SPACE WORKING GROUP REPORT

September 2012

This report reflects the views of one of the six industry-led working groups created to provide advice to the Aerospace Review Head and the members of the Advisory Council. The recommendations therein may not reflect the findings of the Aerospace Review.

For more information on the Review process visit www.aerospacereview.ca.

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Preface

The Aerospace Review was announced by the Government of Canada in February 2012. The review stems from a commitment in the 2011 Federal Budget to "conduct – through a consultative process involving the Aerospace Industries Association of Canada (AIAC) and their member firms – a comprehensive review of all policies and programs related to the aerospace/space industry to develop a federal policy framework to maximize the competitiveness of this export-oriented sector and the resulting benefits to Canadians."

The arms-length Aerospace Review was led by David Emerson, and was supported by a three-person Advisory Council comprised of Jim Quick (current president of AIAC), Sandra Pupatello (former Ontario Minister of Economic Development and Trade), Jacques Roy (professor at HEC Montreal), and a Secretariat. The objective of the Review was to produce “concrete, fiscally-neutral recommendations on how federal policies and programs can help maximize the competitiveness of Canada's aerospace and space sectors”. A final report will be submitted to the Minister of Industry later this year.

As a result of the Budget 2012 commitment, AIAC’s role in the Aerospace Review was to lead and manage the deliberations of the industry-led working groups – an important element of the Aerospace Review. AIAC is the national voice of Canada’s aerospace industry whose mission is to understand, build consensus and provide leadership on aerospace policy issues of interest to the industry. On the working groups, industry representatives were joined by academia and other stakeholders to foster an open exchange on the issues facing the aerospace and space sectors and to ensure different perspectives were taken into account during the Review. This involvement in the Aerospace Review gave industry and other stakeholders an unparalleled opportunity to provide insight and guidance directly to the Review Head in areas of critical importance. Working groups were formed in the following areas:

- Technology Development, Demonstration and Commercialization;
- Market Access and Market Development;
- Aerospace-related Public Procurement;
- Small Business and Supply Chain Development;
- People and Skills; and
- Space.

The Space Working Group (SWG) was formed in March 2012 and was comprised of space industry representatives, academia and other stakeholders:

Dave Caddey, MDA (Chair)
Iain Christie, Neptec (Vice Chair)

Industry representatives:

Jacques Giroux, ABB
Roman Ronge, Aflare Systems
Eddy Morin, Boeing
Ron Holdway, COM DEV
Claude Baril, Composites Altantic
Kieran Carroll, Gedex Inc.
Al Conrad, IMP
Don Asquin, Magellan
Dale Boucher, Norcat
Ian Scott, Telesat
Stéphane Germain, Xiphos

Academia representatives:

Janet Halliwell, J. E. Halliwell Associates Inc.
James Fergusson, University of Manitoba
Tim Barfoot, University of Toronto Institute for Aerospace Studies (UTIAS)

Other stakeholders:

Stewart Bain, Bain Consulting
Geoff Languedoc, Canadian Aeronautics and Space Institute (CASI)
Arny Sokoloff, Ontario Aerospace Council
Ken Mackay, Policy Insights

The SWG was supported in its work by:

Maryse Harvey, AIAC
Frédéric Pilote, Aerospace Review Secretariat
Mac Evans (former President of CSA), Report co-writer
Leslie Swartman (MDA), Report co-writer

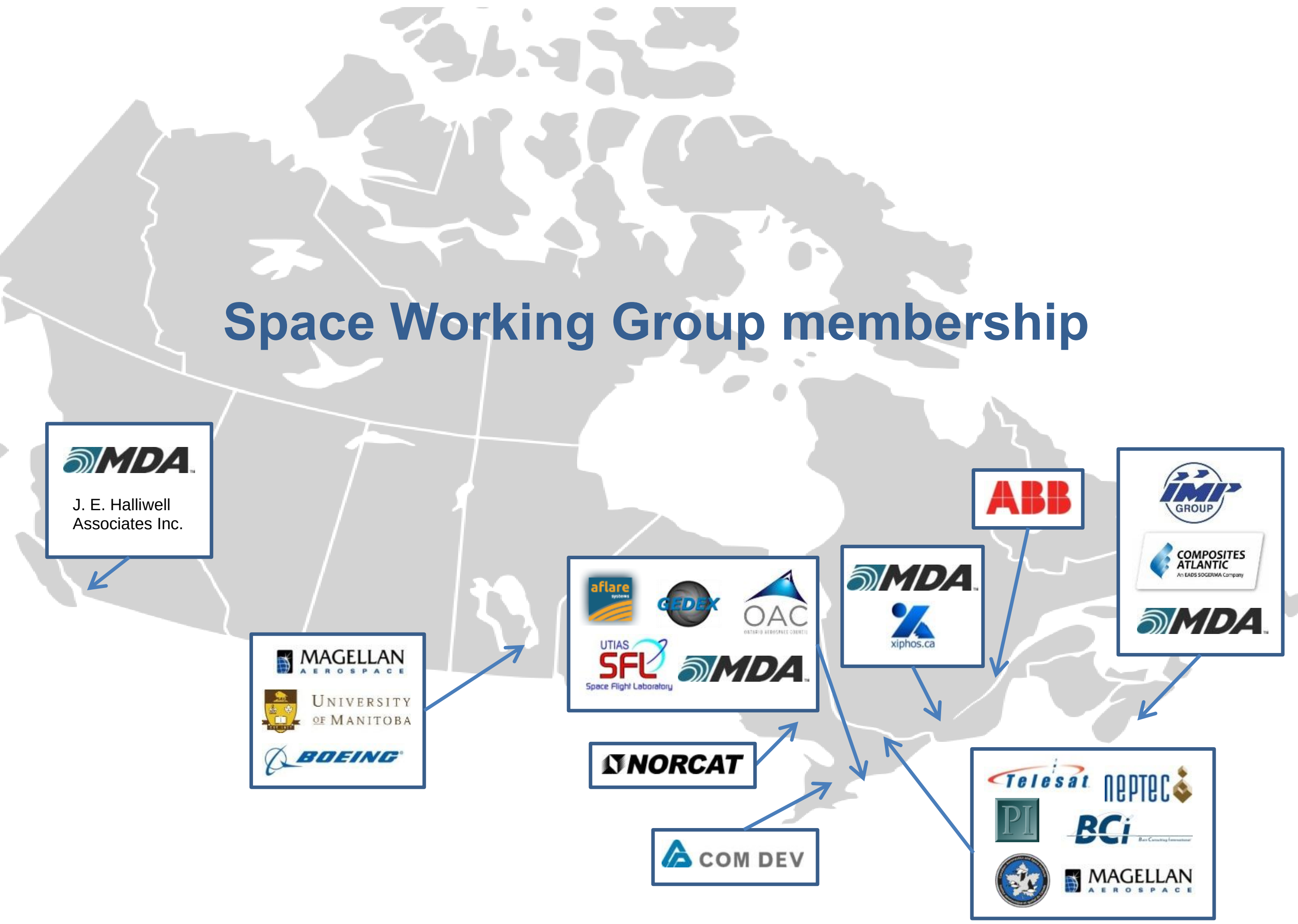
A number of federal government departments were represented by ex-officio members on the SWG, including the Canadian Space Agency, Industry Canada, Department of National Defence, Department of Foreign Affairs and International Trade, Public Works and Government Services Canada, Export Development Canada and Canadian Commercial Corporation.

The mandate of the Space Working Group, as established by the Aerospace Review, was to “examine how Government of Canada policies and programs can best be used to foster the economic growth and competitiveness of the Canadian space industry in order to meet public policy objectives and capture commercial opportunities. Areas to be covered by this working group may include but not be limited to Canada’s current and future strategic needs and the requisite space industrial base; the role of space in issues of security and sovereignty of the North; Canada’s role in major international space projects such as the International Space Station; and the role of the Canadian Space Agency.”

Over a six-month period, the SWG met on numerous occasions to discuss the challenges facing the Canadian space sector, drawing on the insights and views of a wide range of stakeholders and experts. The following report is the culmination of these deliberations and represents the broad opinion of not only the industry sector but also that of the space science and academic community.

The Space Working Group is pleased to present this report and its set of fiscally-neutral recommendations to the Hon. David Emerson, Head of the Aerospace Review. The review is extremely timely and crucially important to the future of this sector. This report represents a consensus on the issues and the solutions and serves as an urgent call to action on the part of the federal government – without which, the future of the industry is in jeopardy.

Space Working Group membership



Executive Summary

The space sector has been a vibrant part of Canada's national fabric for fifty years, delivering culture-defining icons such as the Canadarm, inspiring Canadians through the achievements of our astronauts – Canada has more astronaut flights than any other nation except Russia and the United States – and becoming the third country in space, with the launch of the Alouette 1 scientific satellite in 1962. Through a close partnership between successive Canadian governments, industry and academe, Canada has developed a world-class, export - oriented and internationally - competitive indigenous space industry.

The space sector is unique among industrial sectors. It intertwines industrial capacity with a country's strategic needs in security, communications and remote-sensing. The space sector is also at the forefront of technological advancement, and is leveraged worldwide for higher education, discovery, inspiration and national prestige. On a practical level, Canadians rely on critical space infrastructure in virtually every facet of modern day life – and important services like telecommunications, the internet, electrical power grids, banking, gas pumps and navigation systems would not function without space assets.

The global space sector is witnessing exponential growth and transformation. All G20 countries have space programs, and more than fifty nations now have their own domestic satellite system. In 2010, five countries had a space budget of more than $2 billion (USD), with the US leading the way at $42 billion.[1] Emerging economies like China, India and Brazil are redoubling their efforts to challenge traditional spacefaring nations. With the growing societal reliance on space-based capabilities for everything from communications and navigation to surveillance and environmental monitoring, access to space is not seen as a luxury but as a prerequisite for maintaining sovereignty, increasing a nation's influence on world affairs and improving both economic and human conditions.

Once a leading spacefaring nation, Canada is falling behind its competitors in almost every measurable aspect. We have not had a space policy that outlines overarching government priorities or that emphasizes the importance of industrial development since 1994 – meanwhile, our competitors are realigning their policies towards more economic and export-driven objectives. We are reducing our space expenditures while our competitors are increasing theirs. A smaller percentage of our space budget actually ends up in Canadian industry. Our space program is managed at the departmental level rather than at the national level. Our procurement processes are overburdening and slow. Academic space research and training is compromised by "stop and go" funding and the paucity of flight opportunities. There are diminished opportunities for exposing research trainees for the stringent technological demands of space missions. We do not have an effective process for consulting stakeholders when planning and implementing our space program.

As more and more nations are paying close attention to space, Canada has all but relinquished its leading role. Canadian industry is rapidly losing ground to international competitors who are aggressively supported by their national governments in protected domestic markets leveraging their presence in international markets. In this ultra-competitive global sector, if you are not moving forward, you are falling behind – particularly in technology development but also the ability to retain skilled personnel in industry, government and academe.

This report reviews how Canada became one of the world's leading spacefaring nations, and the key elements that built a successful industry and global presence. It looks at the role of national governments and how they nurture domestic space industries. It looks at why the exploitation of space is increasingly seen as a strategic capability and why that should be important to Canada – the opening of the Arctic being a prime example. It analyses current and future international trends and opportunities and examines the reasons why Canada and Canadian industry are failing to keep pace with the world, dropping our country to second-tier status among spacefaring[2] nations.

The report also outlines the immediate, medium and long-term steps that need to be taken for Canada to re-emerge as a world space power and to place Canadian industry on a more competitive footing. These recommendations include:

- the urgent development of a long term space policy framework that reaffirms the strategic significance of space to Canada and the importance of a domestic space industry and a supportive academic sector;
- a renewed emphasis on space technology development in industry, flight demonstration of new technologies and applications, and space science programs;
- the intelligent use of government procurement as an instrument of industrial development;
- a review of the planning and management of the Canadian Space Program[3] to reflect a whole-of-government national approach to national priorities; and
- a revitalized partnership between government, industry and academia to guide Canada's space program.

With a reinvigorated approach to space, we are confident that Canada can regain its stature as a first-tier spacefaring nation and retain strong and competitive domestic industrial and academic capacities that uniquely serve the country's strategic needs.

NASA

Introduction

The Canadian space industry has been remarkably successful considering its relatively small size and the small government space budget. It has developed world-leading expertise in niche areas such as communications and Earth observation satellites, scientific instrumentation and research, space robotics, and space hardware including satellite components, materials and other equipment. It also has significant capabilities in space services and space systems design and integration. It has built on and exploited the existence of a number of other high technology capacities and sectors in Canada. It reflects the capacity of Canada to compete with the best in a frontier of technological innovation.

In 2010, the Canadian space sector generated over $3.4 billion in revenues (up 14% from 2009) and employed over 8,200 Canadians, about half of whom are in the coveted Highly-Qualified Personnel (HQP) category.[4] With approximately 50% of revenues coming from foreign sales, it is the most export-oriented space industry in the world.[5]

Revenues of the Canadian space industry

The Canadian Space Agency conducts an annual survey of the "State of the Canadian Space Sector". These reports contain information on the revenues of the industry over time. The revenue numbers are categorized by sector of activity (telecommunications, Earth observation, robotics, navigation, science and others) and also by space category (space segment, ground segment, applications and services, and space research). The following charts show these revenues over the period 1998-2010.

Figure 1 - Industry Revenues by sector of activity ($Cdn M)

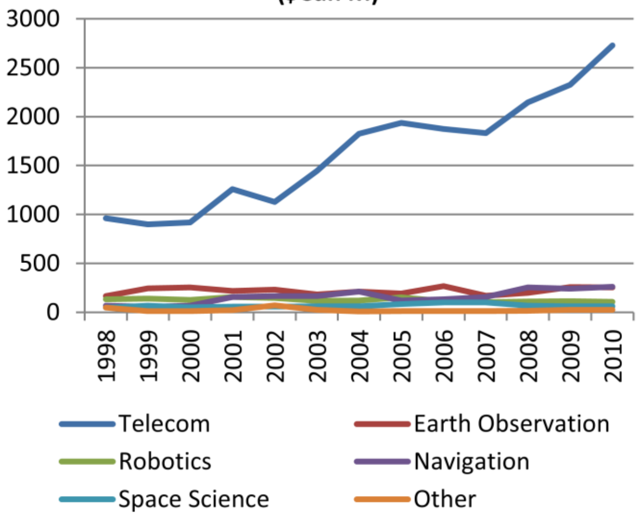
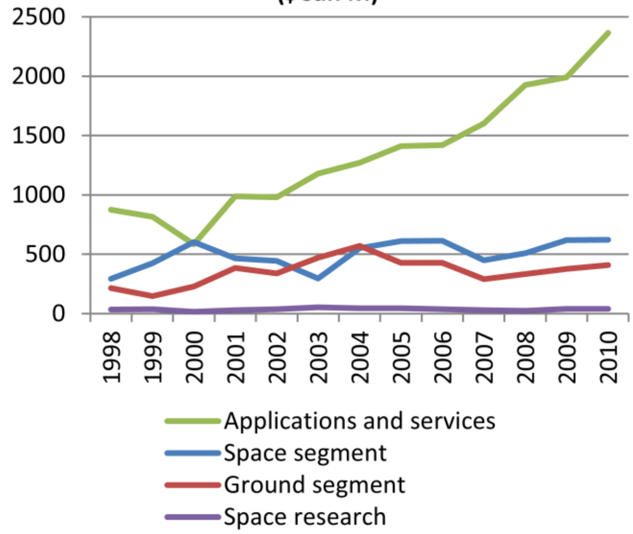


Figure 2 - Industry revenues by space category ($Cdn M)



These charts clearly show that overall industry revenue growth is almost entirely in the applications and services category which is primarily (but not exclusively) in the area of satellite communications services (e.g. Telesat Canada), but also includes Earth observation data sales (e.g. RADARSAT data), and navigation data (e.g. Automatic Identification Systems). Most of these revenues come from the commercial marketplace.

Canadian space industry revenues by space category[6]

	2010 revenues	% of overall Cdn industry	5-yr growth (2006-10)	10-yr growth (2001-10)	Compound Annual Growth Rate (CAGR) 2001-10
Space segment (R&D, manufacturing, testing, integration and launch of platforms (satellites, spacecraft and robotic systems), complete systems, subsystems and components)	$623M	18%	1%	33%	3.2%
Ground segment (R&D, manufacturing, testing and integration of facilities on Earth for controlling space-based systems and satellites, for linking satellites to operational terrestrial networks and for processing satellite-derived data)	$410M	12%	-4%	6%	0.7%
Applications and services (Development and/or provision of services and value-added products and technologies that are derived from the use of space systems and/or data, and the provision of consulting and engineering services)	$2.365B	69%	67%	139%	10.2%
Space research (Primarily research related to non-commercial or pre-commercial space activities)	$40M	1%	8%	33%	3.2%
TOTAL	$3.439B	100%	38%	84%	

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 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%.[7]

With less than 10% of its global revenues from the Canadian government via sales and technology development funding, the Canadian space industry is far less dependent on public sector procurement than is the norm worldwide. It has therefore become renowned for its ability to capitalize on relatively minimal Canadian government technology development and space procurements to produce world-leading innovation – a key commercialization model that has eluded some of Canada's other high technology industries as well as foreign competitors around the world. Even while small, this revenue is critical for the generation of new technologies and applications, and without it, the ability for many companies to sustain operations would be challenged.

Around the world, governments play an important role in the development of the space sector, largely due to defence and sovereignty concerns that require national space systems capable of providing secure communications, space domain awareness and national and global surveillance.

> *"Governments have played an integral role in the development of the commercial space sector. Many spacefaring states consider their space systems to be an extension of critical national infrastructure, and a growing number view their space systems as inextricably linked to national security. Full state ownership of space systems has now given way to a mixed system in which many commercial space actors receive significant government and military contracts and a variety of subsidies."*
>
> **Space Security 2011 report**[8]

The United Kingdom refers to the government-industry export-leveraging experience in our country as the "Canadian model".[9] The basis of the successful "Canadian model" was a close partnership relationship between Canadian governments and the space industry that pursued policies for developing an indigenous space industry. The various space policies and plans[10] approved by governments over the past 50 years made the development of an indigenous space industrial capacity one of the prime objectives of the Canadian Space Program.

In generating these policies and plans, governments worked closely with industry to ensure that maximum industrial benefits were achieved. As a *quid pro quo*, governments expected industry to capitalize on government investments and programs to become successful in the international marketplace. These policies, coupled with the presence of globally-recognized academic space capability and research, led directly to the international competitiveness of the Canadian space industry and its export success.

These conditions, however, do not exist today. The partnership between government and industry is not as strong as it once was and all the benefits from enlightened decisions on policies and programs made by the government some thirty years ago have been harvested. For example, in the successful 'pay-to-play' model that traded Canadian space technology for astronaut flights aboard the US Space Shuttle and the International Space Station (ISS), Canada will use up its final credit for the flight of astronaut Chris Hadfield to the ISS later this year.

In the communications technology area, the same is true. Canadian industry led the world in the implementation of broadband Ka-Band systems. This leadership was based on far-sighted investments made through a strong government/industry partnership over ten years ago. Now Canada faces major competition in the international marketplace for next generation broadband systems, since the government has made no further investment in this technology and the rest of the world has caught up to us.

In all successful spacefaring nations, governments support the development of their industries through the intelligent use of government procurement, technology development programs, science programs, flight demonstration programs and international cooperative projects.

> *"Every country with a serious space program directs government money toward its domestic space industry on the basis that some public goods — such as national defence — will not be provided by the market alone."*
>
> **Professor Michael Byers, University of British Columbia**[11]

"Space remains a strategic sector, often sheltered because of national imperatives and institutional funding. In addition, many countries are now investing in space technologies to advance national objectives," noted the Organisation for Economic Co-operation and Development (OECD) in its 2011 annual report on the world space economy. "The space sector plays an increasingly pivotal role in the efficient functioning of modern societies and their economic development. Despite its usual reliance on relatively high institutional investments up-front, space can increasingly be seen as a source of economic growth," it added.[12]

This government/industry partnership was the hallmark of the "Canadian model" – a model that has not been effectively employed for over a decade. It is worthwhile to look back at why and how that partnership developed and to compare it to the challenging circumstances that the space industry is faced with today.

Canada's 50-year leadership in space

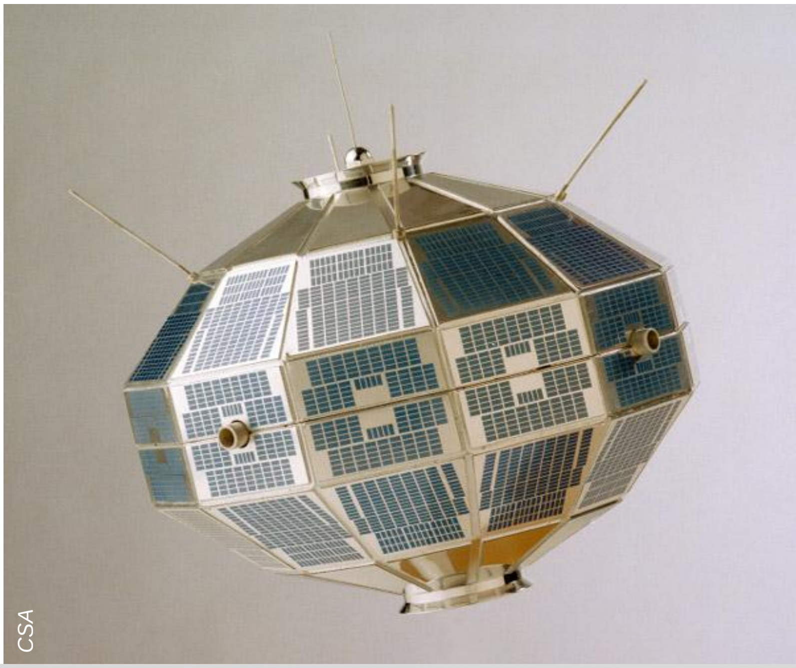
Canada's entry as a spacefaring nation came about not by pitting itself against a competitor in a space race but by the recognition that space could be exploited to serve the needs of Canadians, initially in the area of telecommunications. Canadian research scientists in the middle part of the last century conducted extensive research into the upper atmosphere to better understand its role in radio communications, largely via sounding rockets. This research led to the development and launch of Alouette, a scientific satellite designed to gather critical information that would assist in improving communications between northern and southern Canada. With this satellite, Canada became the third country, after the US and Russia, to have its own satellite in orbit.[13]

With the advent of satellite communications technology in the early 1960s, the Canadian government commissioned a study in 1966 to better understand how space could be effectively harnessed for the country. The study, Upper *Atmosphere and Space Programs for Canada*, which became known as the "Chapman Report" after its lead author John H. Chapman, recommended – following extensive consultation with external stakeholders, including industry – that Canada should focus on using space to meet national needs while doing so in a way that develops an internationally competitive space industry. This ground-breaking report paved the way for the development of a domestic satellite communications system – with Telesat Canada coming into existence in 1969 as a public/private telecommunications service provider. The subsequent launch of Anik A1 in 1972 made Canada the first country to have a domestic satellite communications system in a geostationary[14] Earth orbit (GEO). Telesat would go on to launch many additional satellites with updated technologies and greater capacities. Telesat was privatized in 1991.

Remote-sensing technologies also came to the fore in the early 1970s. Canada provided a ground receiving and processing station for early versions of US Earth observation satellites, paving the way for Canada to take the global lead in these data processors.[15]

Canada's work with the US National Aeronautics and Space Administration (NASA) on manned spacecraft and science, communications and remote sensing satellites and systems deepened through the years, and the strong partnership became a key part of our country's foreign relations with the United States. In the mid-1970s, Canada was asked by NASA to participate in their new post-Apollo program, the Space Transportation System, otherwise known as the Space Shuttle program. A proposal to the National Research Council (NRC) by a consortium of Canadian space companies to provide the remote manipulator, the "Canadarm", was approved by the government and accepted by NASA. NASA eventually bought four more arms to equip its full fleet of shuttle spacecraft. The Canadarm soon became an internationally recognizable icon, synonymous with Canada's high technology capabilities. The resounding success of the Canadarm, which first flew in orbit in 1981, led to further robotic contributions to the International Space Station (ISS) program, first announced in 1984.[16] As one of the five international partners, Canada provided the Mobile Servicing System, which included an additional arm (Canadarm2), a servicing robot (Dextre) and a mobile servicing base from which the robots operated.

