Alignment Architecture (PAA), and the CSA's overall suite of programs. It is possible that the Canada/ESA Cooperation Agreement aligns with more than one Sub-Program or Sub-Sub-Program. The CSA should also assess whether other of its activities or programs would fit under the International Market Access Program

The lack of a fully-articulated plan for the Canadian space sector hinders longer-term planning and decision-making on the part of the CSA and the federal government about which programmes Canada

should be investing in based on alignment with Canada's priorities. The evaluation also found evidence that this also hinders planning on the part of the Canadian space sector. There are no clearly articulated priorities at the federal level for the Canadian space sector to guide decisions about which ESA programmes should be the focus for Canada.

Management Response and Action Plan

	RESPONSIBILITY ORGANIZATION / FUNCTION	MANAGEMENT RESPONSE	DETAILS OF ACTION PLAN	SCHEDULE
RECOMMENDATION # 1				
The CSA should communicate the implications of the Canada-EU Free Trade Agreement to the Canadian space industry and encourage the industry to prepare in order to be better able to compete with European firms.	DG, Policy supported by DG, SST	Implications of the Canada-EU Free Trade Agreement have not been fully assessed yet. As this agreement will be implemented/managed through DFATD, the CSA will engage with officials at DFATD in order to ensure Canadian space industry has access to the information required to leverage this opportunity.	<p>The CSA (DG, Policy) will engage with officials at DFATD in order to ensure Canadian space industry has access to the information required to leverage this opportunity.</p> <p>In their interactions with industry, the CSA ESA Program office and the CSA Counselor for Space affairs in Europe will inform the Canadian space sector of the new Canada-EU Free Trade Agreement. They will also ensure a link to the DFATD division responsible for implementation of the Canada-EU Free Trade Agreement, who is best positioned to explain the implications of the Agreement and assist industry seeking to leverage opportunities with the EU.</p>	On-going

	RESPONSIBILITY ORGANIZATION / FUNCTION	MANAGEMENT RESPONSE	DETAILS OF ACTION PLAN	SCHEDULE
RECOMMENDATION # 2				
There is a need for the CSA and the federal government to establish a strategic direction for the Canadian space sector so that the industry can undertake long-term planning.	CSA President's Office	The Space Policy Framework and Investment Plan approved in 2014 provide high-level directions for the future.	The CSA will continue to participate in discussions related to overall strategic direction taking place at the Deputy Minister Governance Committee on Space, as well as with domestic and international stakeholders.	On-going
RECOMMENDATION # 3				
The CSA should examine its funding allocation to ESA programmes (for example, funding fewer programmes while focusing only on those that have demonstrated higher economic benefits). Such an examination should be conducted in relation to a long-term strategic direction for the Canadian space sector.	DG, SST	We agree that, given the decrease of available budget for ESA optional programmes and the increase of the number of programmes supported by the CSA over the years, there is a need to examine the funding allocation to ESA optional programmes. This will be done as part of the preparatory work towards the 2016 ESA Ministerial Council meeting, the next major decision milestone. The decision making process for that meeting will give consideration to focus funding on ESA programmes best aligned with the prime objectives of the ESA contribution	The next major decisions on the funding allocation to ESA optional programmes will have to be made prior to the 2016 ESA Ministerial Council meeting. When going through the decision making process, consideration will be given to focus funding on ESA programmes that could produce highest economic benefits, i.e. those best aligned with the prime objectives of the ESA contribution program, weighing also the impact of not investing in other optional programmes that align more with the secondary objectives of the ESA contribution program, e.g.	November 2016

	RESPONSIBILITY ORGANIZATION / FUNCTION	MANAGEMENT RESPONSE	DETAILS OF ACTION PLAN	SCHEDULE
		program of the CSA.	access to data and infrastructures (also see recommendation 5).	
		Moreover, all relevant CSA strategic elements should be taken into account when seeking renewal of the Canada/ESA Cooperation Agreement in 2019 and appropriate authorities for Canada’s continued involvement in ESA optional programmes.	In view of the renewal of the Canada/ESA Cooperation Agreement at the end of 2019 (the current agreement is in force from March 2012 to end of 2019), it is expected that all relevant CSA strategic elements will be taken into account when seeking renewal of the Agreement and appropriate authorities for Canada’s continued involvement in ESA optional programmes.	December 2019
RECOMMENDATION # 4				
There is a need for the CSA to undertake broader, formalized consultations with Canadian stakeholders (including industry, government and universities) regarding the selection of ESA programmes in which Canada participates.	DG, SST	The CSA usually consults with all Canadian stakeholders in preparation for ESA Council meetings at Ministerial level (this was done in 2008 and 2012). Only focused consultations were undertaken for the 2014 ESA Ministerial Council meeting, due to the limited scope of the meeting and to the low level of Canadian	In preparation for the 2016 ESA Ministerial Council meeting, the CSA will consult with Canadian stakeholders to support the selection of ESA optional programmes in which Canada will make contributions. If appropriate, consultations will address the benefits/impacts of focussing funding in ESA	Consultations completed by October 2016 or earlier

