Aerospace Review

Mandated by the Government of Canada

Volume 2

Reaching Higher: **Canada's Interests** and **Future** in SPACE

November 2012

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Cat. No. Iu44-90/2012E-PDF
ISBN 978-1-100-21467-2

Aussi offert en français sous le titre *Vers de nouveaux sommets : les intérêts et l'avenir du Canada dans l'espace*.

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The Honourable Christian Paradis
Minister of Industry

Dear Minister,

I am pleased to submit *Reaching Higher: Canada's Interests and Future in Space*, volume 2 of my report pursuant to the mandate given to me as Head of the Review of Aerospace and Space Programs and Policies. Volume 1, entitled *Beyond the Horizon: Canada's Interests and Future in Aerospace*, focuses on the aerospace sector.

The over-arching objective of this volume is to outline the foundations for a Canadian Space Program that helps unlock the country's wealth, improves delivery of public services, supports environmental sustainability, and protects public safety. Canada was one of the first nations in space, and over the coming decades our prosperity and security will depend more than ever on designing, building, and operating an optimal mix of space assets and services.

I have aimed to produce a report that is evidence-based, grounded in a long-term perspective on global and industry trends, innovative, and practical. The report summarizes the Review's findings and sets out broad policy directions. Many of the details underlying its analysis and recommendations can be found in working group reports, research reports, and submissions posted on the Review's website: **aerospacereview.ca**.

It has been an honour to serve as Review Head. I hope the advice contained in these volumes will prove helpful to the government, and thank you for the opportunity to lead the Review.

Yours sincerely,

David Emerson

Aerospace Review Head

David Emerson

Advisory Council Members

Jacques Roy

Sandra Pupatello

Jim Quick

Acknowledgements

A policy development process like the Aerospace Review requires the involvement of a large number of experts and stakeholders. The approach of the Review has been to operate to a high level of transparency, independence, and engagement with interested parties while respecting the Review's clear mandate and timelines. As a result, many were called upon to provide input and support on short notice.

I am very grateful to everyone who answered that call in so exemplary a manner.

Let me begin by expressing my appreciation to the members of my Advisory Council: Sandra Pupatello, Jim Quick, and Jacques Roy. Their professionalism, positive attitude, and wise counsel made our meetings, consultations, and deliberations both productive and enjoyable. Much of what is said in this report reflects their insights and advice.

I would also like to thank the many representatives of the aerospace and space industries, research and academic communities, unions, and provincial governments who chaired or participated in working groups, attended roundtables, hosted my colleagues and me on site visits, met with us bilaterally, and sent in written submissions. I know that for all of you, these activities came on top of your day jobs, and I am grateful for your willingness to contribute your time and expertise.

Special mention must be made of the Aerospace Industries Association of Canada. The Association's board and staff were instrumental in informing aerospace and space companies about the Review and helping to organize the industry-led, multi-stakeholder working groups whose discussions and recommendations have been so important to the Review.

I am appreciative of the willingness of business people, researchers, and government officials in other countries to meet with my colleagues and me during fact-finding trips abroad, and to speak frankly about their own plans and challenges.

The Review also benefited tremendously from information and ideas offered by Canadian public servants from a wide range of departments and agencies in the context of briefing sessions, working groups, and site visits.

Finally, my thanks to the Aerospace Review Secretariat under the leadership of Scott Streiner. The Secretariat provided outstanding support and advice over the intense 11-month period from the initial preparations for the Review to the release of this report. Producing a public policy product covering such a wide range of issues and points of view, and doing so on time and on budget, has been a remarkable achievement.

Having identified many of those whose contributions made the Review possible, let me conclude by emphasizing that I take full responsibility for the findings and recommendations in both volumes of the report.

David Emerson

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Note on data sources

Data in this volume come from multiple sources, including the Canadian Space Agency, Statistics Canada, Industry Canada, the Aerospace Industries Association of Canada, the Organisation for Economic Co-operation and Development, and reports by various space companies and by consulting firms such as Euroconsult.

Unless otherwise indicated, figures in this volume apply exclusively to the space sector as defined on page 3, while figures in the companion volume apply exclusively to the aerospace sector.

Executive summary

Canada has been in space for 50 of the 55 years humans have been there. Ours was the third country to have a domestically built satellite in space, the first to have its own domestic communications satellite, the first to develop a direct broadcast satellite, and – as all Canadians familiar with the maple leaf on the bicep of the Canadarm will know – a pioneer in space robotics.

Space is becoming ever more essential to modern economies and national security. The digital information revolution that is remaking contemporary societies – bringing into being new means of knowledge production, mobile access to global pools of information and entertainment, and new relations between public authorities and populations – is possible in part because of space-based assets and applications. Satellites are playing growing roles in fields as diverse as precision agriculture, resource extraction, meteorology and climatology, environmental monitoring, the delivery of education and health services, emergency response, border surveillance, the operation of civil and military drones, and the rapid deployment of armed forces. And it is not just big, expensive satellites that are providing such capabilities: smaller, cheaper satellites are becoming increasingly sophisticated, offering public and private sector customers a wider range of options when they buy and use space assets.

For all these reasons, dozens of countries have committed themselves to joining established space-faring nations in placing and operating assets in orbit, while a growing number of investors have taken an interest in commercial space ventures, from satellite launch and on-orbit refuelling services to space tourism and space mining.