The Canadian Space Agency (CSA) was established in 1989 as a stand-alone agency responsible for civilian space programs – an important recommendation of Chapman Report more than 20 years earlier. The formation of the agency ushered in the necessary management of the Canadian Space Program and the ever-expanding list of achievements that were catalyzed by increased government investment in space, from $90 million at the beginning of the decade to close to $300 million by the end of it. New technologies were an increasing focus for the CSA, including Earth observation and science satellites. The 1990s saw launch of RADARSAT, Canada's first Earth observation



the satellite, as well as funding for the follow-on RADARSAT-2 and for SCISAT and MOST, the country's first two scientific satellites since the 1970s.

In return for Canada's contributions to the US space program, Canadian scientists were given unprecedented access to scientific data, Canadian space companies developed profitable partnerships with US companies, and Canadian astronauts were given rides on NASA's Space Shuttle fleet. This unique "pay-to-play" arrangement gave Canada a role in space far beyond what we could have achieved on our own. This led to more astronaut rides (8 astronauts on 14 missions) than any other single nation except for the US and Russia, and will conclude with Chris Hadfield's flight to the ISS in December of this year where he will be the commander of the space station for the three final months of his six-month mission – the first non-American, non-Russian to act as Commander.

Throughout Canada's history as a spacefaring nation, private sector involvement was not only encouraged, but mandated. For example, the Chapman Report of 1967 recommended that "systems management and prime contract activities be awarded to Canadian industry for the development and supply of the major hardware portions of the Canadian Space Program".

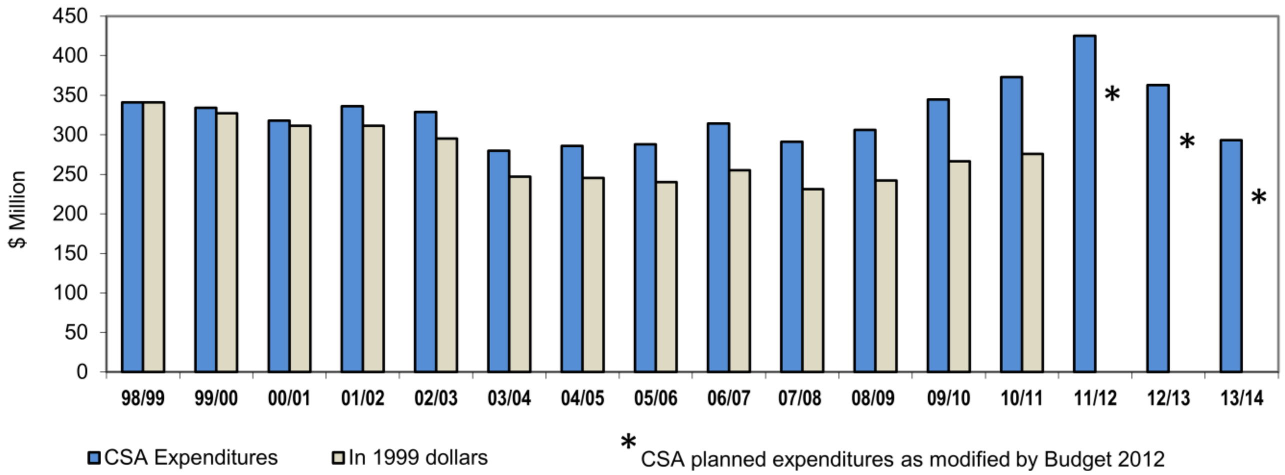
Subsequent space strategies, policies, programs and legislation[17] – including the independent Science Council's 1967 "A Space Plan for Canada", the 1974 "Canadian Policy for Space", the 1990 Canadian Space Agency Act and the Space Policy Framework in the 1994 Long-Term Space Plan – all specifically noted that a primary goal of Canada's space program was the development of an indigenous space manufacturing and services industry. The Canadian Space Program of 1999 simply reiterated the 1994 statement on industrial development, but was notable for the policy change in the way the CSA would be funded henceforth – by a base budget, or "A-base", at a nominal level of $300 million per year (see Figure 3).

Today, Canada is a recognized world leader in satellite telecommunications services and technologies, radar-imaging Earth observation satellites and ground stations, space robotic technology (manipulators, mobility, autonomous systems, cameras and sensors), micro/nanosatellites and optical and scientific instruments, and is at the forefront of futuristic initiatives like on-orbit satellite servicing, space debris removal and space resource exploration. Many of these technologies have spin-offs in terrestrial markets such as industrial production, medicine, mining, energy, security, navigation and transportation.

Canadian Space Agency Budget

Figure 3 shows the actual expenditures of the CSA (in current dollars and 1999 dollars) from 1998/99 to 2010/11. The average expenditures over the period were $319 million in current year dollars, or $276 million in 1999 dollars. The increased funding in the last two years is primarily due to the $110 million allocated to the CSA as part of the government's Economic Action Plan. This special allocation will end in 2011/12. The chart also shows planned CSA expenditures for the future (as reported in the CSA's 2011/12 Report on Plans and Priorities and modified in Budget 2012). The projected CSA budget shows a dramatic decrease starting next year.

Figure 3 - CSA Expenditures (sources: CSA Departmental Performance Reviews (DRP) and Bank of Canada Consumer Price Index (CPI))



Canada's world-class capabilities in space

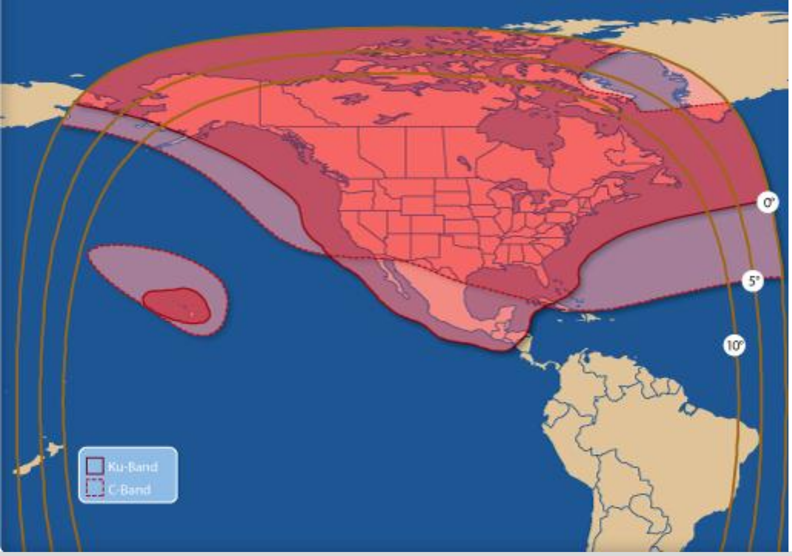
Canadian space capabilities have been developed to serve this country's domestic needs and foreign policy imperatives in addition to creating a high technology economy. By virtue of the unique Canadian government/industry/academic partnership, enlightened procurement policies and extensive international relationships, each of the major segments of the Canadian space industry – communications, Earth observation, space exploration and space science – has become a global leader in specific niche areas, often setting the worldwide standard that others now follow or seek to replicate and surpass.

Satellite communications manufacturing and services

By far the largest segment of the Canadian space industry is satellite communications, accounting for more than 80% of the total revenues generated by the space sector. Within this overall sector, Canadian industry is involved in three fields of activity: satellite operations and services; systems and payloads; and satellite components, such as antennas, switches and digital systems. This sector is the most established and commercially-oriented of the Canadian space sector, with products and services that are internationally competitive.

Demand for satellite systems for consumer broadband, video broadcasting/distribution and military satellite communications is growing, with service providers offering an order of magnitude increase in capacity every few years – although demand still often outpaces supply. Emerging economies are developing satellite systems to meet their own needs at a record pace – indeed, China launched 15 satellites into orbit in 2010 – the same number as the US – and India has one of the largest domestic communications satellites systems, with eleven satellites providing a variety of communications services.[18] Elsewhere, international alliances have come together to develop new, more sophisticated military satellite communications systems, such as the Wideband Global SATCOM system.[19] Going forward, there will be a sea change in advanced digital technologies needed to satisfy the emerging market of both commercial and military "Communications on the Move" mobile broadband systems, both in the geosynchronous orbit (or GEO, some 36,000 km above Earth) and in innovative alternative LEO and MEO (low and medium) orbits.

Telesat's Anik F2 coverage overview



Canadian industrial players have the capabilities to participate in this growing global market. Part of the rationale for the recently announced acquisition by MDA of US-based Space Systems/Loral was the desire of MDA to rapidly develop the capability to enter the growing international market for complete satellite systems manufacturing and bolster its satcom operations in Montreal.

In the intensely competitive satellite telecommunications services segment, Telesat is one of a relatively small number of service providers operating on a global basis. As competition increases, so does the consolidation in this sector, allowing economies of scale that are key to success of satellite operators, and in many cases, survival.

Canadian industry is, however, 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 sector is seen as an economic engine with significant growth opportunities, and national governments are investing in the sector's future success. In such an environment, Canadian firms must find a way to grow both their international and domestic business if they are to remain viable – and government policies play an important role. It is significant that as other nations place high priority on this important economic growth sector, Canada has neglected this strategic sector with no significant investment for the past decade.

Earth observation

The Canadian space industry has well-established industrial capabilities in Earth observation (EO) that cover the full range of activities from space mission management to the design and development of satellite systems and payloads to satellite ground stations and the generation of data products and applications from the information obtained from the satellites. One key technological thrust and expertise is in Synthetic Aperture Radar (SAR) EO through the RADARSAT-1, RADARSAT-2 and the current system in development, the RADARSAT Constellation Mission (RCM). Canada was the first country to develop this technology[20] and remains a world leader in this area, developed in response to a national need. Another capability area is optical remote sensing for measuring important atmospheric and land characteristics.

Together, the Canadian government, industry and academe are global leaders in the development and utilization of Earth observation systems and data to support operational use by both government and industry, in Canada and globally. Long-term trends favour an increase in EO utilization in Canada and worldwide, from monitoring the environment and the opening of Canada's North, to the need for enhanced natural resource management and increased concerns for security and disaster management applications.

This sector is still largely dependent on governments as the anchor customer – as is the case globally, noted by the OECD: "It is estimated that 77% of all new Earth observation satellites in the coming ten years will be owned or operated by a government or military entity, confirming the dominance of public institutions on the supply side."[21] However, this market is experiencing a shift towards greater commercialization. Canadian EO companies are increasingly able to sell data commercially and are currently providing similar operational services to the oil and gas industry, commercial shipping, and other resource and environmental industrial customers. For example, EO products and services are able to monitor oil and gas fields in order to prevent damage to wells during the extraction process, saving millions of dollars, while at the same time monitoring for ecological impact. Similarly, EO companies are monitoring Arctic waters and providing daily information to avoid ice hazards, providing navigation information for commercial shipping and monitoring for environmental hazards such as oil spills in this fragile environment.

SCISAT-1 - 'Mission Possible'

Launched in August 2003, SCISAT was Canada's first atmospheric research satellite since the early 1970s. SCISAT-1 was developed to better understand an important scientific and policy issue – the depletion of the ozone layer, especially over Canada and the Arctic. Weighing only 150kg and consuming 75W of orbit average power, SCISAT-1 is a small but very powerful and cost-efficient satellite. Since its launch, it has detected pollutants in the atmosphere that have never been identified before from space.

Canadian companies were central to the development of SCISAT-1, under the lead of the Canadian Space Agency (CSA). Winnipeg-based Magellan Aerospace was the prime spacecraft contractor and Quebec City's unit of ABB Canada developed the main scientific instrument for the satellite.

In addition to providing an impressive amount of data that advanced scientific research into the Earth's protective ozone layer – assisting Canada and its international partners to achieve their environmental goals – the program also generated significant commercial benefits.

Magellan went on to develop the redundant bus for the CSA's CASSIOPE mission (currently awaiting launch) including the development of a fully-redundant Command and Data Handling Unit (C&DH). Further experience on that program has enabled Magellan to become the bus prime contractor for the RADARSAT Constellation Mission (RCM) program and to develop a second hardware unit, a Power Control Unit (PCU). While still in testing, there has been significant international interest in the PCU for both government and commercial opportunities.

In the case of ABB, the instrument technologies developed by the company were the basis for ABB's contribution to GOSAT, a Japanese mission targeted to the monitoring of greenhouse gases. ABB received a significant contract from NEC Toshiba Space System in Japan for providing the interferometer module of the GOSAT instrument. In addition, ground-based and airborne versions of both the SCISAT and GOSAT spectrometers were sold by ABB in the US, Japan, and China. Altogether, these export revenues – which support jobs in Canada – have already equalled the SCISAT contract value for the spectrometer.

More recently, Magellan and ABB successfully completed the systems engineering and management of a Phase 0 study on the Chemical Aerosol Sounding Satellite (CASS), a follow-on mission to SCISAT-1. CASS will extend our knowledge of the atmosphere and advance the crucial field of climate change research.

Success Stories

Forecasting more success for ABB, improved weather predictions for everyone

NASA's Crosstrack Infrared Sounder, or CrIS, represents a major breakthrough in satellite weather sounders – instruments that profile temperature, pressure and humidity in the atmosphere. When combined with pictures provided by satellite imagers, data generated by sounders give meteorologists the information they need to predict weather more accurately.

ABB's business unit, located in Quebec City, played a major role in the success of the CrIS by developing a prototype of a more efficient interferometer as the result of a $150,000 contract with the Canadian Space Agency's Space Technology Development Program (STDP) in the mid-1990s.

Launched in 2011 aboard a weather satellite, the CrIS is meeting every expectation. ABB is preparing to provide its uniquely Canadian technology to other projects. The company expects to deliver a second flight model of its interferometer later in 2012. This model will be part of the CrIS instrument to be mounted on NASA's Joint Polar Satellite System, JPSS-1. ABB also hopes to land a contract to participate in the subsequent JPSS-2. The two JPSS satellites are expected to be launched in 2016 and 2022 respectively.

Designing, developing, building and demonstrating its interferometer has resulted in approximately $50 million in contracts in the CrIS program over 15 years – a 300-fold return on the initial STDP investment.

NPOESS satellite concept

In addition to serving Canada's national needs, EO data in establishing and developing many international collaborative agreements around the world that have resulted in significant new business for its industry, as well as enhanced Canada's reputation as a reliable and capable partner that can be depended upon over the long term for data continuity and creative advancements in technology. For example, ABB's Fourier Transform Spectrometer technology has been purchased directly by US company ITT Exelis for the CrIS (Cross-track Infrared Sounder) instrument in the new generation of US weather satellites. NEC Toshiba Space Systems did the same for the Greenhouse gases Observing Satellite (GOSAT) of the Japanese Space Agency. In both cases, these technologies were first demonstrated in CSA programs.

Space exploration

Where satellite communications and Earth observation focus on critical data and service provision, space exploration is characterized by challenging, ambitious and inspiring global initiatives and a nation's participation engages domestic science and technology capacity and showcases it on the world stage. Meanwhile, nations secure for their industry, academia and general public in a share in the future scientific discoveries, technology breakthroughs, economic opportunities and societal returns yielded by this global endeavour. Unsurprisingly, given its nationalistic motivations and societal impact, space exploration remains a heavily government-driven market, even though many of the state-of-the-art technologies demanded by exploration are subsequently commercially deployed in other domains – in space and terrestrially. However, due to strong technology overlap, the same capabilities developed for national initiatives are also applicable to the emerging commercial spaceflight market.

> *"The investments in space programmes are often justified by the scientific, technological, industrial and security capabilities they bring. But these investments can also provide interesting socio-economic returns such as increased industrial activity, and bring cost efficiencies and productivity gains to other fields (e.g. weather forecasting, telemedicine, environmental monitoring and agriculture previsions."*
>
> **OECD, The Space Economy at a Glance 2011**[22]

Canada's participation in space exploration traces back three decades and includes some of the nation's best known technological achievements. The Canadarm and Canadarm2 contributions to the US space shuttle and International Space Station programs in the 1980s and 2000s cemented Canadian technology leadership in the area of space robotics while garnering the trust and admiration of multiple international partners. In addition to branding Canada internationally as an advanced technology nation, these iconic contributions also established Canada's space capability as a domestic household name and three generations of Canadians have since been inspired to explore education and careers in science and technology by Canada's exploration participation and the resulting astronaut program.

Canadian industrial capacity in space exploration largely centres around the area of robotics, science instruments and a broad portfolio of next-generation technologies developed under the CSA's preparatory program for future participation – including rovers, robotic arms, satellite servicing robotics, sample handling robotics, rendezvous and docking technologies, sensors and vision systems, life support and medical systems, and drills and mining systems. For example, Canada's Alpha Particle X-ray Spectrometer, or APXS, was delivered to the surface of Mars aboard NASA's Curiosity Rover in August of this year – Canada's second scientific instrument on the Red Planet.[23] Small technology contributions are also planned for the European-Russian ExoMars missions in 2016 and 2018, establishing crucial heritage and credibility for Canadian industry and academic researchers. Finally, a Canadian 3D laser-instrument will conduct advanced mapping of an asteroid surface aboard the NASA OSIRIS-Rex mission that will be the first to return significant asteroid samples to Earth later this decade. There is a significant continued reliance on academe for international leadership in research, new technologies, and the production of HQP in this area.

Canada stands well-placed to thrive in the exploration market of the future. Our industrial capacity spans the exploration and exploitation programs and applications of the future. Much of Canada's expertise is in enabling technologies (communications, remote-sensing, robotics) that are suitable for a vast array of applications and which will be in strong demand for future exploration and exploitation programs. However, our industrial leadership built over the last three decades can no longer be taken for granted and requires careful, focused attention to ensure our seat is maintained at the political table and our share of the benefits and returns from the next phase of space exploration is secured.

Neptec's Vision for Space

In 1992, when Canadian Astronaut Steve MacLean launched into orbit on board shuttle mission STS-52 he carried with him, literally, a Canadian vision for space. As part of the government-funded CANEX-2 series of Canadian experiments on that flight was a Canadian invention known as the Space Vision System or SVS.

Based on the results of the SVS experiments on STS-52, NASA approached the Canadian Space Agency (CSA) in 1994 and asked if they would be willing to have Neptec build and test a more advanced version of the Space Vision System, designed specifically to help them build the space station. This was the beginning of an international joint program that saw Neptec design and build two different versions of the SVS – the Orbiter Space Vision System (OSVS) for the shuttle and the Artificial Vision System (AVS) for the ISS. For over 20 missions, the OSVS and AVS performed on-orbit, helping astronauts manoeuvre the massive segments of the ISS with pin-point precision, making it an essential contribution to the successful completion of the world's largest space construction project.

Part of the Space Vision System designed by Neptec was a Laser Camera System (LCS), originally intended as sensor to be used with the SVS. The LCS was a precision laser scanner that could be used to make very accurate three-dimensional scans of surfaces at distances from one to ten metres away.

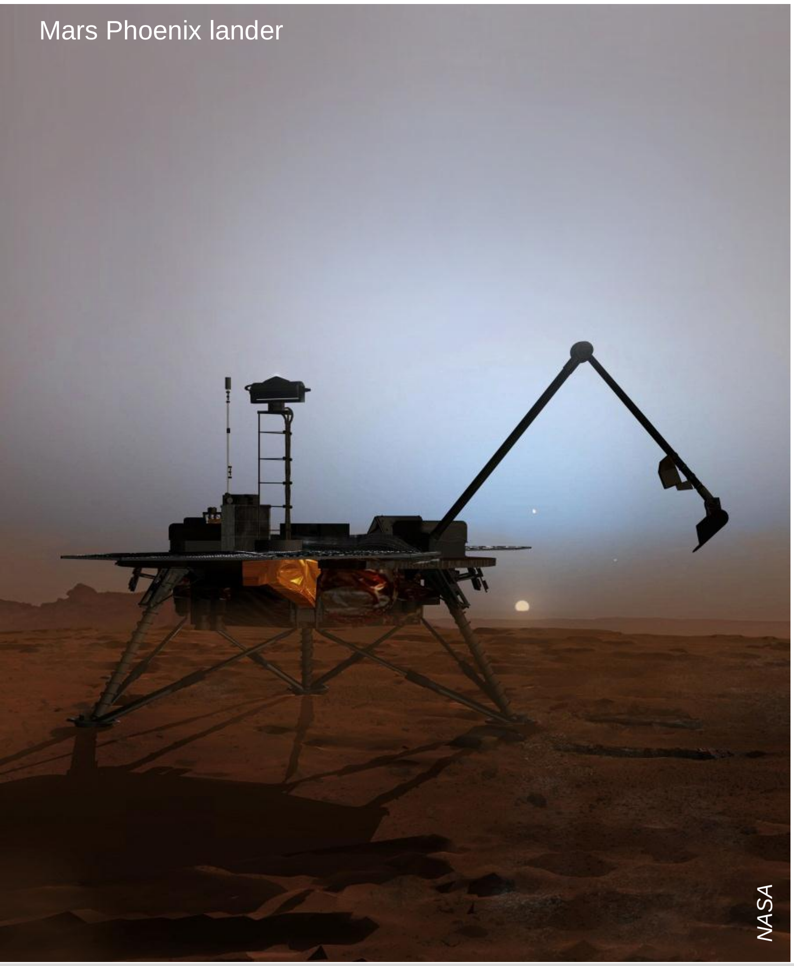
After the space shuttle Columbia NASA needed to find a way of inspecting the shuttle's exterior surface while it was on orbit. In order to clear the shuttle's exterior, they needed to be able to detect and measure damage to accuracies less than a millimetre, while keeping the sensor at least three metres away from the shuttle's fragile tiles and panels, to avoid any chance of causing more damage. Neptec was approached to design and build a new version of the LCS to mount on the new Canadarm inspection boom which was being manufactured by Canada's MacDonald, Dettwiler and Associates (MDA). Using data from LCS, NASA engineers and mission managers were able to determine with confidence that the damage to the shuttle's tiles posed no threat for re-entry and STS-114 was completed successfully. Based on the experience of STS-114, LCS became standard equipment on all shuttle missions, flying 28 more times until the end of the program on STS-135.

Success Stories

Space science

Canadian universities and research organizations have a small, but internationally-renowned cadre of space scientists who are contributing substantially to Earth observation, planetary exploration, space astronomy and our understanding of the universe, studying the multitude of interactions between the Sun and the Earth that affect daily life on this planet, and analyzing pollution in our atmosphere, as MOPITT[24] has been doing since 1999. Their expertise lies in planetary exploration and modeling, analogue field science, data analysis and science instrument development. The results of their work are having a major impact on humankind's understanding of how space affects our daily lives.

In addition to supporting our scientists and engineers, the space science activities of the Canadian Space Program, through the procurement and flight of highly sophisticated instruments, provide important opportunities for technology development and demonstration in our space industries and unique avenues for international cooperation, opening up restricted international markets to Canadian companies.



One such instrument, an FTS (Fourier Transform Spectrometer) built by ABB on-board a Magellan-built satellite SCISAT, was launched in 2003 to study the stratosphere, where the ozone layer is located (see SCISAT success story). SCISAT is providing the most accurate measurements to date of chemicals that affect ozone, which blocks the Sun's biologically damaging ultraviolet radiation and prevents most of it from reaching the Earth's surface. Data from this satellite is making an important contribution to international environmental policy aimed at protecting the ozone layer, such as the Montreal Protocol that bans certain chlorofluorocarbons (CFCs). Other examples include Canada's first space telescope, MOST, which was launched in 2003, and Cassiope, a hybrid satellite that is awaiting launch which will carry a space weather scientific payload and a telecommunications payload which will provide the very first digital broadband courier service for commercial use.