	RESPONSIBILITY ORGANIZATION / FUNCTION	MANAGEMENT RESPONSE	DETAILS OF ACTION PLAN	SCHEDULE
		funding available. Broad consultations are planned in preparation for the 2016 ESA Ministerial Council meeting.	programmes that better align with the prime objectives of the ESA contribution program.	
RECOMMENDATION # 5				
The CSA should assess the positioning of the Canada/ESA Cooperation Agreement (funded through the ESA Contribution Program) within its Program Alignment Architecture (PAA), and the CSA's overall suite of programs. It is possible that the Canada/ESA Cooperation Agreement aligns with more than one Sub-Program or Sub-Sub-Program. The CSA should also assess whether other of its activities or programs would fit under the International Market Access Program.	DG, SST	<p>Although the prime objectives of the contributions under the Canada-ESA Cooperation Agreement, as approved by the appropriate authorities in 2012, are clearly in line with the International Market Access Program (IMAP), the secondary objectives (also approved by the appropriate authorities), are more in line with other CSA programs of the PAA.</p> <p>In the short term, and in line with recommendation 3 (and given the current budget allocation to the ESA contribution program and the fact that it is all under IMAP), the CSA will consider focusing funding in ESA optional programmes which are in line with the objectives of the IMAP Sub-Sub Program.</p>	While looking at the funding allocation of the various ESA optional programmes in preparation for the 2016 ESA Ministerial Council meeting, an analysis of the benefits/impacts of focusing funding in ESA programmes that clearly align with the IMAP will be done.	November 2016

	RESPONSIBILITY ORGANIZATION / FUNCTION	MANAGEMENT RESPONSE	DETAILS OF ACTION PLAN	SCHEDULE
		Given that there might be significant benefits to use the Canada/ESA Cooperation Agreement to meet the objectives of other Sub-Sub Programs of the PAA, the CSA will assess the positioning of the Canada/ESA Cooperation Agreement in time to seek appropriate Policy cover and authorities in the context of the Agreement renewal in 2019.	The benefits of using the Canada/ESA Cooperation Agreement to meet objectives of Sub-Sub Programs other than the IMAP will be further investigated. Recommendations will be presented to the CSA Executive Committee, in view of seeking appropriate Policy cover and authorities in the context of the renewal of the Agreement in 2019.	March 2018

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Appendix B: Logic Model Narrative

Activities and Outputs

Participation to ESA Programme Boards and committees allowing the representation and promotion of Canada's interests and the gathering of information on European space technological, scientific, programmatic and commercial environments. The activities related to the ongoing management of the Canada/ESA Cooperation Agreement comprise the participation of Canadian delegates on ESA Programme Boards responsible for programmes in which Canada participates (or intends to participate) and to the horizontal committees of ESA (Council, Administrative and Finance Committee and Industrial Policy Committee). Participation on these committees and boards (and associated working and steering groups) allows for the representation and promotion of Canada's interests – this can be done formally during the meetings or informally with ESA officials and member state delegates. Participation at these meetings also allows the gathering of significant amounts of information relating to the European Space sector (official documents, results of meeting discussions and of offline meetings with ESA officials or Member State delegations). This information can be useful to the CSA or OGDs in the decision making process or in the development of policies and for the selection and approval of ESA optional programmes. Sometimes information obtained at these meetings can also be communicated to the Canadian private sector (see outreach activities). The amount of information being large, the challenge is for the delegates to identify and share relevant information with colleagues from the CSA and OGDs and other organizations involved in space activities (industry, universities, and research centers).