The space industry in Canada can alternatively be divided into two distinct branches – the space applications and services sector and the space manufacturing sector. Each sector has its own unique attributes and requirements for international competitiveness.

The **space applications and services sector** operates primarily in the open commercial marketplace providing its civilian and defence customers with a variety of space-based services. This sector is characterized by intense competition on a global basis among a relatively small number of service suppliers. Almost all of the growth of the Canadian space industry over the past decade (38%) has occurred in this sector (139% growth)[25] – see Figure 2 for details. The spectacular growth of this segment is a clear indication of the capability of Canadian industry to compete in the international commercial market for communications satellite services (e.g. Telesat Canada), Earth observation data sales (e.g. MDA) and satellite navigation services (e.g. COM DEV).

The largest space market growth over the next decade is expected to occur in the commercial provision of applications and services. More and more, governments will be procuring the provision of services (rather than the procurement of systems), and whole new fields of commercial operation will develop (e.g. access to space, space resource exploration, space-based power, communications and navigation). New arrangements for financing these ventures are being put in place (e.g. public-private partnerships). As well, governments are adopting new regulatory regimes to encourage the provision of space services by the private sector.

In Canada, satellite telecommunications providers pay a wide range of regulatory fees. These include spectrum fees related to the use of orbital slots and radio spectrum, contribution fees used to subsidize service in high cost areas, regulatory fees that pay for the costs of industry regulation by the Canadian Radio-television and Telecommunications Commission (CRTC), etc. Collectively these fees are almost ten times greater than those paid by our largest US-based competitors. In addition to domestic measures, there are a wide range of regulatory issues associated with market entry abroad. Tax treaties are not always respected, resulting in less favourable treatment of Canadian companies. In general, Canadian companies are often put at a competitive disadvantage because of measures taken by other countries to give advantage to their domestic firms.

The provision of commercially-viable space services is a dynamic area and the future will see a whole range of new applications of space technology to meet commercial and national needs. Being first-to-market with flight-proven applications provides a major competitive edge to the services sector. In a globally-competitive market, it is important that the Canadian space services industry has the Canadian government as a model user. This may involve modifying existing commercial space capabilities and services to meet government requirements when the modification represents a more cost-effective approach. This also includes actively exploring the use of inventive, non-traditional arrangements for acquiring commercial space goods and services to meet government needs, including measures such as public-private partnerships.

In the past, Canada has supported the pre-commercial demonstration of new applications through major programs (e.g. MSAT), by developing demonstration payloads and flying them as "hosted payloads" on commercial systems (e.g. government experimental payloads on Telesat's Anik B and Anik F2 satellites), and by being the "first customer" for commercial systems aimed at meeting government needs (e.g. COM DEV's exactEarth). These are very effective mechanisms for exploring new applications in ways that substantially increase the competitiveness of the services sector.

The most important things the government can do to assist the competitiveness of this sector are:

1. review relevant regulations (e.g. data policy regulations, regulatory fees, etc.) with a view to ensuring they promote the growth of commercial markets; and

2. adopt procurement policies that will ensure government departments use commercially available services provided by Canadian companies to the maximum extent possible, while supporting Canadian industrial development policies.

The **space manufacturing sector** (space segment, ground segment, space research and space systems integration) is essential to a nation's ability to act independently in space. This is the sector that allows a nation to design, develop and fly space missions to meet national needs, ensuring that the industry is available when the need arises. All spacefaring nations foster the development of their space manufacturing industries, either to fulfill national policy objectives or to build sustainable export businesses.

> *"Governments continue to dominate the space market, as satellite systems are critical infrastructure for communications and geo-information solutions for civilian and military users. The government market is worth more than double the commercial market, but is largely closed to non-domestic manufacturers. Export opportunities for manufacturers exist with governments in countries with no space industry."*
>
> **Rachel Villain, Euroconsult**[26]

Much of the business of the space manufacturing sector involves the development of one-of-a-kind or first-of-a-kind technologies, often developed to meet a particular national need, that are later leveraged by industry to develop lines of business and export sales. Developing these solutions requires solving challenging technology problems for the first time – and success in the sector requires consistent investment in technology development, often in partnership with researchers in Canadian universities. The risks associated with doing things that have never been done before, for markets that are often restricted, make it virtually impossible for industry to pursue these critical elements on its own. In all successful spacefaring nations, governments assist the development of their space manufacturing industries through government-funded R&D, technology development programs, science programs, flight demonstration programs and international cooperative projects. The space manufacturing industries in all countries rely on their governments to be strategic customers for innovative technologies and services – often as the critical "first buyer" or "first user". In the space sector, it is clear that if your own national government does not buy your technologies, you have little chance of succeeding.

> *"The role of public institutions remains essential in the space sector, not only in terms of the necessary investments in R&D, but also as anchor customers for many space products and services."*
>
> **The Space Economy at a Glance 2011, OECD**[27]

The use of government procurement as an instrument for the development of the space manufacturing sector has been a key part of the Canadian Space Program since its inception. Government procurement policies over the years ensured that government space procurements were conducted in a manner consistent with the objective to develop and maintain an internationally competitive domestic space manufacturing industry. These policies enabled the development of the Canadian space manufacturing industry.

The essential keys to the international competitiveness of space manufacturing industries around the world are:

1. world-leading technologies;
2. flight demonstration of new technologies and applications; and
3. access to restricted government and commercial markets.

COM DEV leverages Canadian government funding into export sales

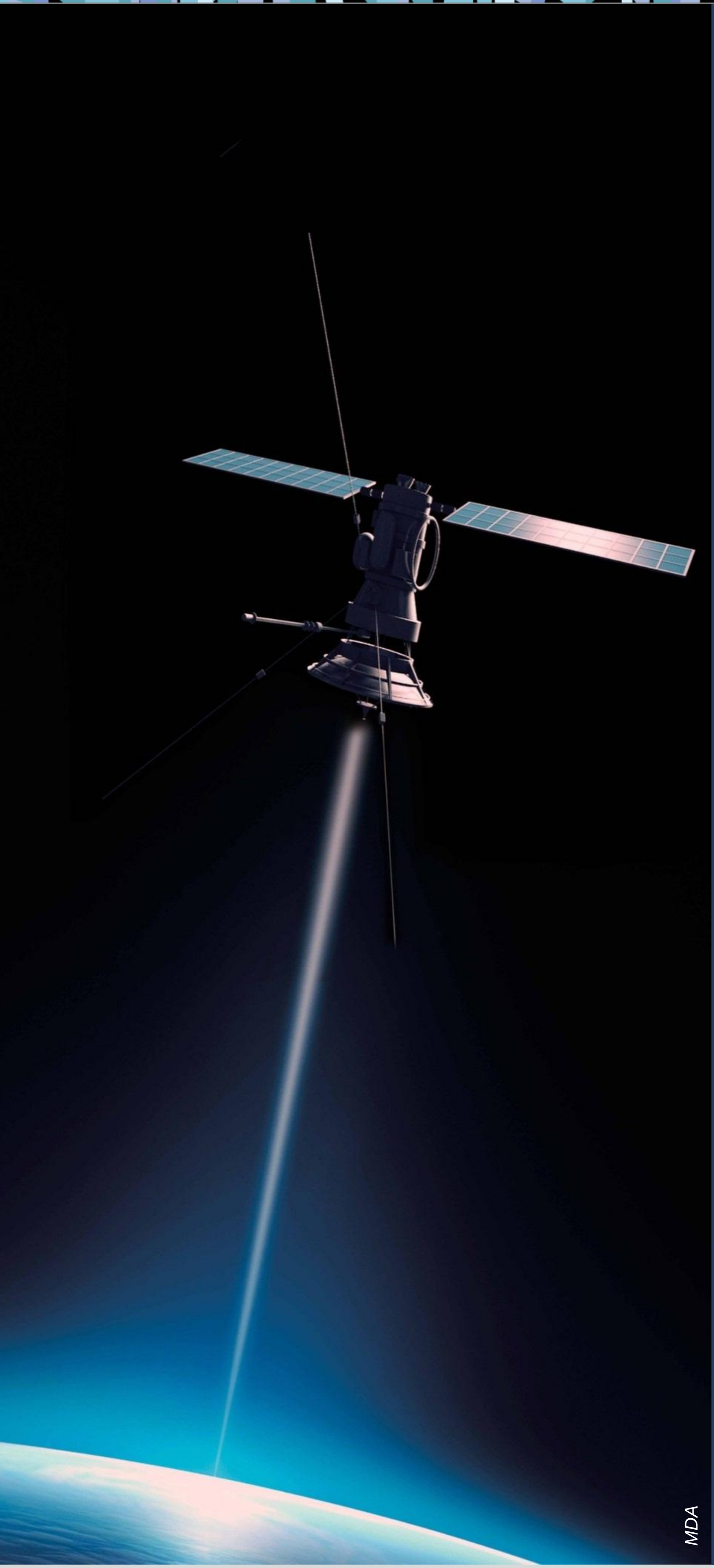
COM DEV has for more than 30 years successfully leveraged Canadian government investment in space technology development to capture a significant market share of the commercial satcom market. In micro-wave filters, multiplexors, switches and ancillaries, COM DEV enjoys global market shares in excess of fifty percent, in some case closer to eighty percent. As a result, COM DEV products are found on more than 850 satellites and spacecraft that have been launched to date – more than any other company in the world. COM DEV space products also have been modified for non-space applications such as Japanese ground radars, NATO naval radar subsystems, and an ice-assessment system for ships seeking to navigate through ice.

The following tables show the substantial multiples COM DEV has achieved by translating modest government technology development funding into commercial returns. The tables cover a decade of Canadian government funding, from 1998 to 2008, and show the export (commercial) revenue earned over the same time period compared to the modest government participation indicated.

CSA Program	CSA STDP/CASTOR Contributions since 1998-2008 (C$M)	COM DEV Products	Sales Achieved to 2008 (C$M)	Key Programs
MUX/MWC Technologies	4.3	UHF, Ku & Ka Band MUX Products	41	Skynet V, Satcom BW2, Sicral, MUOS, Gen 1 TC, Direct TV
SWITCH Technologies	2.0	Low Power & High Power Co-axial, Waveguide & MEMs Switches	19	Terrastar & High Power Ku
ELECTRONICS Technologies	7.0	Channelisation & Routing RF Electronics	67	Sky V, Satcom BW2, WINDS, GS2
TOTAL SATCOM	13.3	Satcom Products	127	

CSA Program	ESA ARTES Contributions since 1998-2008 (C$M)	COM DEV Products	Sales Achieved to 2008 (C$M)	Key Programs
MUX/MWC Technologies	3.5	Ka Band Ancillaries/Filters	7	Eutelsat Ka
SWITCH Technologies	0.3	Ka-Band Switch/Test Set-up	7	Eutelsat Ka
ELECTRONICS Technologies	0.9	Channelisation & Routing RF Electronics	9	Cascade
TOTAL SATCOM	4.7	Satcom Products	23	

Success Stories



Canadian companies combine skills to develop high-accuracy antenna reflector

Under a $939,000 contract with the Canadian Space Agency's Space Technology Development Program (STDP), the Montreal division of the B.C.-based MacDonald, Dettwiler and Associates (MDA) developed a high-accuracy antenna shaped reflector for use on communications satellites. In 2008, in collaboration with a Nova Scotia-based supplier, Composites Atlantic Ltd. (CAL), MDA succeeded in creating a medium-sized (0.9-m diameter) reflector that exceeded the established standards. The MDA and CAL reflectors are lighter and stiffer than the standard ones, and because they are thermally stable, they are also effective over a wider range of temperatures.

Almost immediately, their success was acknowledged by the European Space Agency (ESA) with an invitation to contribute to the ESA's Sentinel program. This led to a second STDP contract for MDA and CAL in 2010. The two firms continued their collaboration, this time to build a larger reflector, one with a diameter of 2.3 meters. Again, the MDA and CAL partnership exceeded expectations and US aerospace giant Boeing, asked the two firms to supply 16 of the larger reflectors.

The opportunity to contribute to ESA's Sentinel-3 mission is certainly significant as well. For one thing, it will allow MDA and CAL to demonstrate their new technology in space for the first time. Set to launch in 2013, Sentinel-3 is the third of five ESA missions specifically designed to meet the operational needs of the Global Monitoring for Environment and Security (GMES) services.

While the original STDP contract was relatively small, the results have been anything but. Technology developed under the contract was almost immediately commercialized, enabling MDA and CAL to secure contracts that previously might have been out of reach for both firms. In addition to ESA and Boeing, organizations now using this Canadian technology include Intelsat, one of the world's largest providers of satellite services. Technology generated by MDA and CAL have seen wide industry adoption and is being used on the following satellites: EXPRESS AM5, EXPRESS AM6, ASTRA 1N, ASTRA 2E, ASTRA 2F, ASTRA 2G, ASTRA 5B, JUPITER-1 and HYLAS-2. In addition, the MDA and CAL reflectors and panels have also been used on W5A – a commercial Eutelsat program. MDA estimates that the revenue generated by these reflectors is around $5 million every year. As well, the opportunity afforded through STDP contracts created a need for highly qualified people to work on reflector projects. Fifteen full-time positions were added as a result of the contracts.

The strategic importance of space to Canada

Around the world, countries have become heavily reliant on space technologies as a key part of their national strategic infrastructure. This was underlined by Futron in their 2011 Space Competitiveness Index: "Today, the value of space is far more than inspirational, emotional, or symbolic. Space is practical, economic and strategic. Countries that participate in space reap tangible scientific, technical and financial rewards that improve the lives of their citizens, increase their base of knowledge, advance their productive capabilities, expand their range of economic activities, and enhance their geopolitical position. Nations active in space accrue strategic benefits over their peers – and nations that lead in space develop sustained advantages that underpin, complement, and augment their leadership across all other dimensions of global commerce, technology, prestige and power."[28]

The strategic importance of space to Canada is beyond doubt. In a country as vast and sparsely populated as Canada, space technologies play a unique and vital role in helping us to communicate to one another and to help monitor our territory for both opportunities and threats. No other technology can provide the scope of information or connectivity required to meet today's urgent demands.

> *"Space is strategic, combining government capabilities with economic, industrial, and social benefits… The strategic nature of space activity will ensure a continued interest in space capability and competitiveness at the nation-state level."*
>
> **2011 Futron Space Competitiveness Index**[29]

Geographically, Canada is the second largest country in the world and has the world's longest coastline. Under the United Nations Convention on the Law of the Sea (UNCLOS), Canada claims an exclusive economic zone along our coastline equal to more than 70% of our landmass. Protecting and managing such an enormous zone is a major challenge. Seventy-five percent of our population lives within 160 km of the US border, leaving the majority of our landmass scarcely populated and difficult to access. We are an Arctic nation with a northern territory that comprises more than 40% of our total landmass. This Canadian geography and demography make it extremely challenging for governments to provide the infrastructure critical to our economic and social growth and to manage our national and international responsibilities for security, safety and resource stewardship.

To meet these challenges, Canada has focused on developing and using space technology and applications in those areas where services cannot be provided effectively or efficiently by any other means and where indigenous capacity and control of technologies is in the national interest. As a result, space technology is intricately woven into the socio-economic infrastructure of the nation providing essential communications systems, air and ship traffic management, weather analysis, resource management, search and rescue, environmental monitoring, and a whole host of security and intelligence services.

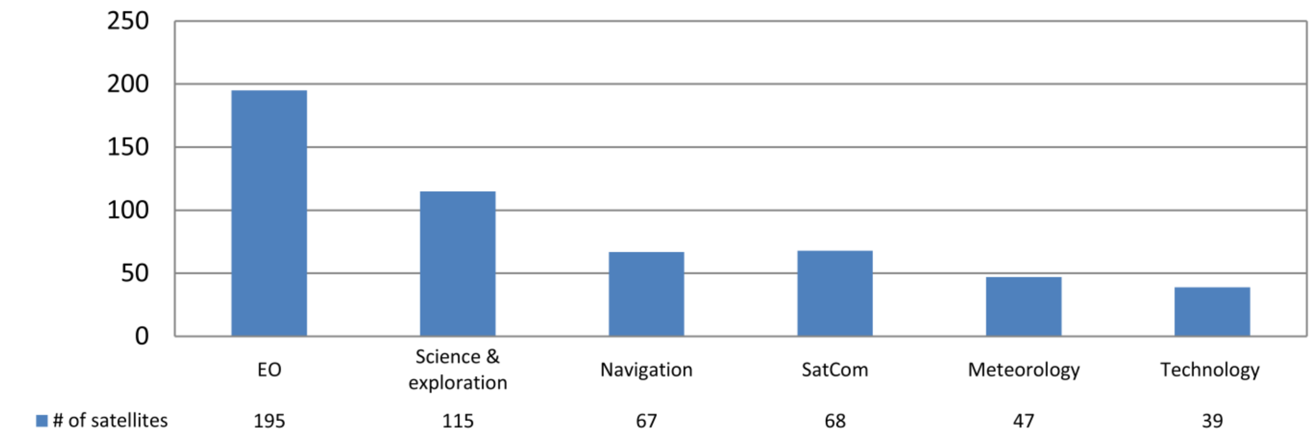
Today, space applications and services are largely taken for granted. But virtually every aspect of modern life in Canada is dependent on space – from printing your morning newspaper to gas pump transactions, from television entertainment and hand-held mobile devices to the inner-most workings of our financial system and the electricity grid. Space is now so interwoven with Canada's economic life-blood that its fundamental contribution to our national infrastructure is often forgotten. It is estimated that space-based applications touch the lives of every Canadian 20-30 times per day every day. As stated in the 2010 US National Space Policy, "Space systems allow people and governments around the world to see with clarity, communicate with certainty, navigate with accuracy, and operate with assurance."[30]

Should key space assets fail, these fundamental building blocks of Canadian society could be crippled, putting the country at significant economic risk. For example, in October 2011, Telesat's Anik F2 satellite experienced an outage that affected services such as telecommunications, broadcasting, internet voice and data, banking and even air traffic control in Nunavut, Newfoundland and northern Quebec and Ontario for almost 24 hours. In Europe, the continent's premiere Earth observation satellite, Envisat, abruptly stopped functioning in April 2012 – forcing ESA to make emergency arrangements for Earth observation data, including with Canada's RADARSAT-2, until Envisat's replacement, Sentinel-1, is launched in 2013.

Projected market for space systems 2010 to 2020

Figure 4 shows the projected market for civilian Government satellites (total of 531) for the decade from 2011 to 2020. In addition, during this time frame, 368 commercial satellites and 246 defence-related satellites are planned. This is a total of more than 1100 satellites to be built during this period, which is equivalent to the total number of satellites currently in orbit. Given Canada's strengths, this graph represents a large potential market for the Canadian space industry.

Figure 4 - Projected market for space systems 2010-2020



Source: Euroconsult

Some of these systems are in the commercial domain where governments can buy services from commercial operators (e.g. satellite communications services, both civilian and military, and Earth observation data). But many of these systems are government-owned, operated and built by domestic industry when it is in the national interest (surveillance, classified military operations and communications). A study by Euroconsult shows that for the period 2010-2020 (see Figure 4), more than 1100 satellites are planned to be launched of which 68% will be for government or defence purposes.[31] While the trend worldwide is to increase the use of commercially available services, national security and sovereignty considerations will continue to be factors in space system procurement decisions by governments.

Canada has also recognized the valuable contribution space technology and science can make to help our country achieve our foreign policy objectives. Canada's original participation in the Space Shuttle program was seen as a way to deepen our country's partnership with the US government. Our subsequent participation in the International Space Station was a direct consequence of our desire to act as a full contributing member of the G7. Our decision to be a cooperating state of the European Space Agency (ESA)[32] was taken in the context of the Government's desire to strengthen our economic ties with Europe. Participation in the space science programs of other nations allowed Canada to forge unique scientific relations at the international level and gave our scientists access to key environmental and other data of importance to Canada, enhanced opportunities for the training of HQP and access to new flight opportunities. The provision of RADARSAT data to our allies has enabled Canada to play a significant role in international security and has given Canada access to a broad range of intelligence information vital to the interests of our country. In the asymmetric world of today, intelligence information and operations are increasingly important to the security of our nation and indeed the world, and the ability of Canada to provide space-based intelligence to our allies on an ongoing basis will be an increasingly important aspect of our foreign policy.

The exercise of sovereignty and the pursuit of foreign policy objectives require a nation to have the ability to act independently in its own best interests. While Canada works closely with its allies, a sovereign nation requires a degree of independence from even its closest friends and it is therefore important that it maintains its strategic capabilities. This was recognized by the Science Council of Canada in 1967, which noted that "The Council believes that Canada should approach the challenge of space as a partner in the world-wide assault on its secrets and its potentialities. This cannot be done from a meagre base, nor could it be achieved in partnership with only one nation... Canada could stand aside in space matters and leave the costly [space system] development efforts to the USA, the USSR and to France and Great Britain, secure in the knowledge that in due course, the hardware and the services would be available, and for sale. The Council's conviction that *a much more dynamic policy is required* arises not out of a spirit of competitive nationalism but out of a realization that sociologically and economically, *Canada cannot afford to expose herself to the degree of economic and technological dependence that the alternative* [*i.e.* not building our own space systems] *would involve*."[33]

Nations define those areas of strategic importance and undertake activities to ensure they have the capability to act when and how they want. In Canada, there are a number of industrial areas (e.g. shipbuilding, space surveillance[34]) where the government has declared that it is in the national interest to have an indigenous capability to meet national needs. In the area of space technology, this capability resides in industry (both in the applications and services segment and the space manufacturing segment) and, to a lesser extent in academe, and enables the government to pursue the development and use of systems to meet unique national needs (e.g. surveillance) without being dependent upon the policies and practices of other nations.

From the beginning of the Space Age, Canada has fostered the development of an internationally competitive space industry capable of meeting national needs and leveraging economic benefits from export sales. This indigenous capability enables Canada to participate in the space activities of other spacefaring nations when it is in our interests to do so. It allows Canada to bring to the table technologies and systems that we can offer to our friends and allies in return for access to their technologies and systems.

Over the next twenty years, changes in Canada's Arctic region will present a unique set of challenges and opportunities for the federal government. A recently-released report on Arctic policy priorities lays out these challenges and opportunities succinctly: "The Arctic is changing. At the root of much of that change is global warming. The Arctic is warming much faster than the rest of the planet, and as a result, sea ice is receding. One impact of this is the opening of Northern sea routes and the prospect of dramatically increased levels of commercial shipping. A second impact is the easier access this provides to the resource wealth of the region – hydrocarbons, minerals, and fish. A third impact is the detrimental effect it is having on land and marine wildlife. These impacts have subsequent reverberations. The increase in economic activity is multiplied many times over as supporting infrastructure and systems are put in place. With the increased activity come pollution and the danger of environmental and humanitarian disasters. With the economic gain comes the desire to protect rights and investments, and the resulting potential for conflict. All of this is at odds with the traditional livelihoods of the Arctic's indigenous peoples."[35]

> *"The North is undergoing rapid changes, from the impacts of climate change to the growth of Northern and Aboriginal governments and institutions. At the same time, domestic and international interest in the Arctic region is rising. This growing interest underscores the importance of Canada to exert effective leadership both at home and abroad in order to promote a prosperous and stable region responsive to Canadian interests and values."*
>
> **Canada's Northern Strategy 2009**[36]

The Economist[37]

Sea ice in the Arctic Ocean, particularly in the region north of Canada, is disappearing at a far greater rate than previously expected, both in terms of ice coverage during the summer months and ice thickness, prompting scientists to believe that the ocean could be navigable in the late summer by the middle of the decade.[38] The idea of open Arctic water in this region has prompted both excitement and concern about potential oil and gas development, new shipping lanes through Canada's Northwest Passage and polar tourism.[39]

Similarly, natural resource development is growing as Canada explores the resource potential of its Northern territories. The US Geological Survey estimates that the Arctic contains up to 30 per cent of the world's undiscovered gas and 13 per cent of the world's undiscovered oil resources.[40] The region also contains vast amounts of coal, nickel, copper, tungsten, lead, zinc, gold, silver, diamonds, manganese, chromium and titanium.

This increased activity creates a need to be able to monitor, manage and control what transpires in Canada's North and will require high capacity satellite communications (both civilian and military), surveillance, weather forecasting, pollution detection, climate and other environmental research data, navigation, ice condition monitoring and other services that derive from space. Governments will be faced with further challenges in providing our northern regions with the critical strategic infrastructure, essential services, and security and safety enforcement that these expanded activities will demand – and which are now provided in the southern parts of the country.

"Canadian Arctic policy is faced with some of the most intriguing, yet complex, challenges in its history. Never before has the very nature of the Canadian Arctic region been altered by such a widespread set of factors. Perhaps the greatest current challenge for Canada is the worldwide realization that the Arctic is melting, and so it is more accessible than ever before… The Canadian government's ability to control what happens in its Arctic region will be tested with this entry of newcomers into the Canadian Arctic who will seek to exploit and benefit from a more accessible Arctic. Thus the melting sea ice will be at the root of the challenges to Canadian Arctic sovereignty and security."

Professor Rob Huebert, University of Calgary[41]

Much of this infrastructure does not yet exist. For example, while geostationary satellites provide for telecommunications services across most of Canada, these satellites cannot "see" the High Arctic area above 70° latitude because of the curvature of the Earth. While some remote communities have local towers that facilitate local communications, there is no continuously-available broadband network for secure, highly-reliable and high capacity telecommunications in the North that will adequately service the expected growth in activity in this area. That means there are no navigation services for ships, aircraft (military and commercial) or Unmanned Aerial Vehicles (UAVs) over the polar areas – and the lack of telecommunications infrastructure also makes rapid response in the case of disasters nearly impossible. Similarly, weather satellites do not cover Canada's polar region above 60°. Not only is it a significant problem for shipping and resource extraction activities to not have timely access to weather data, but the ability for our meteorologists to predict weather in southern Canada is hampered, as many weather systems originate in the North. These two examples outline a significant challenge for Canada as this area becomes the focus of worldwide interest. A Polar Weather and Communications (PCW) satellite system is currently being studied, but no decisions have been made as to whether and when a system may be built.

Furthermore, issues of management and control of our claimed exclusive economic zone will become increasingly urgent and contentious. Exercising sovereignty in the context of growing international interest in the North will require broader surveillance capabilities to identify and classify activities and to take interdiction action as necessary. While exactEarth[42] and Polar Epsilon[43] are providing critical maritime domain awareness information today on the two coasts, meeting these challenges in the high Arctic will necessarily involve a greater dependence on space-based services since no other technology can provide the required wide-area communications, weather information and situational awareness. Space will become even more important to the ongoing development of Canada than it is today and the need for an independent capability to monitor and protect the North will be more critical than ever.

Advancing Canadian communications satellite technologies

Increasing demands for higher capacity communications satellites have called for higher performance spacecraft antenna systems and have spurred the emergence of multi-beam missions in Ka-Band – a frequency that offers dramatic improvements in two-way high-speed Internet services over other frequencies. In order to realize the full potential of the multi-beam coverage, it was realized that a new class of antenna feed horn was needed. In the late 1990s, supported by visionary Government of Canada technology development and flight demonstration programs, MDA engineers developed a novel and unique idea to radically shrink the size of the feed horn while yielding a higher antenna performance. With the existence of the government R&D support and parallel investment from within MDA, the company was able to field the most advanced Ka-Band multi-beam antennas in the world. After initial validation, the Canadian Space Agency (CSA) awarded MDA a $150,000 shared-funding Space Technology Development Program (STDP) contract to further validate the concept as well as to develop the first synthesis tools.

These tools were put to good use a few months later when the Anik F2 Request for Proposals was issued. Telesat's Anik F2 satellite included a flight demonstration of a Ka-Band transponder, the first satellite to commercialize this frequency. The prime contractor selected for the program, Boeing Satellite Systems, decided to use MDA's Ka-Band antenna. The contract was worth $6.5M to MDA.

Through another shared funding R&D contract worth $500,000, MDA was able to add a number of critical multi-beam antenna technologies and also achieve a reduction in the number of reflectors required without sacrificing performance.

A significant amount of internal R&D was invested to further improve the performance of the technology. Encouraged by the simulation results, MDA submitted another STDP proposal in 2006 to advance the Technology Readiness Level for this ground-breaking technology, and received an additional $500,000. The result of this funding allowed for a breakthrough that permitted the same performance of the Anik F2 satellite but with four reflectors, instead of ten. MDA was subsequently awarded the complete KA-SAT multi-beam antenna system for ESA's KA-SAT program, worth approximately $10M.

In early 2008, MDA was awarded an ESA ARTES-4 shared funding contract worth 1.2M Euros for the qualification and testing of MDA's Ka-Band antenna technology. The solutions developed under this program were instrumental in MDA securing the contract for $4.5M from Space Systems/Loral (SS/L) to provide the Ka-Band antennas for the ViaSat-1 satellite, the world's highest capacity broadband satellite which was launched in January 2012.

As the ViaSat program was nearing successful completion for MDA, this world-leading technology was in high demand – for SS/L's Jupiter-1 satellite, a contract worth more than $4M; for Orbital in Avanti Communications' HYLAS 2 program, worth more than $12M; and a recently-announced communications payload for Avanti's HYLAS 3 satellite, worth $35M. MDA continues to see tremendous growth potential in the Ka-Band multi-beam antenna market.

In summary, during the last decade, with less than $3M in CSA and ESA seed funding, MDA has already captured more than $75M in commercial exports on antenna systems alone and expects to win about as much during the next three years. It has also leveraged this technology into complete payload and systems sales, each of which brings revenue within the $30 to $200M range.

Future space opportunities

The global space opportunity landscape continues to grow and diversify. Twentieth century space development was characterized by a steady increase in the access to and utilization of space, in particular the exploration and exploitation of the near-Earth space (from Low-Earth Orbit to Geostationary Earth Orbit, or 'LEO' to 'GEO') that resulted in critical space-based infrastructure which today delivers everyday services to nations worldwide, from global monitoring and navigation to telecommunications and broadcasting. This domain has since seen by far the largest growth in the commercial sector, with revenues in the international commercial space products and services market reaching $102 billion in 2010. Combined with the commercial infrastructure and support industries sector (ground stations and equipment, satellite manufacturing, and launch services) at $87.39 billion, the two segments totaled almost $190 billion, or two-thirds, of the $276.5 billion global space market – a market that has experienced growth of 48% since 2005[44], in spite of the worldwide recession that has negatively impacted other industrial sectors since 2008.

The last decade also featured a dramatic upsurge in the utilization of Earth observation systems and services for national interests. This area is anticipated to continue its growth as more and more countries look to develop their own capabilities. According to space industry analysts, it is estimated that a third of new Earth observation satellites launched between 2009 and 2018 will belong to emerging space economies.[45]

The 20th century also witnessed the commencement of human spaceflight and spaceflight to low Earth orbit and beyond, with the development of space transportation (Soyuz, Mercury, Gemini, Apollo), re-usable manned spacecraft (Space Shuttle), human-occupied orbiting infrastructure (ISS), and preliminary exploration of the universe – from awe-inspiring astronomical observatories (e.g. Hubble) to robotic explorers being dispatched to destinations across the solar system and the first human sorties to planetary surfaces (e.g. Apollo).

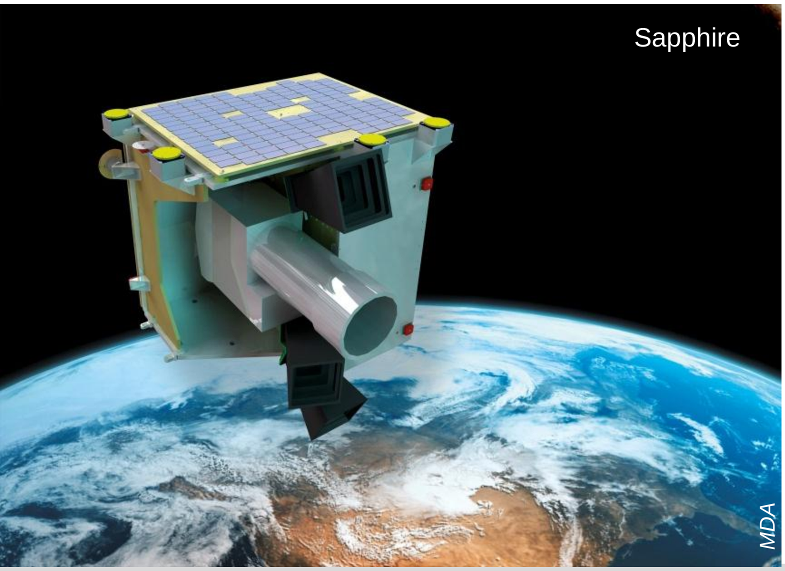
> *"In the first 50 years of space flight, we developed capabilities that support and enable societal and economic good. In the next 50 years, space activities will continue to support humanity's progress and perhaps enable its greatest discoveries."*
>
> **Space Foundation CEO Elliot Pulham**[46]

The 21st century will see even greater reliance on space-based services, a transition of the exploration frontier outwards beyond Earth orbit, a steady expansion of the human sphere of access, influence and commercial exploitation to regions that were previously only the domain of scientific enquiry, an increased focus on sustainability and a richer, more diverse geopolitical landscape than ever before. Meanwhile, global scientific and technological preparations continue to advance, recent successes in the commercial space sector have added welcome and refreshing impetus and social media has opened exciting new avenues for expanded public participation in space development. Growing commercial markets will also provide opportunities for areas of industrial strength not usually associated with space, such as aeronautics, energy and mining.

The landscape for space development over the next two decades is broad and complex, and includes:

- Future satellite communications systems. Satellite communications is the largest and most mature element among space activities. It is the foundation of the space industry and its innovations and industrial capabilities support all other space activities. Satellite communications technologies and services have evolved over decades to meet commercial and government demands for higher bandwidths, greater coverage and lower costs. Future systems will incorporate even more efficient technologies, with increased design life and flexible payloads to enable the satellites to adapt to changing market conditions or operational requirements. For example, the introduction of "terabyte" technologies on board satellite platforms is already being aggressively followed by Canada's competitors in Europe and the United States. Mobile satellite communications, which currently target airline, maritime, and terrestrial customers with safety, personal, business and entertainment applications, are expanding steadily. The almost insatiable demand for bandwidth, particularly in the emerging area of "Communications on the Move" (COTM), will be met once again by exploiting next generation frequency bands, making available much needed spectrum and enabling more advanced networking. In addition, while satellites in geostationary orbit connect every major community in Canada, High Arctic communities and installations as well as mobile platforms such as ships, aircraft, Unmanned Aerial Vehicles (UAVs) and land vehicles are demanding orders of magnitude improvements in data link throughput in the geostationary orbit and are not serviced at all when operating north of 70° latitude. These growing requirements for high bandwidth COTM services can be met by novel satellites systems operating in both geostationary and non-geostationary orbits in combination with low-cost, small and reliable sensor platforms that can be mounted on these vehicles or deployed with dismounted troops. Development of new technologies and of small and hosted payloads to satisfy these emerging requirements will provide a major opportunity for Canadian industry.

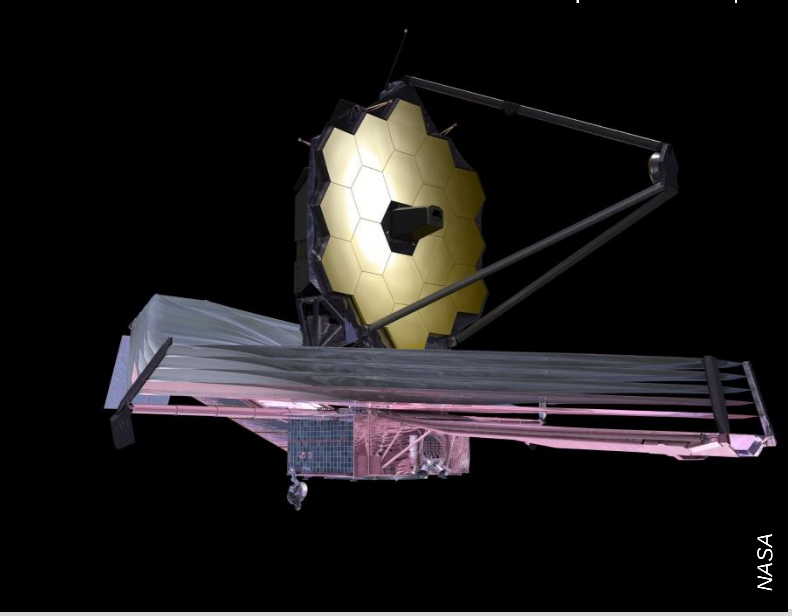
- A growing and increasingly commercial market for Earth observation services. Several long-term trends, such as greater concerns for climate change, pollution and air quality, and the observed opening of Canada's North, will result in a significantly growing demand for Earth observation data to accurately measure atmospheric and environmental conditions in a timely manner. Similarly, the increased concern about security and the need for enhanced natural resource and disaster management will necessitate improved and reliable land observations. These trends are illustrated by the large number of civilian government satellites to be launched between 2010 and 2020, with 195 Earth observation satellites and 47 meteorological satellites to be built globally, representing about 46% of the projected civilian government satellites.[47] Another trend is the shift from scientific to operational satellites, which is already occurring in Earth observation. For example, Europe's Global Monitoring for Environment and Security (or GMES) program will provide multiple successive satellites (the so-called Sentinels) to ensure improvement and continuity of measurements initiated in many cases by scientific satellites. Improving technologies are also increasing the interest in and demand for smaller satellites, which can provide similar capabilities on smaller platforms. While the Earth observation market today is still dominated by government customers, as technologies mature and miniaturize, it will increasingly be possible for private Earth observation missions to support commercial businesses. The RapidEye constellation, designed and built by MDA for the German customer RapidEye AG, was the world's first commercial Earth observation constellation. A more recent Canadian example is UrtheCast, which is building the first publicly accessible High Definition cameras to be installed next year on International Space Station. Initiatives also include the development of business models for Earth observation data that is used to improve weather forecasting models.



- Next-generation space transportation systems, both government and commercial. NASA is working on next-generation heavy-lift spacecraft for missions beyond Earth orbit as well as Orion, a multi-purpose crew vehicle that will act as a 'lifeboat' for the ISS.[48] The Agency is also working with a number of US space and aerospace companies through their Commercial Resupply System (CRS) (formerly known as the Commercial Orbital Transportation Program or COTS) and Commercial Crew Development Program (CCDev) to develop a private sector capacity to shuttle cargo and humans to and from the ISS. SpaceX, a private sector company led and financed by billionaire Elon Musk, has already made history as the first of several potential commercial cargo providers to the ISS and a number of space entrepreneurs (e.g. Richard Branson) are targeting the space tourism market. Already, seven well-heeled space tourists have spent a quarter of a billion dollars for orbital visits, including Canada's Guy Laliberté who paid an estimated $40 million to fly aboard a Soyuz spacecraft and stay for 12 days on the ISS in 2009. When supply approaches demand, flights aboard private spacecraft will be more accessible to more people. Canada – through MDA and Neptec – has built a 30-year business in augmenting space transportation systems with in-space servicing capabilities – from sensors and docking interfaces for rendezvous and capture to complete robotics for full space-servicing capability. With the ever-increasing diversity of space vehicles and government/commercial space infrastructure anticipated over the next decade, the demand in this area is set to increase strongly.

- More capable and sustainable Earth-orbiting infrastructure. This area spans Earth and space surveillance and monitoring (such as Canada's Sapphire and NEOSSat[49] satellites), communications and navigation satellites and services, and planetary protection (space debris removal) and in-orbit space assemblies. Next-generation Canadarm technologies and systems are leading the way in the emerging area of on-orbit robotic servicing with world 'firsts' achieved in autonomous rendezvous, docking and simulated servicing between two free-flying satellites. Canada's MDA is currently developing a commercial refueling and repair service that would extend the life of geostationary communications satellites. Solaren Corp., a US solar energy company has signed a contract with Pacific Gas & Electric to deliver 200 megawatts of space-based solar power by 2016. American private sector entrepreneur Robert Bigelow of Bigelow Aerospace is in the advanced planning for a space hotel later this decade, with two prototypes already in orbit). With space infrastructure set to expand heavily in the 21st century – from fuel depots to serviceable satellites to upgradable space observatories to livable space habitats and space-based solar power – orbital servicing is rapidly becoming a globally-sought space capability and Canada's robotics heritage and leadership in the area is much coveted.

James Webb Space Telescope



- Human and robotic exploration beyond Earth-orbit. Planetary exploration over the next two decades will encompass deeper space exploration, including scientifically rich but previously inaccessible regions, sample returns from planetary surfaces, extended-duration human missions and early space resource exploration. As in other areas, commercial interests are also starting to spread to the planetary domain. Google's Lunar X-Prize is incentivizing privately-funded teams to land a robot safely on the Moon. In the longer term, there will be greater interest in the exploration of valuable energy and mineral assets beyond LEO (e.g. the much-publicized US space mining company Planetary Resources Inc. aiming to prospect for deep space water and mineral resources). The same Canadian technologies being developed for and flown on government space science and exploration initiatives are directly transferable – and subsequently technically competitive – to this newly emerging commercial market.

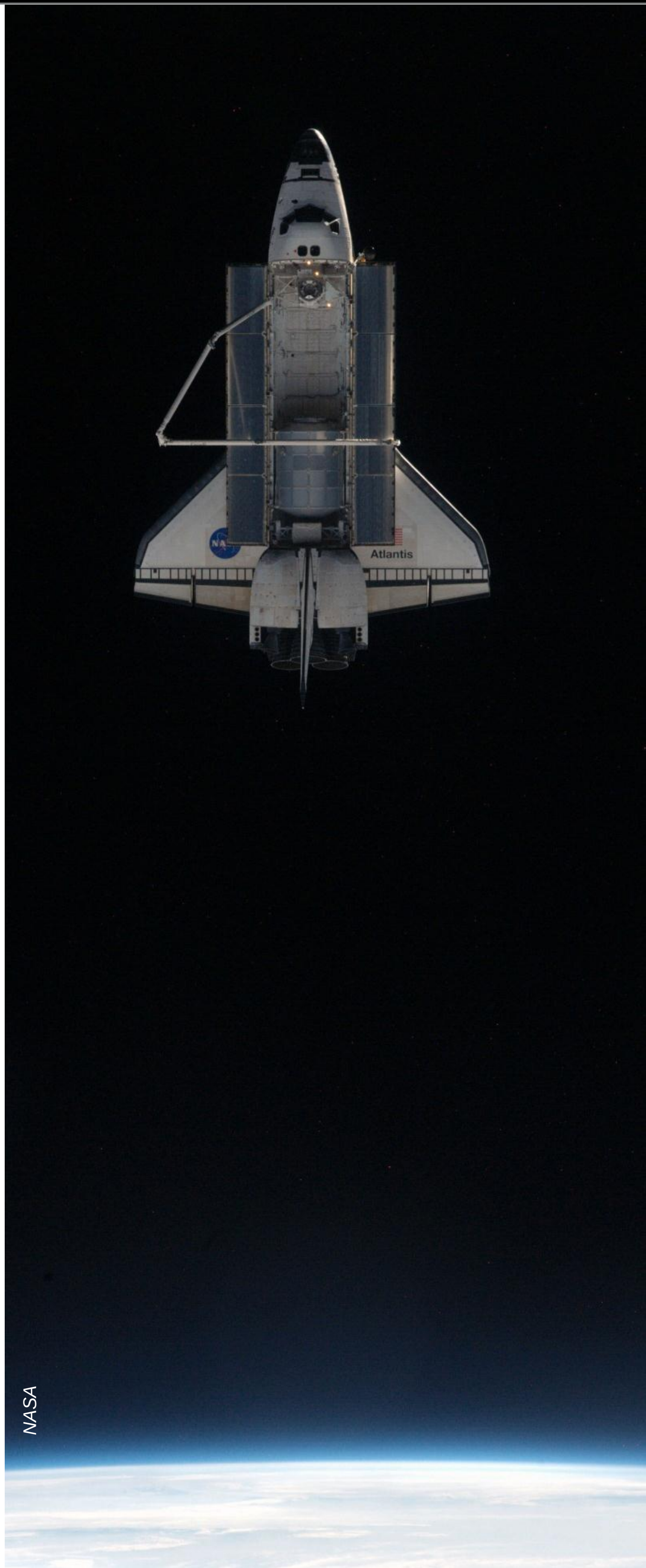
- Next-generation space astronomy. Next generation telescopes will explore further into the universe beyond our solar system and address outstanding questions in fundamental physics. NASA is currently developing the James Webb Space Telescope to be launched in 2018, for which Canada is contributing a fine guidance sensor built by COM DEV. Canada already has heritage in this area, and launched its first space telescope, MOST, in 2003, and is a partner in Europe's Planck space telescope which launched in 2009. The University of Toronto's Institute for Aerospace Studies (UTIAS)' Space Flight Laboratory is also a world leader in developing constellations of astronomy nanosatellites – currently six Bright target Explorer (BRITE) nanosats have been built as a joint Canada/Poland/Austria project, and are soon to be launched, to carry out stellar-astronomy observations. NEOSSat, the world's first space telescope dedicated to detecting and tracking asteroids and satellites, is awaiting launch.

- Greater international co-operation. With the transition of the ISS into its operational phase and multiple nations focused heavily on their next-generation transportation systems, the global exploration community is participating in an unprecedented level of open dialogue on the next destination beyond ISS and the precise sequence of missions to the Moon, Mars, asteroids and even deep space habitats over the next two decades.[50] These nations are collectively considering the political, technological and financial challenges facing this next era of global space development and how best to access, influence and share its significant economic and strategic potential. As well, there is a sharp increase in the number of new space nations now pursuing national exploration programs for scientific, technological and socio-economic advancement – in particular China, India, Korea and a number of new European nations. Canada's iconic contributions in this area over the past 30 years have established Canada as a trusted, respected, welcomed and even anticipated partner going forward in global exploration. Participation in these programs and markets will reinforce Canada's reputation as a leading high technology country, offer opportunities to our scientists to contribute to game-changing scientific discoveries, and enable Canadian companies to benefit from promising and potentially profitable new commercial ventures. Conversely, if Canada does not prepare itself for these emerging markets, we will miss the opportunity to benefit from potentially very large space markets.

"Partnerships are reducing costs, stimulating innovation and redistributing resources. In many respects, the promise of space exploration has never been greater in the history of humanity."

Space Foundation CEO Elliot Pulham[51]

Much of Canada's success in space arose from a government initiative to bet on the future importance of space-based telecommunications and take steps to ensure Canadian industry could enter this market. The Chapman commission's recommendations on this topic led to the formation of Telesat (now the fourth-largest space telecommunications services company in the world) and our strong domestic communications satellite equipment industry. In this report, we are urging the government to continue the practice of forecasting important trends in future space markets – some of which have the potential to become at least as important as global satellite communications, potentially even much more so – and making some initial investments to foster Canadian industry participation to help secure a leading position for Canada. We need to be as bold as the original pioneers of Canada's space age.



Challenges facing the Canadian space industry

As we look forward to the future, there are significant opportunities and challenges on the horizon for the Canadian space industry. Market projections indicate continued growth in the use of space systems. Over the next ten years, more than 1100 civilian (government and commercial) and defence-related satellites are planned to be built and launched.[52] This is equivalent to the total number of operational satellites currently in orbit. This growth in the number of satellites follows the 41% growth rate in the global space economy ($289 billion in 2011) over the past five years.[53] The continued growth in the international market for space systems and components is a major opportunity for established space industries, such as the Canadian space industry.

Canada's space industry should be well positioned to continue growing its space-export sector. It has excellent, globally-competitive technology, outstanding international partnerships with NASA, ESA, the Russian Space Agency and the Japanese Space Agency, and close relationships with global prime-contractors around the world, largely due to partnering opportunities created by working together on international space projects.