Selection and approval of ESA optional programmes leading to the signature of Canada/ESA Programme Arrangements. The selection and approval of ESA optional programmes is crucial as it determinates the programmes and activities on which Canadian organizations will be eligible to bid. The ESA optional programmes in which Canada participates are selected and approved in accordance with the criteria and process developed by the CSA and leads to the signature of Arrangements which are Treaties, i.e. legally binding under international law. The level of funding committed for each of the approved programme is specified in the programme declaration associated with the Arrangement. It should be noted that this level of funding can be increased at a later date (with adequate available budget and appropriate authorities) by decision of the CSA Executive Committee.

Outreach activities for the Canadian space organizations. This activity ensures that the Canadian space sector is aware of the opportunities provided by the Canada/ESA Cooperation Agreement and that they are guided, when appropriate, on how to best benefit from these opportunities. It can take several forms: phone calls (by Canadian delegates) to companies and organizations involved in specific activities, emails sent to the space community, organization of information sessions and information placed on the CSA web site. The number and type of outreach activities largely depends on availability of human resources at the CSA and on the Canadian space sector's need for information and support. The CSA also has to ensure the level of the outreach activities is in line with the size and breadth of the potential opportunities in order to avoid creating false expectations from the Canadian industry.

Immediate Outcomes

Canadian space organizations are awarded contracts in ESA programmes and activities: As noted above, Canadian organizations are eligible to bid only on ESA contracts relating to programmes and activities to which Canada contributes financially – this is why the selection of ESA programmes considered for Canada’s participation must take into account the potential for contracts involving the development of innovative technology applications and hardware for Canadian industry. Canada also has to contribute to the ESA General Budget; hence Canadian organizations can also receive contracts from activities financed through the General Budget. However, many items financed under the General Budget do not lead to industrial contracts (for e.g., ESA employees’ salaries) and most activities financed under the General Budget have a less technical nature and will normally not generate results to the same extent as activities under optional programmes. In accordance with ESA industrial policy and the Canada/ESA Cooperation Agreement, it is expected that Canada will reach a reasonable overall industrial return coefficient. In view of the discontinuation of the statistics planned for the end of 2014, the ESA Council has set a minimum target of 0.96 for the overall coefficient of Member States. Even though Canada, not being a member state, has no legal right to this target, it has been informally agreed with the ESA that actions would be taken if there were indications that this target would not be reached for Canada. Keeping in mind that the ideal return is 1, but that it is almost impossible for all Member States and Canada to reach 1, the target has been set at 0.96 for the end of 2013 and 2014 (in line with the guaranteed return for Member States). For most programmes in which Canada participates, the minimum target set in the Programme Declarations or Implementing Rules is 0.84.

Enhanced decision-making process and policy development in the CSA and OGDs. Participating in ESA’s Programme Boards and horizontal committees gives Canada access to a wide range of information (technical, programmatic, political, commercial and more) which can be useful to all of Canada’s space sector activities.

Maintained/increased Canadian participation to scientific teams selected by ESA. Participation in some ESA programmes (such as EOEP and ELIPS) facilitates Canada’s participation on the scientific teams responsible for the scientific directions of the missions and exploitation of the resulting data. For example, in ELIPS, Canadian scientists may respond to ESA Announcements of Opportunities and if they are selected (or part of the selected teams), they may have access to ESA facilities for their project. In EOEP, Canadian scientists may also respond to an Announcement of Opportunities to suggest Mission Concepts. If their mission concept is selected at all phases of the selection process, then they will be involved in the scientific team (potentially as a Principal Investigator). When Canadian scientists are involved at the beginning of the mission definition stage, it facilitates their involvement in the exploitation of the data if the mission is selected at a later stage.

Intermediate Outcomes

Canadian space organizations maintained/increased the number of alliances with European industry to supply their technologies, products and services. During the ESA procurement process and in delivering

on ESA contracts, Canadian industry is exposed to many European companies (primes which will manage the sub-contracts to Canadian companies, or European team members on a contract). This gives them the opportunity to showcase their expertise and potentially expose them to additional opportunities such as teaming up with these same companies in future contracts (ESA or others). Exposure to the expertise of European primes/partners also supports the increased capability of Canadian space organizations.