However, the world is changing rapidly. While the space market was once the domain of very few countries (including Canada), there are now more than 50 countries that own and operate space systems, with ten more to be added to this list in the next five years.[54] From 1990 to 2010, the number of countries with space programs over $100 million annually has almost doubled (from 11 to 20)[55] and there are now five countries that spend more than $2 billion US annually on their space programs – US, China, Japan, France and Russia).[56] This host of new spacefaring nations, each pursuing the objective of developing their own companies with space technologies and applications, presents a major challenge to established space industries.

Canada stands at a crossroads. Our country's leadership position developed over the past 50 years is seriously eroding. The following are a number of areas that need critical attention if we are to reverse this situation.

1. **<u>Space Policy</u>**

The changing world order in the space domain means established players, including Canada, will have to adapt and follow new policies and strategies in order to remain competitive. To respond to this situation, all of the major spacefaring nations – and Canada's fiercest competitors – have revised their space policies in the last few years (e.g. the United Kingdom, Russia and France in 2012; China in 2011; Germany, Italy and the US in 2010 and Japan in 2009). Japan has also recently enacted legislation, stemming from their 2009 space policy, which elevates coordination of its space program to its Prime Minister's Cabinet office. These policies provide the vision each nation wishes to pursue in space, the objectives for their programs and their implementation strategies.

> *"China has been looking for ways to exert its growing economic strength and to demonstrate that its technological mastery and scientific achievements can approach those of any global power."*
>
> **The New York Times, upon the release of China's 2011 space policy**[57]

A fundamental aspect of all these policies is the development of an internationally-competitive space industry that supports national needs. For example, the US, our largest space competitor (and customer) adopted in 2010 a space policy that states that "the United States is committed to encouraging and facilitating the growth of a US commercial space sector that supports US needs, is globally competitive and advances US leadership in the generation of new markets and innovation-driven entrepreneurship".[58] It further states: "To promote a robust domestic commercial space industry, departments and agencies shall purchase and use commercial space capabilities and services to the maximum practical extent when such capabilities and services are available in the marketplace and meet United States Government requirements".[59] The UK Civil Space Strategy, released in July 2012, states that "the UK Space Agency has a role to play in assisting the space sector to capture more business in all areas, but particularly the global commercial and security markets which are forecast to grow most strongly."[60]

ABB's planetary exploration instrument is worth a 'MINT'

The Miniature Interferometer, or MINT, project started as a contract worth $500,000 from the Space Technology Development Program (STDP) of the Canadian Space Agency. The interferometer modulates the incoming light, producing a signal that can then be mathematically transformed into a spectrum of light allowing the analysis of the scene under observation. The wide range of applications spans the commercial domain where the interferometer can be used in industrial analyzers remote sensing instruments for environmental or defense and security monitoring, and in space where they are used for weather forecasts, greenhouse gas and pollution measurements and chemical compositions.

In space applications, MINT forms the basis of a compact, powerful instrument for measuring the atmosphere or the surface of planets. It is very likely that MINT will find its way in a planetary mission in the coming years, from Mars to Jupiter, Saturn and their moons.

Expanding from the MINT technology, ABB started a major R&D effort to develop the MB3000, its new family of industrial analyzers. The MB3000, launched in 2007, represents a major technological breakthrough into the market of low-cost, high-performance industrial analyzers. What started as a small technology development project with seed money from the CSA has blossomed into a healthy export business for ABB, with roughly 300 units sold every year.

Success Stories

The European Space Agency has a mandate to "improve the world-wide competitiveness of European industry by maintaining and developing space technology and by encouraging the rationalization and development of an industrial structure appropriate to market requirements, making use in the first place of the existing industrial potential of all Member States".[61] ESA's 2007 Space Policy goes further: "A competitive European space industry is of strategic importance. Europe needs strong and globally competitive companies in the development and manufacture of space systems and the provision of satellite capacity and value-added services. To achieve this goal, it is essential that European public policy actors define clear policy objectives in space activities and invest public funds to achieve them. This public investment could help create a critical mass stimulating further public and private investment. A focused industry policy for space will also stimulate companies competing throughout the full value chain and help industry to manage the highly cyclical variations in demand typical of the space sector, invest in technology and ensure the maintenance of critical capabilities. An effective industry policy needs to cover many factors including regulation, public procurement and R&D."[62]

In Canada, there has not been a cabinet-level, government-wide space policy since 1994. To be effective, a space policy framework needs to be conceived and promulgated at the national level to reflect the "whole-of-government" approach that coordinates the space activities, plans and operations of more than a dozen government departments.[63]

The space industry does not consider the *Canadian Space Strategy*, generated in 2004 by the CSA, to be a national strategic framework, as it was applicable to the CSA only and thus had no impact on the conduct of the space activities of other government departments (e.g. Department of National Defence (DND), Department of Foreign Affairs and International Trade (DFAIT), Industry Canada, etc.) or their overall coherence. While the strategy articulated a vision for Canada's future in space, it gave only passing reference to the development of the Canadian space industry and it neglected to outline the key considerations for an internationally-competitive space industry. Another policy document, the National Aerospace and Defence Strategic Framework, developed after significant industry consultations and announced in 2005, has not been widely adopted, and a more recent CSA effort to develop a "Long Term Space Plan" has been shelved."

In a comparative analysis of international space programs developed for the Aerospace Review Secretariat, Euroconsult noted that “the CSA has been directly in charge of the revision of the national space plan, but contrary to most countries, the process was not connected at Federal government level, therefore it lacks political impulse. The absence of a long term strategic vision makes the orientations of the Canadian space program less clear than benchmarked countries.” It further stated that “the Canadian space program is not driven by an industry policy. The CSA implements a program aimed at serving government needs – Industry Canada having not developed an integrated space industry approach. This results in the absence of a coherent industry strategy to sustain, develop and create space-based capabilities.”[64]

Without a longer term policy framework, Canada’s space industry has no basis to plan for technology evolution to meet national needs, much less to leverage export market performance. It is very difficult for Canadian industrial players, big and small, to plan capital and human resource investments, to maintain capacity between gaps in Crown programs, to invest significantly in R&D without certainty regarding which Crown programs, technology development programs and flight demonstration programs will be pursued, and when they will be initiated. Industry also needs to understand the direction of key government policies that affect competitiveness, such as procurement policies, risk capital for commercialization of R&D, export controls or the data policy and regulatory environments affecting the services sector. This long period of neglect has also resulted in drift and delays in important programs.

Space projects typically have execution periods of two to five years, and each project follows an equally long period of requirements analysis, concept/project definition and technology definition and development. Given this model, all projects require long planning horizons and seamless communications between the government, university and industry players in order to effectively maximize the return on their highly-trained work forces and specialized research and manufacturing facilities. Since the Canadian space industry’s ability to compete internationally is critically tied to achieving synergy through dovetailing its activities with those of Canadian universities and the CSA, to meet both Canadian needs and the changing needs of global export markets, the Canadian space industry, and to a lesser extent Canadian universities, quickly become at serious risk of losing important critical mass if the Canadian Space Program has no strategic

Micro-wheels, mega-success for Dynacon

In 1994, the Canadian Space Agency (CSA) solicited Dynacon, a small Toronto-based engineering firm, to develop a Space Shuttle mid-deck experiment called the Dynamics Identification and Control Experiment (DICE) and supported the preliminary design stage, over the period 1995-2000, with approximately $500,000 of funding for the development of several hardware breadboards, including a miniaturized Reaction Wheel attitude control actuator. In that same time period, Dynacon won funding from the precursor to the Space Technology Development Program (STDP) to develop a “MicroWheel”, a miniature reaction wheel product. Approximately $750,000 of technology development funding flowed to Dynacon under this “STDP Round 0” phase.

By 2003, seven MicroWheel-200s had been sold to two export customers – SpaceDev in the US for their CHIPSat microsat and SIL in the UK for their FedSat microsat. In addition, Dynacon leveraged these reaction wheel sales to also sell these customers complete attitude control subsystems, including computer boards and ACS software and engineering support. These two sales alone amounted to more than $1M in revenue for Dynacon. Subsequently, Dynacon made a successful product line of the MicroWheel-200 product, and a larger MicroWheel-1000 product. Dynacon and its successor company have to date delivered at least 27 of these reaction wheels to offshore clients, for a total revenue of more than $1M.

The original work on DICE and the reaction wheel also spawned another success story. In 1996, Dynacon co-wrote (with astronomer Slavek Rucinski) a proposal for the CSA Space Science Branch’s Small Payloads Program to develop a space astronomy microsatellite mission relying on four of these miniature reaction wheels to accomplish extremely high-accuracy pointing. This proposal was ultimately accepted, resulting in Dynacon developing the highly successful MOST microsat – which is still operating after 9 years in orbit. Since 2003, Dynacon’s MOST subcontractor, the Space Flight Laboratory (SFL) at UTIAS, has also developed a successful nanosatellite-exporting business (with more than 10 satellites sold to date), based directly on the “microspace” satellite development methods pioneered by Dynacon’s team on MOST.

Soon after, Dynacon proposed the NEOSSat satellite mission, which has been funded since 1992 by Defence R&D Canada (DRDC) and the CSA, and is now nearing launch. NEOSSat also makes use of four MicroWheels.

Success Stories

direction. Once lost, that critical mass will be difficult, if not impossible, to recover as other nations will quickly step into the vacuum with their own replacement technologies.

In particular, many developing nations have ambitious and well-funded space programs that make them immediate threats. The national space organizations of India and China are likely to move quickly to fill any gaps vacated by Canada. But they are not alone. Other countries like the UK, France, Germany, Korea, Norway and Spain are also serious threats. Recognizing the unique opportunity to generate new long-term sustainable, high-value jobs in space, their governments have aggressively increased their investments in advancing their space technology base, even in the face of very difficult financial conditions forcing major cuts elsewhere in their budgets.

The lack of an updated government space policy was identified by the 2011 Futron Space Competitive Index as a major cause of Canada's slip from 6th to 7th place in world space competitiveness from 2010 to 2011. "In particular, Canada experienced declines in space policy indicators, due to perceptions of strategic drift caused by delays in its planned policy updates."[65] It further noted that "in the coming years, improvements in Canada's space position will depend on clear-sighted leadership and an unwillingness to rest on the laurels of past space achievements. If Canada seeks to enhance its space industry competitiveness, it will need to complement its skilled workforce and world-class industrial strengths with more sustained government investment and policy support."[66]

"Canada retains a skilled space workforce, but delays in space policy refresh and implementation are significantly offsetting these competitive advantages."

2012 Futron Space Competitiveness Index[67]

In developing space policies in the past, Canadian governments have worked closely with the Canadian space industry in order to ensure maximum industrial benefit from Canada's space expenditures. This close partnership between government and industry has been one of the strengths of our space program and was a primary factor in the successful development of a domestic space industry.

The very effective partnership arrangement that once existed in Canada is breaking down. Industry is seen less and less as a strategic partner and more and more as simply a supplier – which is out of step with every other industrial nation. This change in relationship from partner to supplier prevents the Canadian Space Program from being an effective tool in the ongoing development of a competitive space industry. The very foundation that has made Canada's space industry so successful in the international marketplace is crumbling and needs to be rebuilt.

Another major thrust of the space policies of our competitors is the use of international cooperation as a means to share the costs and risks of space programs and to open international markets for their domestic industries. International cooperation has been a hallmark of the Canadian Space Program since its inception and has allowed our industry to become known by foreign industry and governments. Our industry has built a strong reputation for excellence and is often sought as a participant in international programs. We have undertaken cooperative programs with most of the major spacefaring nations.

For example, one of our country's biggest areas of space cooperation has been the International Space Station program. Canada recently extended its participation in this program from 2015 to 2020, but the source of funding remains unknown. We have also had cooperative programs with the United States in all civilian and defence program areas (communications, science, Earth observation, space exploration) and are seen as a valuable and reliable partner. As well, Canada is a cooperating state within the European Space Agency that gives us the unique right to join their programs and receive industrial contracts, particularly in the area of space applications – however, Canada's funding of this partnership has dwindled in recent years, and we are currently unable to access partnership programs, such as ESA ARTES.[68] Euroconsult noted this in its overview of Canadian space policy: "ESA participation enables Canada to leverage its resources while sharing technical expertise, knowledge and infrastructure… However, Canadian participation to ESA programs has decreased over time due to decreasing budget and more focus on national users requirements."

With the number of spacefaring nations increasing rapidly, Canada must not only continue to deepen current traditional partnership arrangements but it also needs to expand its international cooperation efforts beyond these traditional partners if we are to retain our current technological influence and benefit from the expanding international market.

There is urgency to filling the space policy void. In a time of fiscal restraint and an uncertain global economy, Canada must articulate a competitive space policy framework with a strong international cooperation thrust that will allow us to get more "bang" from our existing space expenditures if we are to continue to foster an internationally-competitive space industry. The longer Canada waits to update its space policy to reflect new global realities and to reinstate industry development as a primary goal of our space activities, the less competitive our industry will become.

Recommendation 1

That the Government of Canada gives urgent priority to the development of a space policy framework for the Canadian Space Program that:

- *provides a long-term vision and planning for Canada's space activities – government, private sector and academe;*
- *re-affirms that the development, manufacture and operation of space systems is of strategic importance to Canada;*
- *identifies the development of a competitive space industry as a fundamental objective;*
- *reflects a whole-of-government approach including export controls, risk capital for R&D commercialization and regulatory functions;*
- *specifies international cooperation as an essential element;*
- *promotes the use of Canadian commercial space capabilities and services to the maximum extent possible, consistent with national security considerations and industrial development objectives; and*
- *requires extensive consultation with all stakeholders (governments, industry, academia, international partners) during the planning, development and implementation of the Canadian Space Program.*

2. Industry Development Policy

The space business by its nature entails large investments, complex technology development and implementation, long lead times and extended intervals between major contract awards. As such, it is a constant challenge for Canadian companies to maintain the critical mass – in knowledge and capability – that is required to remain internationally competitive, without consistent government investment. In most nations, governments give priority to the development of their domestic space industry as a national strategic sector.

Like the defence sector, the strategic importance of an indigenous space industry is explicitly recognized by the exclusion of space from the government procurement regimes of all major trade agreements (World Trade Organization (WTO)[69], North American Free Trade Agreement (NAFTA)[70], and the Agreement on Internal Trade (AIT)[71]). Space is considered to be part of the national security exemptions of these trade agreements. This allows governments to use space procurements, space technology development, and space science and space research as tools in the development of indigenous space industries.

All spacefaring nations use measures of one form or another to encourage the development of their indigenous space industries. The US applies the "Buy America Act" to NASA procurements and invests in US technologies through Department of Defense (DOD) procurements. The European Space Agency has a "juste retour" or "fair return"[72] policy that essentially excludes non-European industry. These policies not only support the development of indigenous industries, enhance their respective national space industrial base and contribute significantly to their domestic industry's competitive advantage in the international civil and commercial space sectors, but they also ensure that government expenditures remain in their own countries rather than going to off-shore suppliers.

> *"Since the beginning of the space age, government support for research and development (R&D) in the space sector has been crucial for developing civilian systems and applications."*
>
> **OECD The Space Economy at a Glance, 2011**[73]

In the past, the Canadian space industry has also benefited from government policies to establish a domestic industrial capability to design, build and operate space systems to meet Canadian needs and provide high-value exports for the international market. For example, the Chapman Report of 1967 recommended that "systems management and prime contract activities be awarded to Canadian industry for the development and supply of the major hardware portions of the Canadian Space Program". Subsequent space strategies, policies, programs and legislation[74] – including the independent Science Council's 1967 "A Space Plan for Canada", the 1974 "Canadian Policy for Space", the 1990 Canadian Space Agency Act and the Space Policy Framework in the 1994 Long-Term Space Plan – all specifically noted that a primary goal of Canada's space program was the development of an indigenous space manufacturing and services industry.

Indeed, when the CSA was established, one of its core objectives was to "plan, direct, manage and implement programs and projects relating to scientific or industrial space research and development and the application of space technology".[75] In the past, the CSA (and its predecessors) accomplished this through specific technology development programs like the Space Technology Development Program (STDP) and the Advanced SatCom Program, through participation in ESA technology development programs and through the space science program. Canadian industry was able to leverage the results of these programs into substantial sales. Several success stories illustrating how CSA contracts and technology development funding has helped Canadian companies commercialize their technologies are scattered throughout this paper.

"Our Nation's economic competitiveness is due in large part to decades of investment in technology and innovation. Since NASA's inception, we have used innovative technology development programs to generate new science, exploration, and aeronautics capabilities. Our innovations have enabled our missions, contributed to other government agencies' needs, cultivated commercial aerospace enterprises, and fostered a technology-based U.S. economy."

NASA 2011 Strategic Plan[76]

The primary objective of the STDP is to develop capabilities for "breakthrough or disruptive technologies with the potential to give Canada a competitive advantage and recognition as a valued partner" and to "promote the entry of new industrial players with new capacities to serve the national and international government and private sector landscape". Likewise, the Advanced SatCom program (1997-2001) was designed to "support new Canadian developed technologies and enhance the capacity of Canadian industry to secure market niches in the area of multimedia/broadband satellite communications".[77]

Other countries continue to aggressively fund technology development. For example, the United Kingdom recently announced an aggressive technology development program, with £200 million of funding for "catapult" centres. A Satellite Applications Catapult Centre was unveiled in January 2012 with a goal of helping "UK businesses develop new satellite-based products and services and stimulat[ing] growth across the UK economy".[78]

Another very important way for governments to help the space industry become more competitive is to provide ways and means to find flight opportunities for industrial technologies. In the international space business, technology that has been demonstrated in space has a huge competitive lead on technology that has not flown. Conversely, the lack of flight heritage is considered the largest barrier to success for most international space companies. The United Kingdom has recognized this and recently put in place a specific program for technology development and flight demonstration – the TechDemoSat program.[79] This program addresses the problem industry faces in obtaining first flight demonstration for new equipment and technologies in space. The program objective is to provide “an in orbit test bed for UK technology” with “rapid flight qualification”.

In the past, the Canadian government has undertaken successful flight demonstration programs, such as the 1999 Anik F2 Payload Demonstration Program, which involved the testing of cutting-edge communications satellite technology. This program was a public/private partnership and upon its launch in 2004, marked the first satellite in the world to fully commercialize the Ka-Band frequency. Ka-Band has since become the frequency of choice for high capacity broadband multimedia services, both fixed and mobile.

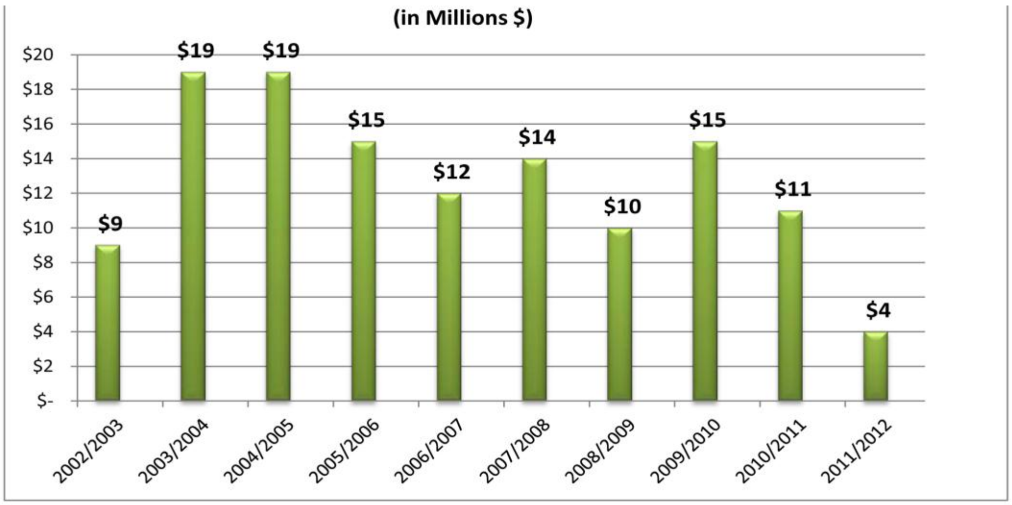
When the A-base funding of the CSA was established at a nominal level of $300 million in 1999, industry understood that this level of funding was for core activities (such as science and technology development and demonstration) and that new major programs of a national scope would be developed with additional funding approved by Cabinet. This would allow the CSA to continue its crucial role of supporting technology development and demonstration in industry.

Since then, it has become increasingly apparent that funds for these core activities are being “raided” to support major new projects that have not been fully funded with incremental funds (e.g. ISS[80], RADARSAT-2[81] and RCM[82]). For example, the STDP program has in the past decade (2003/04 to 2010/11) provided between $10 million to $20 million in annual funding to industry, but has dropped off significantly in 2011/12 to $4 million, because of the need to reallocate internal funding to RCM. The diminution of these core functions means that the STDP program is less of a stimulus for broader commercial success within the space industry than in the past, which stifles innovation and industry competitiveness, and has a negative impact on the ability of Canada’s scientific community to develop and maintain international partnerships.

In other space agencies, these fundamental programs are generally protected from “raiding” by other major programs. For example, the space science and technology programs at ESA are part of the “mandatory” or core programs of the agency and constantly represent about 23% of the overall $5 billion ESA budget.[83] The Advanced Research in Telecommunications Systems (ARTES) program alone is allocated about 5% (approximately $200 million annually) of the overall ESA budget and has the objective of supporting “the competitiveness of European industry on the world stage by stimulating the research and development of a wide range of new technologies, innovative systems, products and services

Space Technologies Development Program

Figure 5 - STDP Contract Expenditures



Explanatory notes:

Generally, STDP Expenditures vary in accordance with PWGSC procurement process and/or on the basis of Contractors' ability to deliver on schedule. For year 2011-2012, a substantial amount of STDP budget was reallocated to other CSA priorities.

Source: CSA

and their qualification and demonstration”. In the United States, in 2010, NASA’s combined science and technology development programs accounted for 25% (approximately $5 billion) of NASA’s overall budget of almost $19 billion.[84] In Canada, the 1994 long-term space plan allocated over a ten-year period approximately 25% of the CSA budget to technology development and science. The Canadian space industry believes that in order to be competitive with the rest of the spacefaring community, Canada needs to re-establish the goal of spending a minimum of 25% of its space budget on technology development, flight demonstration and science – a reasonable balance between operational and R&D funding.

The reduction in the budget for the STDP is further complicated by the current terms for technology development funding which ties it entirely to government needs or missions. The CSA has put greater pressure on programs like the STDP to support only that R&D which addresses specific government needs.

This represents a change from previous years as it puts the needs of government ahead of the needs of industry – whereas when these programs were conceived, the needs of the government were balanced with the needs of industry.[85] This puts Canadian space companies at a disadvantage in the commercial marketplace compared to their international competitors, whose host governments focus their technology development investments on areas tied to exports and economic activity, not necessarily towards internal government needs.

For example, in Europe, ESA funds research and development and technology demonstrator projects in areas of high economic activity and strategic importance, such as the satellite communications manufacturing sector. Within European countries, France, Italy and Germany have actively supported their satellite communications and navigation industry through civilian investment. In addition, Italy, Spain, France, Germany and the UK have all sponsored national military satellite systems. In the US, NASA’s investments in this area, while less visible, are as active, and US Department of Defense investments in advanced military satellite communications (MilSatCom) and Wideband Global System (WGS) are well documented. There is also work being funded in agencies such as the Defense Advanced Research Projects Agency (DARPA) and the Defence Information Systems Agency (DISA).

In Canada, there is a misconception that satellite communications is a mature market, and therefore it

COM DEV advances remote life support systems

Canada is recognized as a world leader in the fields of bio-regenerative life support systems and greenhouse technologies which are key to safe and dependable food supplies in harsh and remote locales. COM DEV and the Canadian Space Agency are supporting the University of Guelph in a collaborative research and development project by the National Science, Engineering and Research Council (NSERC) to demonstrate new Innovative Technologies in Challenging Environments (InTICE). One such program is CanALSS (Canadian Advanced Life-Support Systems) which aims to develop controlled-environment food production on multi-year manned voyages to asteroids and Mars. It targets development of technologies for automated food productions that will provide fresh vegetables for astronauts, while renewing their on-board atmosphere and recycling water. The full cost of CanALSS development is estimated at about $10 million per year.

Research into this area is allowing for immediate and unique terrestrial spin-offs for Canada. COM DEV, the University of Guelph, the University of Alberta, the Aurora Research Institute (Inuvik), Medina Quality Assurance, and the Arctic Energy Alliance have teamed to spin off autonomous food production and monitoring technologies currently being used on the International Space Station and deployed over the last 10 years at the Devon Island Greenhouse, and applying them to address urgent Canadian socio-economic issues in food security and environmental stewardship in Northern communities.

Although the current market for fresh vegetables in Canada’s North is only about $50 million per year, the global market for modular ‘Space Farm’ Systems for isolated communities and military bases, mine sites, and oil and gas operations, is in the billions of dollars. This ongoing partnership between government, university and industry will also continue to improve food security of urban centres, and reduce the cost and pollution from transporting the products to market, while also providing fresher more nutritious products.

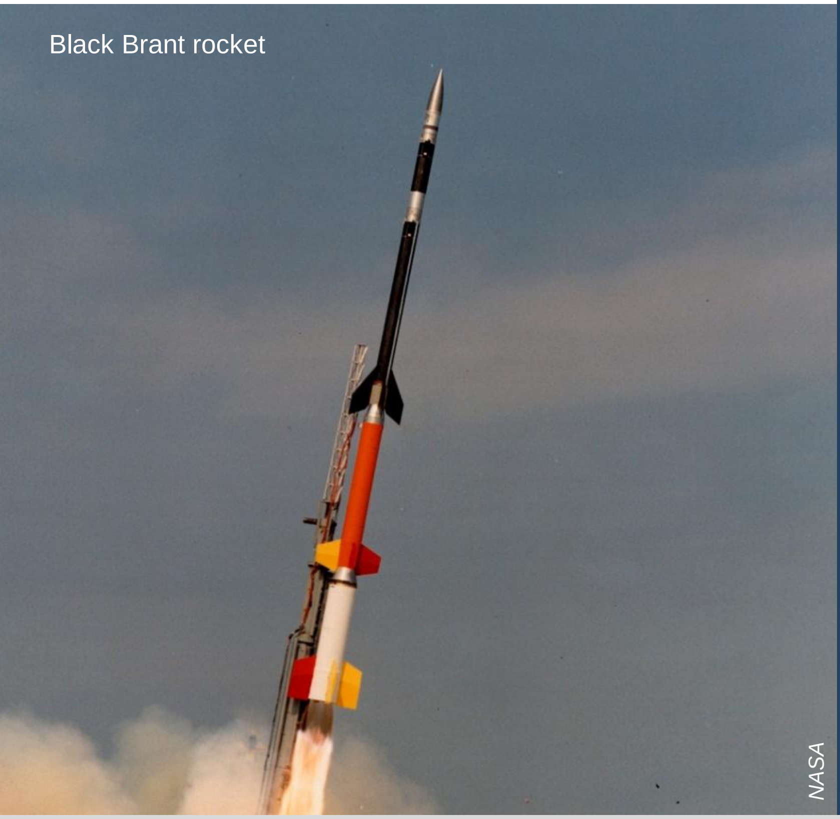
Success Stories

does not require technology development support – a flawed argument, since technology and products related to this sector are in constant evolution. Furthermore, satellite communications is deemed to be a commercial market, and inherently not considered a government need or mission and has therefore not recently been eligible for technology development funding.

In its analysis for the Aerospace Review Secretariat, Euroconsult pointed out this disparity: “Canada appears less focused on satellite application R&D than other countries that increasingly put industry competitiveness as a number one priority, focusing instead on operational procurement.” It further noted that “more recently, the [CSA] has moved from a technology-driven approach to a user-driven approach with the aim to serve government users needs.”[86]

With respect to R&D, the CSA has over the years developed an internal R&D capacity as part of its legitimate need to be aware of the latest technology trends in the space field. However, in some cases, industry feels that the CSA is conducting R&D that would better serve the nation if it were done in industry and academe. Doing this R&D extramurally would enhance the competitiveness of the industry and would support a broader base of space science activity in our universities.

Black Brant rocket



Black Brant: Over 50 years of successful launches by Magellan Aerospace

Magellan Aerospace / Bristol maintains a strong presence in suborbital rocket development and launch due to its Black Brant sounding rocket. The Black Brant is one of the most reliable sounding rockets ever built, with a proven success rate of 98%. Since 1962, more than 1,000 Black Brants have been launched from 20 sites around the world. In June of 2012, Magellan Aerospace celebrated the 50th anniversary of this extremely successful venture.

The origins of the Black Brant trace back to a research initative into anti-ballistic missile systems by Canadian Armament Research and Development Establishment (CARDE) (now DRDC Valcartier) during the 1950s. CARDE provided between $5M to $10M of in-kind support to Magellan Aerospace / Bristol to develop a Propulsion Test Vehiclesystem. The first test flight in September 1959 from Fort Churchill, Manitoba, was a complete success. In response to a need for sounding rockets to study the effects of auroras on long distance communications, Magellan Aerospace / Bristol modified the Propulsion Test Vehicle design to create the first Black Brant sounding rocket.

In its latest configuration, the Black Brant XII enables suborbital payloads up to 20 minutes to perform research into the Earth’s atmosphere, the aurora, astronomy or micro-gravity. The Black Brant family of rockets has also been used for theatre missile defense training. Its proven track record and credible design heritage made NASA and CSA long term repeat customers.

This early government investment not only spawned approximately $230 million in rocket sales to date, it also allowed Magellan / Bristol to enter the adjacent rocket fuels and payloads space and military markets, for a further $1.2 billion in revenues to date, for a total return on the initial investment of roughly 200:1.

Success Stories

This argument was supported by the 2011 Expert Panel Report on R&D (the "Jenkins" panel). In its special report on Procurement, it stated: "Another avenue [to promote innovation] is to enhance contracting out of R&D required by government departments and agencies. Science-based departments and agencies tend to keep research required to inform their regulatory function in-house, but they also tend to keep research related to their social and economic mandates largely in-house, more for historical than any detailed cost benefit analysis… Setting specific department-by-department targets for external R&D contracts would promote business innovation while potentially improving outcomes for contracting departments and strengthening their ability to deliver on their mandates." The report went on to say that "it bears noting that the rules in international trade agreements exempt R&D contracts and "first product or service" and "prototype development" from open bidding. This means that there is considerable scope to ensure that contract R&D is undertaken by Canadian-based suppliers."[87]

While it is understood that the CSA needs an internal R&D capacity in order to be an "intelligent" manager of the Canadian Space Program, industry feels that increasing amounts of R&D is done internally, perhaps due to smaller budgets available for external R&D, and that the appropriate balance has been lost.

The effect on industry of the diminution of R&D, technology development and demonstration activities by the CSA can be seen in the minimal growth the space manufacturing sector has experienced over the past decade, barely keeping up with inflation (see Figure 2). In an industry where technology innovation and flight heritage are vital to international sales, the reduction of the CSA's ability to conduct these activities severely tilts the international playing field in favour of our competitors whose own governments are maintaining or increasing this support. We are losing ground to established and new international competitors as their governments step up their funding for technology development and demonstration. The Canadian space industry has had to severely curtail its investments in R&D and has had to reduce staff, resulting in reduced capacity, loss of the technology edge required to be competitive internationally and fewer export sales.[88] This downward spiral urgently needs to be remedied if Canada is to remain competitive and grow.

<u>Recommendation 2</u>

That the Government of Canada articulates a space <u>industry development policy</u> applicable to all departments and agencies *that:*

- *identifies technology development, flight demonstration of new technologies and applications, and space science programs as core activities of the Canadian Space Program and ensures a minimum of 25% of the A-base budget of the CSA is allocated to these areas;*
- *encourages technology and applications development and demonstration in a broad range of commercially-viable applications in addition to those supporting the needs of government;*
- *ensures all government space system procurements, grants and contributions are supportive, to the maximum extent possible, of the development of an indigenous, internationally competitive space services and manufacturing industry;*
- *ensures, to the maximum extent possible, that government-funded space R&D is conducted in industry with the support of Canadian academia as appropriate; and*
- *ensures relevant regulations (e.g. data policy regulations, regulatory fees, and ownership restrictions, etc.) support the development of the Canadian space services industry.*

3. <u>Procurement Policy</u>

Government procurement is an important instrument of industrial development and is fundamental to the competitiveness of a nation's space industry. All international trade agreements recognize this and allow governments to undertake special activities to develop and protect domestic space industries. As a result, all major spacefaring nations have adopted space procurement policies and industrial strategies that support the development of their respective space industries.

Canada has in the past had similar procurement policies that ensured all government space procurements, in addition to meeting national needs, were conducted in a manner consistent with the objective to develop and maintain an internationally competitive domestic space industry.[89] These policies were developed in consultation with the space industry and were fundamental to the development of a Canadian space industry capable of meeting national needs and achieving substantial export sales. As a result of these policies, Canada developed world-class satellite services companies, ground segment and space segment prime contractors, subsystem and component suppliers, scientific instrumentation providers, spacecraft bus providers and systems design and integrators.

Recently, however, Canada's civilian and military space procurement policies have become less and less supportive of the development and maintenance of either space manufacturing or services in Canadian industry, primarily because industry development is no longer seen as a fundamental objective of Canada's space program and the longstanding partnership between industry and government has been allowed to wither. This change is having a negative effect on the competitiveness of the space industry since it ignores internationally-accepted practices that allow countries to protect and nurture their indigenous space sector and capacity and tilts the playing field in their favour.

In general, Canada's procurement rules favour open competition in order to obtain the lowest possible cost from competing suppliers, be they foreign or Canadian, giving Canadian taxpayers the most "bang for their buck" through competition amongst the largest number of qualified firms. Therefore "price" is invariably the key driver, not industrial capacity. In the space manufacturing sector, this approach is out of step with every other nation we compete with. For example, the industrial policy of ESA "exploits the advantages of free competitive bidding, *except where this should be incompatible with other defined objectives of industrial policy*".[90] In other words, ESA industrial policy establishes competition as the norm, but acknowledges that the objectives of industrial policy are paramount.

The Canadian space industry is relatively small and is focused on excellence in niche areas – with very little overlap. It is also disconnected from the larger aerospace players – unlike most other spacefaring nations, where there are large aerospace and space conglomerates.[91] The domestic market is not large enough to allow these niche players to survive so they have had to become internationally competitive. The global marketplace provides ample competitive pressure to ensure that these Canadian firms remain efficient and effective suppliers. The procurement process should ideally recognize an internationally competitive Canadian space capability and concentrate on helping that capability compete with their real international competition.

With space increasingly seen as strategic to a country's security and sovereignty, national militaries are playing a larger role in government space activities. This was noted by the Space Security 2011 report: "Security has become a key driver of established government space programs, pushing spending higher and encouraging dual-use[92] applications. Indeed, in the absence of dedicated military satellites, many actors use their civilian satellites for military purposes or purchase data and services from satellite operators. Such activities contribute to the blurring of the divide between military, civilian, and commercial space assets and applications."[93]

The Futron 2012 Space Competitiveness Index also highlighted this blurring of the lines: "Militaries also have long realized the force multiplication potential of space assets, including secure communications, reconnaissance, tracking, and coordination of war-fighting forces. Yet increasingly, military space is interwoven with civilian and commercial space systems and infrastructure – adding a new layer of complexity to governmental decision-making, national industrial policy, and the participation of the private sector within the space arena."[94]

With the emergence of a strong military space program in Canada.[95] there is also a need to ensure that this program, in addition to the civil space program, is also used as an instrument for the development of the Canadian space industry. A realignment of DND procurement policies to include an industrial development mandate and to include an aggressive leadership role in the adoption of innovative Canadian ideas is required.

With changing policies in the United States, where Department of Defense co-operation with coalition partners appears to be the new paradigm, the ability for DND to meaningfully contribute to coalition infrastructure starts with Canada's space and defence industry. For example, DND will continue to be the largest and a growing user of satellite communications within the Canadian government. With a renewed emphasis on unmanned surveillance and remotely controlled intelligence methods replacing "boots on the ground", a modern and innovative satellite communications system is a key coalition resource.

The Expert Panel on R&D noted the lack of a DND industrial policy in its report in 2011. "Notwithstanding recent changes, Canada is generally an outlier internationally with respect to the use of defence procurement to promote an industrial base. This results in an uneven playing field internationally, Canadian-based companies do not have the explicit support of their government through guaranteed purchases or defence support programs while at the same time being excluded from many foreign markets by domestic procurement restrictions in those countries. Further, even in foreign markets that are open, the lack of "first buyer" support from the federal government hinders Canadian companies' marketing efforts against highly supported foreign competitors."[96]

Canadarm technology – from space to Earth

In the mid-1970s, Canada took the historic decision, following the successes of the Apollo program, to join the US Space Shuttle program. The "Canadarm" quickly became a mainstay within the US human spaceflight architecture, flying on 91 shuttle missions beginning in 1981 through to the retirement of the shuttle program 30 years later in 2011.

Canada's initial investment in the Canadarm technology, amounting to approximately $100 million over 10 years, allowed MDA to build a successful business in space robotics exports. Sales to NASA alone subsequently exceeded $1 billion for robotic tools, interfaces and additional robotic arms, establishing MDA as the largest international NASA contractor worldwide.

In the mid-1990s, Canada was invited to participate in the International Space Station (ISS). Canada's role would build directly on the heritage established with the Canadarm program and take on the assembly of the ISS as well as its external servicing over the duration of its operational life. The Canadian contribution – the 3-element robotic Mobile Servicing System-included a larger, more capable successor to the shuttle robotics, Canadarm2, transported on a mobile base which carried a state-of-the-art highly dexterous twin-armed robot, Dextre, that could support, work alongside or even substitute astronauts in supporting external ISS operations.

In the last half decade, MDA has achieved world firsts in the area of robotic satellite servicing demonstrations as well as the first Canadian successes in planetary exploration, with key roles for Canadian technology on both of NASA's recent Mars science missions as well as an upcoming asteroid sampling mission. This robotic technology continues to evolve in order to address the challenges of the next decade, where new levels of automation will be required, from assembly of deeper space infrastructure, refueling and repair of orbiting satellites, and deeper space exploration to the potential exploitation of space-based energy and mineral resources.

MDA has also applied its space robotics portfolio to enable technological advancements in terrestrial markets on Earth, such as advanced autonomous control, high-accuracy, advanced sensing, safety-criticality and extreme-environment robotics, particularly in the areas of health, energy, mining, security and environment.

- *Health: neuroArm, the world's first MRI-compatible neurosurgical robot developed in collaboration between MDA and the University of Calgary permits experienced brain surgeons to remotely, safely and more effectively operate with minimally-invasive precision on patients while they remain within the MRI machine. neuroArm has now supported more than 50 successful patient operations since 2008, and MDA is expanding its medical business with robotic surgical systems for early breast cancer treatment and pediatric care.*

- *Energy: Space robotics designed for complex tasks by remote operators while surviving the extreme thermal and radiation environments of space are a natural fit for similar hazardous environment applications on Earth, including the nuclear and hazardous waste sector. MDA has developed robots for various domestic and international customers to inspect the interior of reactors and radioactive waste storage tanks – tasks previously not possible due to radiation levels and limited access ports.*

- *Mining and Natural Resources: Advanced sensing and control technologies are particularly useful for the mining and resources sector in the development of autonomous underground vehicles and mapping and modelling of underground mine faces.*

- *Security: Vision systems supporting robotics operations are being further adapted in the security market for a number of police forces across Canada to provide advanced situational awareness for rapid response teams to safely and remotely assess inaccessible, dangerous or hostile environments using small remotely-operated vehicles, 3D modelling and hazardous substance detectors.*

- *Environment: MDA has recently collaborated with snowmobile-inventor BRP on electric lunar rover technologies developed under the CSA's space exploration program, which has enabled BRP to enter the zero-emissions vehicles market with their first-ever commercially-released electric vehicle – a product of space cooperation which is now being manufactured exclusively in Quebec and sold globally to a range of markets.*

Success Stories

As mentioned by the Expert panel, one important way the government can use the procurement process to promote a competitive industry is to be a strategic customer for innovative Canadian technologies and services – often as the critical "first buyer" or "first user" – particularly where there is an opportunity for the nation to establish a niche or international state-of-the-art capability. This in turn allows our sector to build a sustainable export business from Canada. This is a practice that countries the world over utilize to support their industry champions. In the space sector, this cannot be overstated – if your own national government does not buy your technologies, they have little chance of succeeding internationally – and international customers have come to expect technologies to be adopted domestically first.

For the space sector, the best example for a government "first customer" role is the Canadarm on the Space Shuttle. Canada invested in the R&D of the first Canadarm and bartered it for scientific returns and Canadian astronaut rides on NASA's Space Shuttle fleet. Since that first investment, Canada has enjoyed an enviable 10:1 return on investment beyond the barter trade, from direct follow-on export sales to NASA for additional Canadarms and their operations. Not only did this establish sustained space robotics business, Canada continues to be the world leader in this critical area.

Another approach that would favour the space services industry is for the government to procure commercially available (or modified) services, such as using "hosted payloads" where a government payload is added to a commercial satellite. In these cases, the government's procurement processes need to be sufficiently flexible to fit into the commercial satellite program. The government cannot expect commercial programs to start and stop based on the government's planning or procurement processes. Similarly, the government needs to be sufficiently nimble in responding to international opportunities that arise within a narrow timeframe, and alter the rules to allow a quick and decisive response by the CSA.


NASA

One of the more successful aspects of past Canadian space procurement policies were steps to ensure that recipients of major government contracts implemented these contracts in a manner consistent with the government's industrial development objectives. These steps applied to the entire supply chain. For example, in the 1980s and 1990s, major contract recipients were responsible for following the government's regional distribution policy for space expenditures. These recipients had an obligation to maximize Canadian content in the implementation of the contract. Many new space companies got their start through this process.

There are other areas where efficiencies can lead to more industrial innovation. For example, government space procurements should specify the high-level functional requirements the procurement is to meet, rather than mandating detailed design specifications. This would allow industry to propose innovative solutions for meeting the requirements – potentially providing a better product at a cheaper price. Failure to do so in some current programs has resulted in government engineers and managers improperly diverting their efforts into *designing* satellites, an activity that is far better carried out by the engineers who are responsible for *delivering* those satellites to the government customer. This approach is currently used in certain other major government procurements (e.g. DND) and its use in the space program would encourage industrial innovation, promote more industry-academic partnerships, and would reduce the overhead costs of program management while still providing the government with appropriate oversight and accountability. This approach would allow more of government space expenditures to be spent in industry (because of reduced overhead costs), maximizing the industrial development benefits of the space program.

This idea was recently supported by the Expert Panel Report on R&D, which stated, "One promising avenue to encourage innovation would be through specifying requirements in terms of their performance or functional characteristics, rather than their design characteristics. This would leave greater scope for new ways of achieving or surpassing requirements and open the door to innovation. While performance specifications are mentioned in the federal government's contracting policy, it does not focus on this, stating only that the 'best value may be promoted if performance specifications are stressed'."[97]

Another major concern of the space industry is the noticeable increase in recent years in the time between program approval by the government and the issuance of contracts. Space technology and applications development is moving at ever increasing speed with more and more international competitors. To be competitive in this environment, government procurements need to be delivered in a timely fashion.

Government procurement is one of the most important tools for maintaining space industrial capacity. While the Canadian space sector derives only 10% of its global revenues from government, these sales are absolutely vital for the generation of new technologies and applications and providing the flight heritage essential for capturing international sales. No other entity can serve this role and without it, the ability for many companies to sustain operations would be challenged – impacting not only the competitiveness of the industry, but compromising the federal government's ability to act in its own sovereign interest. Streamlining the government's procurement policies so that they contribute to, and do not hinder, industrial competitiveness would be extremely helpful to the Canadian space industry.

Recommendation 3

That the Government of Canada adopts space program procurement policies that:

- *recognize industry development as a specific goal in both civilian and military procurements;*
- *promotes industry competitiveness by acting as the "first-user" or "first-buyer" of innovative Canadian technologies;*
- *encourage competition only in cases where competition will aid the development of a competitive industry;*
- *require contract recipients to implement contracts in a manner that supports the industrial development objectives of the government;*
- *are based on a statement of objectives and high-level functional requirements (as opposed to detailed specifications);*
- *use international competitiveness of a bidder and its ability to bring these technologies into a wider export market as one selection criteria;*
- *are flexible in order to accommodate the schedule and financial needs of commercial suppliers and in order to respond to narrow-time-frame opportunities; and*
- *are timely.*

4. Management of the Canadian Space Program

The increasing importance of space can be seen by the diversity of space interests across government departments. When the CSA was established in 1989, it accounted for almost 90% of total government expenditures in space. Since then, the Department of National Defence has increased its space expenditures and now accounts for about 27% of the total Canadian Space Program budget.[98] Up to 16 federal government departments and agencies have space-related expenditures or are users of data derived from space assets, particularly for their Earth observation, surveillance and communications requirements. Seventeen federal departments and agencies have an interest in maritime domain awareness.

The same diversity exists in the United States, as expressed by the National Academy of Sciences: "Civil space is often associated with NASA, but increasingly, other federal departments, including the Departments of Commerce and Transportation, have civil space programs. A growing private sector is active, as are important university and industrial research programs. The diffusion of civil space capabilities and responsibilities, however, is both beneficial (contributing to more parts of the economy and tapping the unique expertise of each agency) and problematic (confusing roles, missions, goals, and objectives)."[99]

To manage this complexity, most of the major spacefaring nations have established space agencies to implement their civilian space programs combined with Cabinet-level interdepartmental or inter-agency processes to ensure coordination, planning and implementation of all space activities of the nation and to reflect the strategic national nature of space technology and applications. Some space agencies even have reporting lines to the executive branch.

In Europe, the governing body of ESA is a council of Cabinet ministers from each member state, and in the US, the head of NASA is a Cabinet-level appointment.

Japan has recently established a new space strategy office within the Prime Minister's Cabinet Office to coordinate the Japanese space program and to ensure national level planning and control, and they have lifted the restrictions on their space agency to pursue military space programs. These structures allow major space program decisions – objectives, programs and funding – to be made at the national level in response to national, rather than departmental, needs. It allows integration of similar needs of many departments into a national need sufficient to warrant national action. These structures ensure that their space programs will pursue national objectives and will not be limited by the interests of one particular department.

Prior to the formation of the CSA, there existed a formal interdepartmental process that ultimately involved Cabinet ministers which ensured a national perspective and effectively coordinated the space programs of many departments. Such a formal management structure no longer exists. While the CSA Act gives the Minister of Industry the responsibility to "coordinate the space policies and programs of the Government of Canada"[100], it is the Canadian space industry's perception that there is no Cabinet-level process to facilitate this. In the absence of a national level focus for the space program, the result is that major opportunities of strategic interest to the nation as a whole may not be seized because they are not of sufficient interest when viewed through the lens of a single department. It is difficult, if not impossible, for Industry Canada to place the priorities of other departments ahead of its own departmental priorities.