Maintained/Increased technological capabilities of Canadian space organizations, including space qualifications and flight opportunities for Canadian technologies/hardware/applications. When Canadian industry is awarded ESA contracts to develop innovative technologies, applications and hardware, it is expected that the TRL of their technologies and potential space products will increase – potentially up to space qualification. In addition, ESA being a much larger organization than the CSA, with a much larger number of missions being launched each year, it is expected that participation in ESA programmes will increase opportunities to fly Canadian technologies and products.

Maintained/Increased number of Canadian OGDs and scientists with access to data/infrastructure that meet their needs. Canada's involvement in ESA Programs that produce space data of interest to OGDs or Canadian scientists should facilitate access, and thus lead to an increased use of ESA space data by Canadian organizations, even though such access cannot be guaranteed by Canada's participation in the programmes and may require additional investments from Canada. When Canadian scientists are involved in ESA missions (for example as part of the scientific teams), this further facilitates access to the data, and also allows them to influence, to a certain extent, the nature of the data produced in order to meet their needs. It should be noted that private entities could also make use of ESA space data for commercial purposes and that Canada's participation in ESA programmes could facilitate this as well even if this is not part of the program objectives.

Ultimate Outcomes

Maintained/increased competitiveness of Canadian space organizations in European and global markets. In addition to the ESA contracts awarded to Canadian organizations as a direct result of Canada's financial contributions to the General Budget and selected optional programmes, it is expected that those contracts, through exposure to the European space industry and increased technological capacity, flight opportunities and market access should make the Canadian sector more competitive in European and global markets. This will lead to additional contract opportunities in Europe or outside Europe, especially in areas where commercial markets are mature (such as satellite communications). This should translate to increased revenues (national and export) for the Canadian space sector.

Maintained/increased capacity of Canadian space organizations to successfully meet the requirements of Canada space endeavours. The increased technological capacity and flight opportunities for the Canadian space sector as well as increased competitiveness should enable them to better meet the requirements of Canadian space endeavors. This can be demonstrated by examples of Canadian led space programs/activities that utilize technologies or products developed or flown by Canadian

organization under ESA contracts, or under follow-on contracts. This outcome can also be achieved indirectly: ESA contracts and follow-on contracts contribute to the health of the Canadian industry, thus enabling it to be ready to meet CSA's requirements when needed (i.e. by limiting the dependence of the Canadian space industry on the Canadian government).

Appendix C: Canada's Return Coefficients

The following table presents Canada's return coefficients overall, by programme family and by programme in which Canada participates – 2003-2014.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Overall (including ISS)	111%	112%	107%	118%	111%	109%	110%	106%	104%	99%	98%	
Overall(excluding ISS)										98%	96%	99%
General Budget	100%	86%	76%	64%	54%	50%	44%	45%	46%	33%	46%	37%
Mandatory activities	175%	212%	176%	157%	131%	116%	106%	104%	127%	93%	92%	78%
FAMILY OF PROGRAMS												
Microgravity		0%	0%	62%	62%	38%	44%	37%	48%	52%		
Human Space Flight		704%	216%	225%	213%	164%	193%	175%	200%	191%		
Robotic Exploration							7%	5%	11%	50%		
Total Science & Exploration		755%	233%	193%	152%	106%	90%	75%	86%	94%		
Microgravity										52%		
Human Space Flight - excluding ISS Exploitation programme										145%		
Robotic Exploration										50%		
Total Science & Exploration (excluding ISS)										80%		
Telecommunications	102%	103%	100%	101%	101%	101%	105%	105%	102%	102%		
Navigation	112%	111%	107%	110%	105%	102%	108%	106%	102%	102%		
Total Satellite Communications/Nav	103%	105%	102%	102%	101%	101%	105%	105%	102%	102%		

Total Earth Observation	108%	86%	89%	121%	112%	117%	118%	113%	116%	112%		
Technology	139%	112%	110%	110%	108%	108%	110%	109%	111%	111%		
INDIVIDUAL PROGRAMMES IN WHICH CANADA PARTICIPATES												
Environmental Satellite Development Programme	101%	100%		78%	77%	77%	75%	72%	71%			
EOPP -2	116%	119%	118%									
EOEP+ EOPP Extension	100%	70%	80%									
EOEP					125%	131%	129%	124%	128%	120%	117%	121%
GMES SE	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
GMES SC				43%	16%							
Earth Watch -Infoterra		100%	100%	100%								
ELIPS				18%	49%	30%	38%	32%	42%	46%	44%	41%
Aurora Preparatory activities			43%	72%	104%	100%						
Aurora	287%	142%										
Aurora Core			0%	6%	37%	52%	58%	59%	58%	66%	108%	110%
Aurora-Mrep 1									93%	74%	101%	100%
Aurora Exomars				5%	3%	3%	7%	5%	9%	49%	55%	102%
Transportation Early Activities							83%	379%	224%	220%	154%	99%
Transportation Human Expl.							61%	3%	130%	115%	114%	111%
Artes 1 per 1	150%	152%	147%	141%	140%	139%						
Artes 1 per 2	406%	443%	169%	185%	155%	144%	158%	164%	167%	168%	171%	172%
Artes 1 phase V							208%	211%	183%	130%	138%	138%
Artes 3 per 1		100%	100%	100%	100%							
Artes 3 per 1 Projets PH	100%	100%	100%									
Artes 3 per 2 phase Impl.	100%	100%	100%	100%	100%	100%	100%	100%	100%			
Artes 4 per 2			100%	100%								
Artes 4 per 2 phase 2					100%	100%	100%	100%	100%			

EVALUATION OF THE INTERNATIONAL MARKET ACCESS PROGRAM

PROJECT # 14/15 – 02-02

Artes 3-4 phase 1							100%	100%	100%	100%	100%	100%
Artes 5 period 2	100%											
Artes 5 period 1 phase 2		100%	100%									
Artes 5 period 1 phase 3		100%	100%	100%	100%	100%	100%	100%	100%			
Artes 5 per 2 phase 4		100%	100%	100%	100%	100%	100%	100%	100%			
Artes 5 Ph 3	100%											
Artes 5 per 4	100%											
Artes 5 SE 5.1							100%	100%	100%	100%	100%	100%
Artes 5 SE 5.2									100%	100%	100%	100%
Artes 8 element II-1					100%	100%	100%	100%	100%	100%	100%	100%
Artes 8-IV							100%	100%	100%	100%	100%	100%
Artes 9 - GNSS	121%	119%	113%	111%	110%	110%	108%	108%				
Artes 9 - GNSS /2	0%	15%										
Artes 21									92%	97%	104%	139%
Technology Mission - Artemis	7%	17%										
Artemis-Operational continuation			7%	10%	12%	12%	51%	56%				
Galileosat Definition	100%	100%	100%	100%								
EGEP					19%	13%	77%	64%	52%	63%	39%	47%
GSTP 2	100%	100%										
GSTP 3	100%	100%	100%	100%	100%	100%	100%	100%				
GSTP 4				100%	100%	100%	100%	100%	100%	100%	100%	100%
GSTP 5								100%	100%	100%	100%	100%

Appendix D: ESA Science Teams with Canadian Members

Exomars instrument Teams⁵⁵

Earth Science Advisory Committee (ESAC)⁵⁶

Earth Care Mission Advisory Group⁵⁷

Swarm Mission Advisory Group⁵⁸

Flex Mission Advisory Group⁵⁹

Sentinel-1 Mission Advisory Group⁶⁰

Sentinel-2 Mission Advisory Group⁶¹

⁵⁵ ExoMars Instrument, October 2014

⁵⁶ ESA/PB-EO (2013) 26, September 3, 2013

⁵⁷ ESA/PB-EO (2013) 26, September 3, 2013

⁵⁸ ESA/PB-EO (2013) 26, September 3, 2013

⁵⁹ ESA/PB-EO (2013) 26, September 3, 2013

⁶⁰ ESA/PB-EO (2013) 26, September 3, 2013

⁶¹ ESA/PB-EO (2013) 26, September 3, 2013

Appendix E: Technology Readiness Levels Defined⁶²

TRL 1 Basic principles observed and reported: Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.

TRL 2 Technology concept and/or application formulated: Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.

TRL 3 Analytical and experimental critical function and/or characteristic proof-of-concept: Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brassboard implementations that are exercised with representative data.

TRL 4 Component/subsystem validation in laboratory environment: Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.

TRL 5 System/subsystem/component validation in relevant environment: Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.

TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space): Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.

TRL 7 System prototyping demonstration in an operational environment (ground or space): System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.

TRL 8 Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space): End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.

⁶² http://esto.nasa.gov/files/TRL_definitions_AIST.pdf

TRL 9 Actual system "mission proven" through successful mission operations (ground or space): Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.