This is not solely a problem in Canada. In the US, a report by a review committee of the National Academy of Sciences noted a similar concern. "National space policy too often has been implemented in a stovepipe fashion that makes it difficult to recognize connections between space activities and pressing national challenges. Often, senior policy makers with broad portfolios have not been able to take the time to consider the space program in the broader national context. Rather, policies have been translated into programs by setting budget levels and then expecting agencies to manage those budgets. The committee believes that the process of aligning roles and responsibilities for space activities, making resource commitments, and coordinating across departments and agencies needs to be carried out at a sufficiently high level so that decisions are made from the perspective of addressing the larger national issues whose resolution space activities can help achieve. How this process is accomplished might change from administration to administration, but the need for an approach that will elevate attention to the proper level remains essential."[101]

Compounding the problem, the CSA has given priority in recent years to the pursuit of major programs that are dictated by the needs of other government departments (e.g. RADARSAT Constellation Mission and the Polar Communications and Weather satellite program). However, in the process, the CSA has become the *de facto* "champion" for these operational programs, not the user departments. As a result, in times of fiscal restraint when departments are required to find the resources for new projects, the CSA is expected to find some of these resources for these "operational" programs from its A-base funding. While the CSA is the only government agency with the technical and programmatic expertise to implement these programs, these operational programs are clearly in the national interest and promise substantial benefits to a number of user departments.

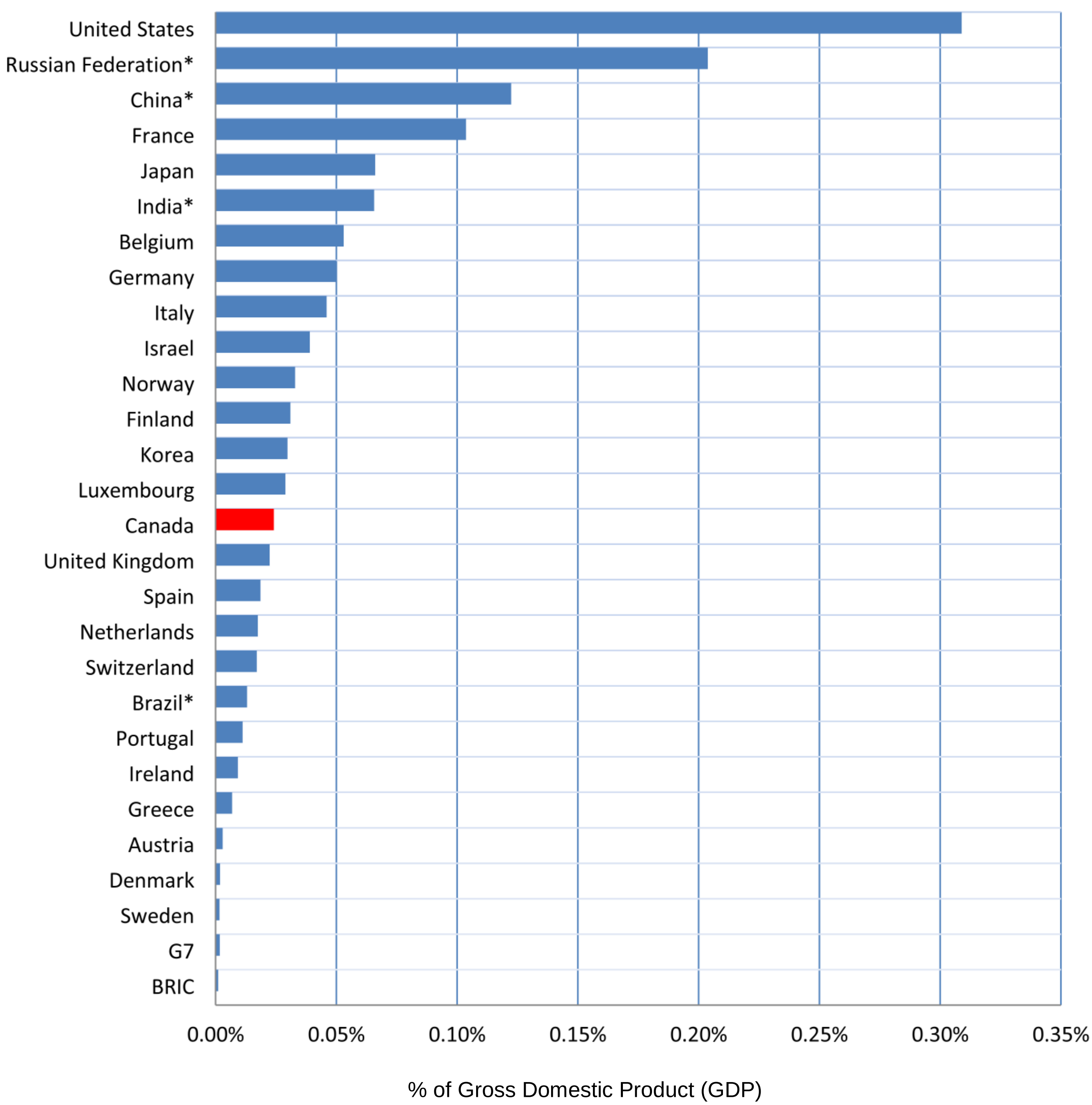
All of the above-mentioned points make it clear that space is an interdepartmental activity with an increasingly broad national impact – and the governance of the Canadian Space Program needs to reflect this.

In terms of the funding of the Canadian Space Program, Canada is among one of the few spacefaring nations to have reduced its space budget over the past five years (see Figure 6). We have slipped from being one of the elite spacefaring nations and now find ourselves amongst the much larger pool of second-tier countries – indeed, the size of our space budget has dropped to 15th highest in the world as a percentage of GDP[102] (see Figure 6). This funding decline has occurred at a time when the percentage of government space expenditures actually going to Canadian industry has fallen from about 75% to 50% in the last decade (see Figure 7) – compared with the European Space Agency that spends 86% of its budget in industry.[103] While there has recently been an infusion of space funding – for robotics in the 2009 stimulus Budget and for the construction of RCM in the 2010 Budget (although the CSA was forced to reallocate $100 million of its budget toward this program) – the overall CSA budget has been steadily decreasing over time, with inflation and 'budget-raiding' seriously eroding the CSA's ability to operate. For example, the purchasing power of the Canadian civilian space program is now about 40% less than it was in 1999 when the CSA A-base was set at $300 million per year (see Figure 8).

Civilian Space Budgets

Figure 6 shows the 2009 civilian space budgets of the major spacefaring nations as a percentage of GDP. In this comparison, the Canadian civil space budget ranks 15th overall, considerably less than our major space competitors – USA, Russia, China, France, India, Japan and Germany. (Source: OECD The Space Economy at a Glance 2011)

Figure 6 - 2009 Civilian Space Budgets



Canadian Space Agency Budget

Figure 7 shows the percentage of the CSA expenditures on S&T (more than 95% of the CSA's total budget). In the late 1990's, as much as 75% of the CSA budget was spent in Canadian industry. Over the past decade this percentage has dropped to around 50%.

Figure 7 - CSA Expenditures in Canadian industry

(Sources: Statistics Canada Federal Expenditures on S&T and ESA contracts to Canadian industry)

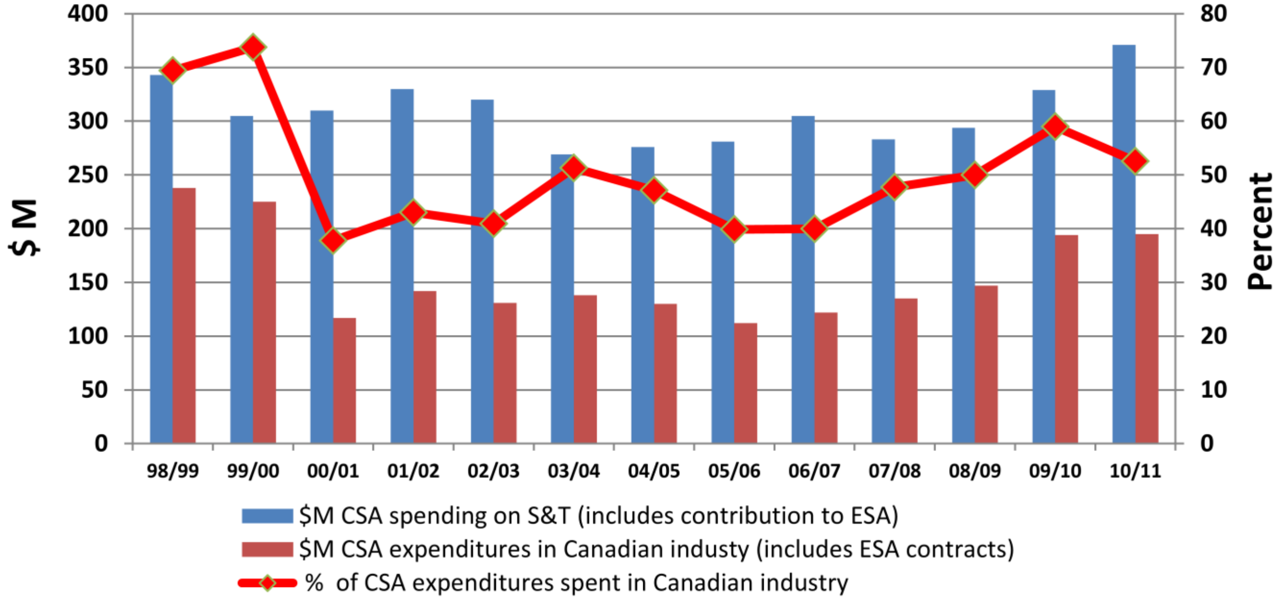
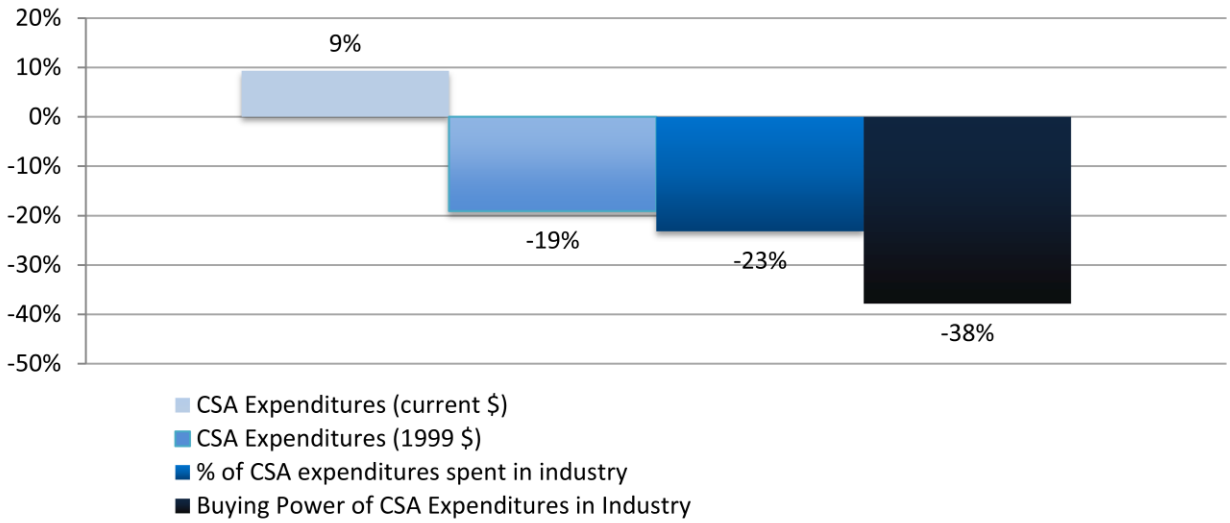


Figure 8 shows the effect of inflation and the reduction in the portion of the CSA budget being spent in industry. The combination of these factors means that in 2010/11 the value of CSA expenditures in industry is 38% less than it was in 1998/99.

Figure 8 - Change in buying power of CSA - 1998/99 to 2010/11



This grim budgetary situation is exacerbated by a lack of stability, predictability and long-term direction in the Canadian Space Program. Ironically, the ability of the Government of Canada to provide longer term funding to our space program – as permitted in the Financial Administration Act – sets Canada apart from our closest competitor, the US, where NASA budget levels can only be determined looking to the year ahead. By not planning multiple years in advance, we lose the ability to leverage our inherent competitive advantage over other jurisdictions.

The Auditor General noted the budgetary and management issues facing the CSA in her 2002 report on the Canadian Space Agency. "The current and future financial obligations imposed by these two major Crown projects [ISS and RADARSAT-2] seriously limit the Agency's flexibility to fund new program initiatives and pursue the full range of scientific developments currently envisaged under the Canadian Space Program. They have meant the cancellation or postponement of approved activities. They also limit the Agency's ability to provide new opportunities to Canada's research and development community, to maintain a position of excellence worldwide in the exploration and use of space, and to optimize the benefits of participating in international space activities. Overall, they have created an imbalance between the Agency's obligations and its financial capacity, a situation that is likely to worsen in the next five years."[104]

According to the review committee of the National Research Council of the National Academies, the US finds itself in a similar situation. "NASA is being asked to accomplish too much with too little… Rather than requiring that a broad and ambitious program be fit into an arbitrarily constrained budget, as has been the case in recent years, a sustainable strategy would first define the program that the nation is committed to undertake and then realistically define the resources that are required to accomplish that program." It further stated that "civil space programs have largely been assigned budget levels that are incrementally based on previous years' budgets, with only tenuous connections to the evolution of the programs or their capabilities. An effective process would connect space policy to broader national needs, and then consider the necessary resources and implementation…"[105]

If Canada is to derive maximum benefit from its space expenditures, we have to be more effective in our space expenditures than our competitors. Canada also must view space at the national, rather than departmental level. The development of space policies, the articulation of industrial development policies, and decisions on program priorities must be taken at the national level, as is done in most spacefaring nations. There needs to be a "whole-of-government" approach to the Canadian Space Program.

Recommendation 4

That the Government of Canada reviews the management and priorities of the Canadian Space Program with a view to ensuring:

- *the planning and management of the program reflects a whole-of-government approach;*
- *space program decisions are taken at the national level, reflecting national priorities;*
- *effective coordination of the civilian and military space programs in order to maximize industrial development;*
- *existing budgets and priorities are appropriately aligned; and*
- *expenditures in industry are maximized.*

Conclusion

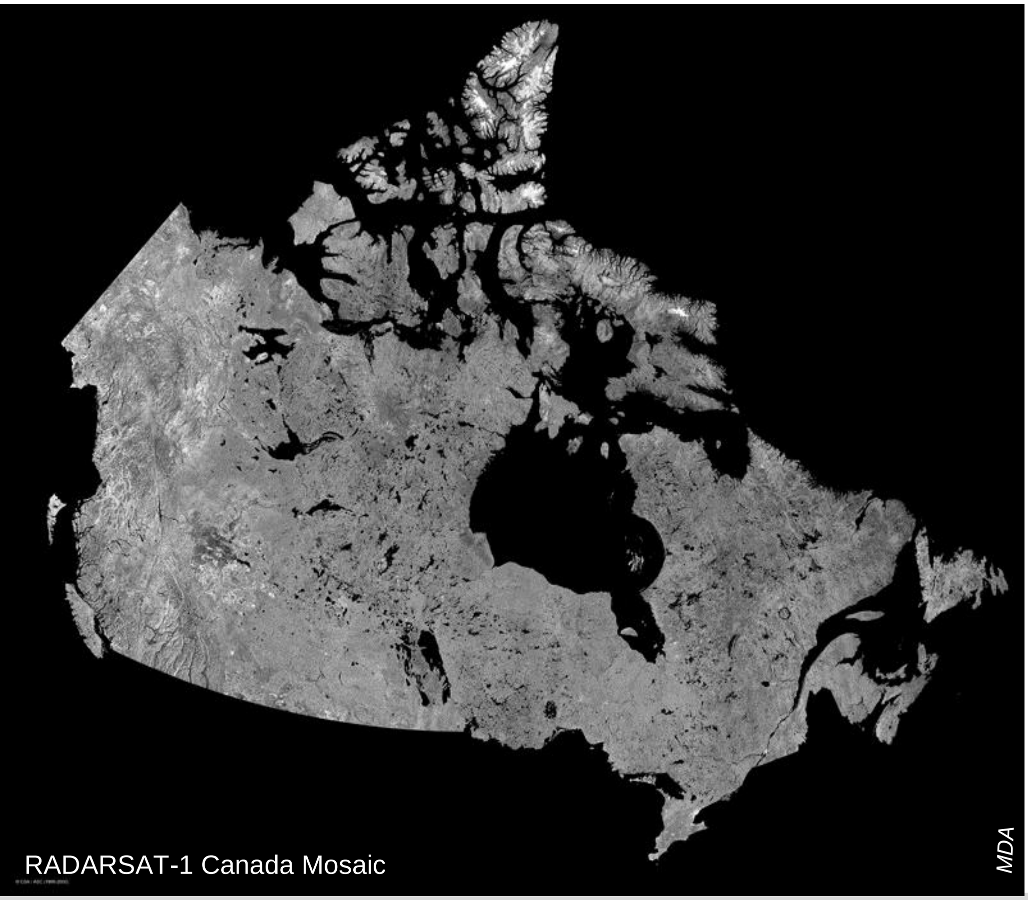
Once a leading spacefaring nation, Canada is falling behind its competitors in almost every measurable aspect. We are reducing our expenditures while our competitors are increasing theirs. A declining percentage of our space budget actually ends up in Canadian industry, which is against the international norm. Technology seed funding in Canada has all but vanished, while our competitors are realigning their technology development policies towards more economic and export-driven objectives. We do not have a space policy that outlines overarching government priorities, that offers stable and predictable funding or that recognizes the importance of industrial development – while all of our major competitors have recently revised their domestic space strategies. Our space program is managed at the departmental level rather than at the national level – while many other spacefaring countries have national level governance or oversight.

Furthermore, our procurement processes are overburdening and slow. Academic and industrial space research and training is compromised by “stop and go” funding, the paucity of flight opportunities, and our inability to take advantage of new international partnering opportunities. And we do not have an effective process for consulting industry and academic stakeholders when planning and implementing our space program – an important element of the early years of Canada’s space program.

Canada needs to do better in all of these areas. Government of Canada space expenditures need to be more efficient in terms of meeting national needs and enhancing industry competitiveness in the rapidly changing international marketplace. If we can manage our space program more effectively using the recommendations in this report, Canada can once again become a leading spacefaring nation which is competitive on the world stage. But we need to act quickly to stem the downward spiral in Canada’s space capacity and to take advantage of growing global opportunities for space development, exploitation and exploration – otherwise, the continuation of this grand success is at serious risk of collapse.

Space has been utilized by nations worldwide for discovery, innovation, advancement and the protection and management of national interests for over fifty years. The Canadian Space Program delivers critical national services, science and innovation, tangible economic impact and high-profile political partnerships, and it uniquely serves the wider socioeconomic agenda from education to national prestige and investments in our nation’s future.

The Canadian space industry has played an important role in helping make Canada what it is today – a proud, independent and innovative country. We are also pleased to participate in the Government of Canada’s Aerospace Review. We are confident that, as the next era in space exploration and exploitation unfolds, this report sets Canada on a bold path toward the next 50 years in space.



RADARSAT-1 Canada Mosaic

MDA

ANNEX I – Industrial space policies and plans of the Government of Canada

Throughout Canada's history as a spacefaring nation, private sector involvement was not only encouraged, but mandated. The various space policies and plans approved by governments over the past 50 years made the development of an indigenous space industrial capacity one of the prime objectives of the Canadian Space Program.

In generating these policies and plans, governments worked closely with industry to ensure that maximum industrial benefits were achieved. As a *quid pro quo*, governments expected industry to capitalize on government investments and programs to become successful in the international marketplace. These policies, coupled with the presence of globally-recognized academic space capability and research, led directly to the international competitiveness of the Canadian space industry and its export success.

Below are excerpts from the various space policies and plans developed in the last 50 years.

Upper Atmosphere and Space Programs in Canada (the Chapman Report), 1967

Page 111:

Therefore we recommend…Government policy on use of telecommunications satellites for domestic communications be developed so as to ensure Canadian control and maximum use of Canadian capabilities of the development and manufacture of both space and ground components of the various systems.

Page 112:

The domestic need for launch vehicles and space hardware is growing. Developments of this nature in other countries are fully supported by government on military or other grounds. Therefore we recommend: (a) that industrially based, study and research and development programs, fully funded, be undertaken on launch-vehicle systems and components to meet Canadian needs. (b) that systems management and prime contract activities be awarded to Canadian industry for the development and supply of the major hardware portions of the Canadian Space Program.

A Space Program for Canada, Science Council of Canada, July 1967

Page 10:

The manufacture of equipment for both space and ground components of telecommunications systems has important industrial potential. Canada has already achieved notable success in this field, and has demonstrated her capability for building satellites as well as ground support equipment. It is extremely important that policies be evolved which, subject to reasonable cost differentials, will secure the optimum use of Canadian capabilities in both the development and manufacture of such equipment or its major components. This applies not only to equipment for domestic use but to a share of the facilities used by international agreement.

Page 13:

A major program of research and technological development in the upper atmosphere and space could provide an important opportunity for the further development of Canadian industry. The opportunity is not simply to secure a certain volume of business that might be placed elsewhere, but to achieve the type of production, the manufacturing facilities, and the know-how that will be part of the industrial technology of the future. What is developed for space research today, may well determine the bread and butter production of the next few decades.

Study programs, and research and development projects on space facilities and components, should, as far as possible, be placed with Canadian industry. In many cases these must be fully funded by the central agency, but cost-sharing should be maintained or develop in so far as it is economically justified. Systems management contracts and prime contracts for the development and supply of the major hardware portions of the program, should be awarded directly to Canadian industry. This should not, however, preclude the negotiation of agreements with other countries or international agencies on a reciprocal basis for the sharing of development and production in the space field.

The success of an industrial development program arising out of the space effort will depend on the extent to which the new technology and production methods are transferred to other fields of activity, in the everyday lives of people. It is expected that a special study and development activity will be required to effect this transition. Partly, the solution lies in the dissemination of information, and in such services as market analysis and industrial design, but essentially it is the modern equivalent of the old-fashioned entrepreneurial genius that is needed.

A Canadian Policy for Space, 1974

The Cabinet Committee on Science, Culture and Information…agreed that:

(a) the following general statements should be approved:

(i) Canada's primary interest in space should be to use it for applications that contribute directly to the achievement of national goals;
(ii) utilization of space systems for the achievement of specific goals should be through activities proposed and budgeted by departments and agencies within their established mandates;
(iii) at the international level, Canada's ability to use space should be furthered by participating in international activities in space, negotiating agreements for the continuing access to science, technology and required facilities, and maintaining knowledge of foreign space activities in order to respond quickly to potential opportunities and threats to national sovereignty; and
(iv) at the national level, Canada's ability to use space should be furthered by the support of research appropriate to the need to understand the properties of space, the potentialities of space systems, and the search for potential applications, and technology programs to develop the industrial capability essential to meeting future requirements for operational space systems.

(b) the following principles should be endorsed:

(i) a Canadian industrial capability to design and build space systems to meet Canadian needs should be maintained and improved and Canada should continue to rely on purchasing launching services for her satellites but should enhance access to such services by participating in the supplying nation's space program, and
(ii) the necessary Canadian industrial capability should be maintained and improved by moving government space research and development activities into industry in accordance with the 'Make or Buy' Policy, and by the establishment of research, development and manufacturing capabilities leading to international trade and economic benefit to Canada,

(c) the Minister of Communications, in consultation with the Minister of Industry, Trade and Commerce and the Minister of State for Science and Technology, and other interested departments and agencies should bring forward suitable plans and procedures to provide that, to the optimum extent, Canada's satellite systems are designed, developed and constructed in industry:

(i) under Canadian program management and with overall Canadian design authority,
(ii) under procurement policies and procedures which will progressively increase the utilization of Canadian sources, and
(iii) with an increasing proportion of space qualified components from Canadian sources.

Canadian Space Agency Act, 1990

5 (2) In carrying out its objects, the Agency shall

(a) assist the Minister to coordinate the space policies and programs of the Government of Canada;
(b) plan, direct, manage and implement programs and projects relating to scientific or industrial space research and development and the application of space technology;
(c) promote the transfer and diffusion of space technology to and throughout Canadian industry;
(d) encourage commercial exploitation of space capabilities, technology, facilities and systems; and
(e) perform such other functions as the Governor in Council may, by order, assign.

Space Policy Framework, 1994

Principle #1: Space is of strategic importance to Canada's transition to a knowledge-based economy, and to the social, scientific, sovereignty, security and foreign policy objectives of the Federal Government. The Canadian Space Program is a chosen instrument for the implementation of the new objectives of the Government in research and development, science and technology, economic and industrial development, export expansion and employment, improved efficiency and effectiveness of Government operations, and the maintenance of Canada's sovereignty in the new world economic order.

Principle #6: Building on areas of industrial and technical competency, implementation of the Canadian Space Program will seek to foster an internationally competitive, export-oriented Canadian space equipment and services sector, open to a growing number of firms, often small and medium-sized enterprises.

Principle #9: The exploitation of the strategic environment of space is also deemed essential to protect national security and to enhance Canada's sovereignty in the new political and economic world order. A growing degree of synergy will be promoted between civil and non-aggressive defence space activities with a view to contributing to world peace and security, and to optimizing the effectiveness of federal funds.

Excerpt from a backgrounder of the 1994 Space Policy Framework on the CSA website:

Industrial Commercialization Strategy

The most dramatic change in the space sector in recent years has been the growth of commercial space activities, a development that in Canada has been as much the result of deliberate strategy as natural economic forces. A key legacy of the last quarter century of Canadian space activity is its space commercialization objective, which as articulated by the Space Policy Framework is "to foster an internationally competitive, export-oriented Canadian space equipment and services sector."

The CSA pursues this objective through a variety of strategies and policies:

At a funding level, the Canadian Space Agency, which manages all federal civil space expenditures, out sources some 75-80% of all the money it receives. Virtually all that the Canadian Space Agency does in space it does through procurement, mostly from industry but also from universities and specialized research institutes. In this the Agency aims to ensure that key locus of space capability in Canada resides not in government labs or with public servants but in the private sector, which has a greater ability and propensity to commercialize that capability and the Canadian tax payer's investment.

At a policy level, the Canadian Space Agency has established a variety of guidelines for fostering the growth of industry. These include an emphasis on providing contracts to SMEs, a goal of ensuring that Canada's space investments are made in all regions of the country, and, most importantly, ensuring wide consultation with industry during the development of Canada's space programs and projects.

At a program level, the Canadian Space Agency supports space commercialization at virtually all stages of the development cycle. Technological development programs support everything from advanced (leap-frog) to near-market technologies and always in partnership with Canadian industry. In addition, the Agency maintains a Commercialization Office which is mandated to support the commercial exploitation of space capabilities, technologies, facilities, and systems with the aim to maximize the social and economic benefits of the Canadian Space Program. Its main functions are to provide intellectual property management and to support technology transfer.

But the most important element in Canada's space commercialization strategy is the Government's long-term strategy of balancing public and private sector roles in a given sector of space activity in accordance with that sector's level of commercial maturity. The Government's objective is to privatize and commercialize space activities as they become commercially self-sustainable, leaving to industry the task of leading Canada's activities in commercially mature sectors and leaving to Government the responsibility for commercially immature sectors. Thus, in satellite communications, a commercially mature sector, the Government's role is limited to advanced technology and applications development and regulatory activities. In satellite remote sensing, a still maturing sector, the Government's role is greater, as investor, anchor tenant, and partner with the private sector. And in space robotics and infrastructure servicing, a very young sector, the Government's role is much greater, covering all procurement and technology development.

The Canadian Space Strategy, 2004[106]

A DYNAMIC SPACE INDUSTRY AND EXPANDED MARKETS

The Canadian Space Agency recognizes that the best means of turning scientific and technological advancements into innovative products and services is through industry. Industry is also the best vehicle for providing a broad range of services to diverse groups of users – from individuals to public and private organizations. With its highly skilled workforce, the space industry in Canada not only generates wealth in our economy, but also provides Canadians with competitive products and services that would otherwise have to be procured from foreign sources.

The Canadian Space Agency will continue to foster the growth of a viable, vibrant space industry in Canada. The Agency will promote our national space industry as the primary custodian and developer of our space technology base, including our capability to design, build and where and when appropriate, operate space and ground-based assets.

Canada's space industry must be sufficiently large and diverse to meet our needs and goals in space. We must also sustain the high calibre of products and services our industry has demonstrated to date. However, given that the Canadian market is relatively small, it is critical that industry be able to leverage foreign investments and generate export sales. Capitalizing on export revenue depends on industry's ability to commercialize highly competitive products and services, as well as the Government of Canada's ability to establish open trade regulations with its closest international partners. In order to help industry meet and succeed these challenges, the Canadian Space Agency will align its programs and actions to build synergies that will bolster industry's competitiveness and market development efforts.

National Aerospace and Defence Strategic Framework, 2005

Page 3: The space sector is a key element of the aerospace industry. While contributing to the economic well-being of the country, Canada's space program supports key policy areas such as security and sovereignty, the environment and sustainable development. In most cases, it is both essential and strategic to have a domestic space sector capable of meeting our national needs. As a result, the market dynamics for space vary greatly from the commercial aerospace sector, as governments are often the main – and in some cases the sole – customers for space products and services. Canada's space companies have world-leading capabilities in niche areas such as communications and navigation, Earth observation sensors, ground stations, services and applications, space robotics and scientific instruments. Annual revenues have increased by more than two-thirds from $1.4 billion in 2000 to $2.4 billion in 2004. Satellite communications continues to be the largest revenue generator, accounting for three-quarters or $1.8 billion of total revenues. Other key segments include satellite navigation and space science. The industry's internationally competitive position is attested to by exports of $1.2 billion in 2004, representing half of the industry's total revenues, the highest proportion of any space-faring nation.

Page 4: In space and defence, firms have built their success on domestic government programs that developed and manufactured systems for national needs. These eventually became the core capabilities for commercial and government markets. In addition, the defence and space sectors have benefited from a myriad of agreements between the US and Canadian governments over more than 50 years that have led to a highly integrated North American technology and industrial base.

Page 21: Why Invest in Aerospace and Defence?

Most governments in countries around the world that have aerospace and defence industries invest in the development of those industries. One of the primary drivers for government intervention is the link between the industry and national security. The economic characteristics of the industry with its high development costs, high risks and long payback periods, combined with the highly cyclical nature of the sector, have also been driving forces calling for government involvement. These characteristics make it difficult for the private sector to shoulder all financial requirements alone and require the government to intervene to support the sector. Internationally, governments have used various policy instruments on the supply and demand side to create an environment that nurtures the industry. Instruments utilized include state ownership, domestic market protection, R&D funding, directed public procurement, export sales financing, domestic content requirements and offsets (including placing work with local firms for aerospace and defence contracts). Within that supportive environment, the aerospace and defence industry is the driving force, and it finances, designs, develops, produces and markets aerospace and defence products. Traditionally, government investment in the industry was justified on defence and national security grounds, but economic factors and the pursuit of national objectives are also important justifications. Investments in the aerospace and defence industry help meet some key economic and social policy objectives.

Page 25: A Vision for the Aerospace and Defence Industry in Canada to 2025

The government endorses the vision developed by stakeholders across the industry:

Canada will be home to a growing, innovative and diversified industry, recognized as a leader in serving global aerospace and defence markets and a preferred location for investment.

With the Framework, the government commits to working with the Canadian aerospace and defence industry and other stakeholders toward ambitious, achievable goals.

Through the work, commitment and collaborative partnership of governments, companies, workers, academic groups and other stakeholders, Canada will create an aerospace and defence industry that is a:

* source of national pride and a globally recognized brand of Canadian excellence;
* creator of national wealth and provider of challenging and rewarding jobs for Canadians;
* key contributor to security and military readiness in Canada and among our allies; and,
* lever for effectively achieving a wide range of public policy objectives and needs.

Endnotes

[1] Five countries with annual budgets over $2 billion (USD) include the US, China, Japan, France and the Russian Federation. ~ Organisation for Economic Co-operation and Development, *The Space Economy at a Glance 2011* (Paris: OECD Publishing, 2011), 9.
[2] There are over 60 nations with government agencies engaged in activities related to space exploration and exploitation.
[3] The objectives of the Canadian Space Program (CSP) are to "ensure the development and application of space science and technology to meet Canadian needs and to ensure the development of an international competitive space industry in Canada", as cited in numerous CSA documents, including its most recent *Report on Plans and Priorities (2012)*, http://www.asc-csa.gc.ca/pdf/rpp-2012-statements-eng.pdf.
[4] Defined as individuals who have university degree qualifications at the bachelor's level or higher. According to the 2001 Census of Population, there were approximately 3.7 million highly qualified persons (HQPs) in Canada – over 15% of the 24 million labour market population, aged 15 years and over. The space industry in Canada accounted for 4,344 HQP in 2010, over half of the workforce. ~ Canadian Space Agency. *State of the Canadian Space Sector 2010* (St-Hubert: CSA, 2011), 17.
[5] For example, European companies only export 22% of their goods and services outside of Europe, according to Eurospace, the association of European space industries ~ ASD-Eurospace, *Facts and Figures, The European Space Industry in 2010* (Paris: Eurospace, 2011), 8.
[6] CSA, *State of the Canadian Space Sector 2010*, 12.
[7] Ibid, 10.
[8] Cesar Jaramillo, ed., *Space Security 2011* (Kitchener: Pandora Press, 2011), 108.
[9] *"Canada has played a relatively small but central role in the international human spaceflight programme by contributing its skill in building robotic equipment in return for both commercial contracts and flights for Canadian astronauts – in total 14 flights by 8 astronauts so far. This successful programme has been identified as one possible model for UK developments in exploration." "A human space exploration programme could be pursued through joining the nascent ESA exploration programme or through bilateral collaboration with NASA (the 'Canadian Model')."* ~ British National Space Centre, *Space Exploration Review* (London: BNSC, 2009), 88, 15.
[10] Outlined in greater detail in Annex I.
[11] Michael Byers, "For Sale: Arctic Sovereignty? How losing a Canadian satellite to the US would be like losing our eyes on the North," *The Walrus*, June 2008.
[12] OECD, *The Space Economy at a Glance*, 29, 3.
[13] Facts in this section taken from the following publication: W. M. (Mac) Evans, "The Canadian Space Program – Past, Present and Future (A history of the development of space policy in Canada)", *Canadian Aeronautics and Space Journal* (2004).
[14] Geostationary Earth Orbit (GEO) is a circular orbit approximately 22,000 miles (35,786 km) above the Earth's equator that follows the direction of the Earth's rotation. A satellite in a geostationary orbit appears stationary, always at the same point in the sky, to ground observers. Most communications and weather satellites operate in this orbit.
[15] MDA is a leader in Earth observation systems, having built over 70% of the world's civilian multi-satellite Earth observation ground stations, located in over 70 locations around the world, on all continents including Antarctica.
[16] Following discussions between Prime Minister Brian Mulroney and US President Ronald Reagan at the "Shamrock Summit" in Quebec City on March 17, 1985, Canada signed on to the ISS program a year later.
[17] Outlined in greater detail in Annex I.
[18] OECD, *The Space Economy at a Glance 2011*, 100, 102.
[19] For example, the Wideband Global SATCOM system, or WGS, is a constellation of satellites developed for the US military to provide additional bandwidth and communications capabilities for command and control, communications, and computers; intelligence, surveillance, and reconnaissance (C4ISR); battle management; and combat support information. Australia has signed on to WGS 6 and Canada recently signed on to WGS 9 to share in global capacity.
[20] MDA built the first SAR processor for SEASAT, the world's first radar satellite, which was managed by NASA's Jet Propulsion Laboratory and launched in June 1978.
[21] OECD, *The Space Economy at a Glance 2011*, 64.
[22] Ibid, 11.
[23] NASA's 2008 Phoenix mission included a Canadian-made weather instrument which ironically made the first ever observations of snowfall on Mars).
[24] MOPITT is Canada's first major instrument to measure pollution of the Earth's atmosphere from space and was launched on the Terra platform of NASA's Earth Observing System (EOS) on December 18, 1999.
[25] CSA, *State of the Canadian Space Sector 2010*, 18, 20.
[26] Euroconsult, "50% more satellites to be launched in the decade ahead," press release, August 25, 2011, http://www.euroconsult-ec.com/news/press-release-33-3/48.html.
[27] OECD, *The Space Economy at a Glance*, 31.
[28] Futron Corporation, *Futron's 2011 Space Competitive Index: A Comparative Analysis of How Countries Invest In and Benefit from Space Industry* (Bethesda: Futron Corporation, 2011), 1.
[29] Ibid, 15.
[30] The White House, *National Space Policy of the United States of America* (Washington: 2010), 1.
[31] Euroconsult, "50% more satellites to be launched in the decade ahead".
[32] Since January 1979, Canada has had the special status of a Cooperating State within ESA. By virtue of this accord, the Canadian Space Agency takes part in ESA's deliberative bodies and decision-making and also in ESA's programmes and activities. Canadian firms can bid for and receive

contracts to work on programmes. The accord has a provision ensuring a fair industrial return to Canada. Canada is the only country outside of Europe to have such an arrangement. The arrangement was renewed for a 10-year period in 2010.
[33] Science Council of Canada, *A Space Program for Canada* (Ottawa: Queen's Printer, 1967), 7.
[34] In 2008, the federal government blocked the sale of MDA to a US company because the deal did not provide a "net benefit" to Canada. The Investment Canada Act was amended in March 2009 to include "national security" as a criteria to review a future foreign investment.
[35] Polar View, *The Contribution of Space Technologies to Arctic Policy Priorities*, (Tromsø: Polar View, 2012), 44-45.
[36] Canada. Indian Affairs and Northern Development. *Canada's Northern Strategy: Our North, Our Heritage, Our Future* (Ottawa: Minister of Public Works and Government Services Canada, 2009), 1.
[37] "The Melting North", *The Economist*, Special Report, June 16, 2012, http://www.economist.com/node/21556798.
[38] Robin McKie, "Rate of Arctic summer sea ice loss is 50% higher than predicted", *The Guardian (UK)*, August 11, 2012, http://www.guardian.co.uk/environment/2012/aug/11/arctic-sea-ice-vanishing.
[39] Randy Boswell, "Arctic ice meltdown nears 2007 record", *Postmedia News (Canada)*, August 11, 2012, http://www2.canada.com/calgaryherald/news/story.html?id=94091365-8402-4056-84d8-66c26cc14e3d&p=2.
[40] Kenneth J. Bird, et al, *Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle, 2008*, U.S. Geological Survey Fact Sheet 2008-3049 (2008), http://pubs.usgs.gov/fs/2008/3049/.
[41] Rob Huebert, "Canadian Arctic Sovereignty and Security in a Transforming Circumpolar World," *Foreign Policy for Canada's Tomorrow*, No. 4, Canadian International Council, July 2009, 1.
[42] exactEarth is the leading organization in the field of global Automatic Identification System (AIS) vessel tracking, collecting more ship monitoring data and delivering the highest quality information to government and commercial customers around the world. exactEarth is jointly owned by COM DEV International and a Spanish firm.
[43] DND contracted MDA to implement Polar Epsilon, a project based on surveillance from space to detect, identify and track potential maritime threats. The two new ground stations, located at DND facilities in Aldergrove, BC, and Masstown, NS, download RADARSAT-2 data in near-real time, allowing the system to detect and report ships in Canadian waters in less than 10 minutes of their illumination by the radar beams.
[44] Space Foundation, *The Space Report 2011: The Authoritative Guide to Global Space Activity* (Washington: Space Foundation, 2011), 32.
[45] Ibid, 135.
[46] Space Foundation, "Space Foundation's 2012 Report Reveals 12.2 Percent Global Space Industry Growth in 2011", press release, April 5, 2012.
[47] Euroconsult, "50% more satellites to be launched in the decade ahead".
[48] Space Foundation, *The Space Report 2011,* 71.
[49] Sapphire and NEOSSat are expected to launch later in 2012 on the same launch vehicle. Sapphire will perform surveillance of objects in deep space and provide timely relevant and accurate tracking data on Earth-orbiting objects. It will serve as Canada's contribution to the United States Space Surveillance Network. NEOSSat is a Canadian satellite that will be the first space telescope dedicated to the search for near-Earth asteroids and track high Earth orbit satellites. While NEOSSat is a joint Canadian Space Agency and Defence R&D Canada project built by Microsat Systems Canada Inc. with support from Spectral Applied Research, Sapphire, built by MDA with support from COM DEV International and Surrey Satellite Technology Limited will be DND's first operational satellite.
[50] The International Space Exploration Coordination Group (ISECG) was formed in November 2007 to coordinate the work of 14 national space agencies (Canada, United States, Europe, United Kingdom, Germany, Italy, France, China, Japan, Korea, Russia, Ukraine, India and Australia) toward a shared vision for human and robotic space exploration.
[51] Space Foundation, "Space Foundation's 2012 Report".
[52] Euroconsult, "50% more satellites to be launched in the decade ahead".
[53] Space Foundation, "Space Foundation's 2012 Report".
[54] OECD, *The Space Economy at a Glance 2011*, 20.
[55] Euroconsult, "Leading Government Space Programs Under Strong Budget Pressure", press release, March 27, 2012, http://www.euroconsult-ec.com/news/press-release-33-1/55.html.
[56] OECD, *The Space Economy at a Glance 2011*, 9.
[57] Edward Wong and Kenneth Chang, "Space Plan From China Broadens Challenge to U.S.", New York Times, December 29, 2011, http://www.nytimes.com/2011/12/30/world/asia/china-unveils-ambitious-plan-to-explore-space.html?pagewanted=all.
[58] The White House, *National Space Policy, 3.*
[59] Ibid, 10.
[60] UK Space Agency, *UK Space Agency Civil Space Strategy 2012-2016* (London: UKSA, 2012), 10.
[61] European Space Agency, *Convention for the establishment of a European Space Agency,* Article VII (b) (Paris: ESA, 1975).
[62] European Space Agency, *Resolution on the European Space Policy: ESA Director General's Proposal for the European Space Policy*, ESA BR-269 (Paris: ESA, 2007).
[63] Discussed in greater detail in recommendation #4.
[64] Euroconsult, *International overview of space governance and policies for the Canadian Aerospace Review*, June 27, 2012, 7, 63.
[65] Futron Corporation, *Futron's 2011 Space Competitive Index*), 27.
[66] Ibid, 32.
[67] Futron Corporation, *Futron's 2012 Space Competitive Index: A Comparative Analysis of How Countries Invest In and Benefit from Space Industry, Executive Summary* (Bethesda: Futron Corporation, 2012), 4.
[68] A full description of ESA ARTES appears in the next section under Industrial Development Policy.
[69] "Nothing in this Agreement shall be construed to prevent any Party from taking any action or not disclosing any information which it considers necessary for the protection of its essential security interests relating to the procurement of arms, ammunition or war materials, or to procurement

indispensable for national security or for national defence purposes." ~ World Trade Organisation Uruguay Round Agreement, Agreement on Government Procurement, Article XXIII, Exemptions to the Agreement, January 1, 1996.
[70] "Nothing in this Chapter shall be construed to prevent a Party from taking any action or not disclosing any information which it considers necessary for the protection of its essential security interests relating to the procurement of arms, ammunition or war materials, or to procurement indispensable for national security or for national defense purposes." ~ North American Free Trade Agreement, Article 1018, Exemptions, January 1, 1994.
[71] "Nothing in this Agreement shall be construed to: (a) require the Federal Government to provide, or allow access to, information the disclosure of which it determines to be contrary to national security; or (b) prevent the Federal Government from taking any action that it considers necessary to protect national security interests or, pursuant to its international obligations, for the maintenance of international peace and security." ~ Agreement on International Trade, Article 1804, National Security, July 18, 1994.
[72] ESA Member States invest a little under €3 billion annually through ESA, and a similar amount in national programmes. ESA programmes are governed by the industrial policy principles established in the ESA Convention, in particular by exploiting competitive bidding while distributing industrial contracts in proportion to funding from Member States ('fair return').
[73] OECD, *Space Economy at a Glance 2011*, 50.
[74] Outlined in greater detail in Annex I.
[75] Canadian Space Agency Act, S.C. 1990, ch. 13, s. 5.
[76] National Aeronautics and Space Administration, 2011 NASA Strategic Plan (Washington: NASA, 2011), 16.
[77] Information obtained from the Canadian Space Agency website.
[78] UK Technology Strategy Board, "Technology Strategy Board announces Satellite Applications Catapult Centre", press release, January 4, 2012, http://www.innovateuk.org/content/press-release/technology-strategy-board-announces-satellite-appl.ashx.
[79] UK Space Agency, "UK Space Agency welcomes start of TechDemoSat design programme", press release, October 18, 2010, http://www.bis.gov.uk/ukspaceagency/news-and-events/2010/Oct/uk-space-agency-welcomes-techdemosat.
[80] The launch of Canada's third component for the ISS was delayed for three years, adding about $13 million to the Agency's costs.
[81] In 1998, the United States withdrew its launch services for RADARSAT-2, delaying the program by more than two years and adding $167M CAD to its cost.
[82] Budget 2010 provided $397M in new funding for RCM Phase D (construction phase), but required the CSA to reallocate an additional $100M from its A-base.
[83] European Space Agency, *Annual Report 2009* (Paris: ESA, 2009), 89.
[84] Space Foundation, *The Space Report 2011*, 44.
[85] The Leapfrog Technology Program, a precursor to the STDP, was designed to include "the development of technologies of next generation spacecraft subsystems aimed at enhancing the international competitiveness of our industry and at preparing Canada for future space missions." ~ Canadian Space Agency. *The Canadian Space Program* (St-Hubert: CSA 1999), 18.
[86] Euroconsult, *International overview of space governance and policies for the Canadian Aerospace Review*, 7, 59.
[87] Review of Federal Support to Research and Development – Expert Panel Report, *Innovation Canada: A Call to Action, Special Report on Procurement* (Ottawa: Minister of Public Works and Government Services Canada, 2011), 8, 26.
[88] For instance, MDA's space robotics facility in Brampton – the core of Canada's robotics industrial capacity – has seen a decrease in employment over the past five years, from a high of 544 employees in January 2007 to 397 in January 2012, and a projected workforce of 315 in January 2013, a reduction of 42% since 2007.
[89] See Annex 1.
[90] ESA, *Convention for the establishment of a European Space Agency,* Article VII (d).
[91] Euroconsult, *International overview of space governance and policies for the Canadian Aerospace Review*, 63.
[92] Goods and technologies are considered to be dual-use when they can be used for both civil and military purposes. Examples of dual-use technologies are satellite communications, Earth observation/remote sensing and navigation.
[93] Jaramillo, *Space Security 2011*, 129.
[94] Futron Corporation, *Futron's 2012 Space Competitive Index,* 3.
[95] Canadian military space activity is coordinated by the Directorate of Space Development (D Space D) at the Department of National Defence.
[96] *Innovation Canada: A Call to Action*, 6.
[97] Ibid, 7.
[98] Euroconsult, *International overview of space governance and policies for the Canadian Aerospace Review*, 8.
[99] National Research Council of the National Academies, Committee on the Rationale and Goals of the U.S. Civil Space Program, *America's Future in Space: Aligning the Civil Space Program with National Needs* (Washington: National Academies Press, 2009), 51.
[100] Canadian Space Agency Act, S.C. 1990, ch. 13, s. 5.
[101] National Research Council of the National Academies, *America's Future in Space*, 63-64.
[102] OECD, *The Space Economy at a Glance 2011*, 53.
[103] ESA's total costs in 2010 amounted to €3709 million. Around 86% of ESA's 2010 costs were incurred in industrial contracts in the Member States for research or project-related activities, the running of technical or operational facilities, technical assistance and IT ~ European Space Agency, *Annual Report 2010* (Paris: ESA, 2010), 70.
[104] Canada. Auditor General of Canada. *Report of the Auditor General of Canada to the House of Commons*, Chapter 7 – Canadian Space Agency – Implementing the Canadian Space Program (Ottawa: Minister of Public Works and Government Services Canada, 2002), 7.
[105] National Research Council of the National Academies, *America's Future in Space*, 52, 53.
[106] This policy was not approved by Cabinet, and remains only an internal CSA policy framework.