Canada – with its vast geography, dispersed population, isolated communities, long coastlines, rich endowment of natural resources, and northern location – has a particular need for space assets and applications. The right mix of satellites and associated ground infrastructure, for example, will be indispensable if the country is to accelerate wealth creation, protect the environment, and assert its sovereignty as the North opens.

Historically, space-related activity has largely been led by governments. Motivated partly by prestige, partly by curiosity, and partly by the desire to support provision of public services, governments have borne much of the cost and risk of space exploration and activity. Where market economies exist, governments have done so in partnership with companies that have received contracts to design and manufacture space assets for public as well as private use. In Canada, the result has been the creation of a $3.4 billion space industry that employs 8,000 workers across the country, derives 80 per cent of its revenue from satellite communications, and generates half of its revenue from sales abroad, making it one of the most export-oriented space sectors in the world.

By virtue of niche strengths in areas like satellite communications, Earth observation, and space robotics – along with strong global networks and a positive reputation – the Canadian industry is well-positioned to take advantage of emerging opportunities, succeed commercially, and contribute to the public good.

But business as usual will not be good enough. Advancing the national interest through space-based activity and fostering a competitive Canadian space industry will require resolve, clear priorities that are set at the highest levels, and effective plans and programs to translate these priorities into practice. If the Canadian effort in space has been hampered over the past decade, it is partly because there has not been sufficient clarity of purpose, lines of authority among public agencies have been blurred, and processes for procuring space assets and services have failed to adapt to new global realities and the commercial capacity of space firms. In a sector whose undertakings are innovation-dependent, long term, expensive, and complex, it is critical to have concrete goals, predictable funding, and orderly implementation.

Many of the recommendations made in the companion volume on aerospace apply to the space sector as well, from including aerospace and space as priorities in the government's Science and Technology Strategy, to reviewing export and domestic control regimes to ensure that they are not unnecessarily restrictive, to encouraging youth to consider aerospace- and space-related studies and careers.

This volume focuses on policy and program improvements specific to the space sector. It recommends that:

1. The government explicitly recognize the importance of space technologies and capacity to national security, economic prosperity, and sustainable growth, and that the Minister of Industry bring 10-year, 5-year, and annual government-wide priorities for the Canadian Space Program to the Cabinet Committee on Priorities and Planning, which is chaired by the Prime Minister, for discussion and approval each spring.
2. The government establish a Canadian Space Advisory Council, reporting to the Minister of Industry, with membership from industry, the research and academic communities, provinces and territories, and federal departments and agencies.
3. A deputy minister-level Space Program Management Board be created to coordinate federal space activities, project-specific arrangements be put in place to ensure disciplined project management, and all agencies and departments with a role in the Canadian Space Program be required to report on how they are implementing priorities set out by Cabinet.
4. The Canadian Space Agency's core funding be stabilized, in real dollar terms, for a 10-year period; major space projects and initiatives be funded from multiple sources, both within and beyond the federal government; and increased international cooperation be pursued as a way of sharing the costs and rewards of major space projects and initiatives.
5. The scope of space projects, project timelines, and performance requirements be finalized as early as possible in the project definition phase.
6. Space asset and service procurement processes be competitive in nature and proposals be assessed on the basis of their price, responsiveness to scoped requirements, and industrial and technological value for the Canadian space sector.
7. Total funding for the Canadian Space Agency's technology development programs be raised by $10 million per year for each of the next three years, and that it be maintained at that level.
8. Where costs are modest and there is no risk to public safety, the government create conditions conducive to the expansion of space-related commercial activity.

Space has been important to Canada over the last half century, but not nearly as important as it will be over the next half century. Simply put, it will be an essential tool of nationhood for a country that aspires to provide long-term prosperity and security to its people, protect its natural environment, and discharge its international responsibilities.

The question is not whether Canada should be in space, but how public policies and programs can ensure that its presence there, and related activities on the ground, best serve the public interest and help the space sector thrive. Fundamental to reaching these objectives is a Canadian Space Program characterized by considered and explicit priorities that are implemented through sound governance, solid management plans, modern procurement practices, and greater emphasis on technological and commercial development. Although increased investment in space infrastructure and services may eventually be required, all the elements described above can be achieved in a fiscally neutral way. There is no reason for equivocation or delay.

Review mandate and process

Space-based assets are strategic infrastructure essential to the functioning of modern economies and societies. They have made possible a global communication revolution, new ways of monitoring the Earth's surface and atmosphere, the command and control of transportation systems and military hardware, and a more profound understanding of our place in the universe.

A particular feature of progress in space has been the pervasive presence of government. In part, this has stemmed from the near inseparability of space from national security and geopolitical influence. But it also reflects the reality that space is a "long game" with significant risks and the need for patient money.

That reality is changing, as technologies advance and more and more private companies capitalize on space-related opportunities. But the gradual shift in the public-private balance in space does not affect one incontrovertible truth: space will be vital to securing Canada's national interests into and beyond the middle of the century. If Canada is to remain among the global leaders in space, business as usual won't be enough. Today, as dozens of countries scramble to join established space-faring nations in sending and operating assets high above the surface of the Earth, Canada needs a "reset" to define clearly what it wants and needs to do in space in the decades ahead.

The structure of the space industry

The space industry is composed of three main segments:

- *the space segment encompasses the design, manufacturing, and deployment of hardware into space (e.g., satellites and spacecraft);*
- *the ground segment includes the design, construction, and operation of equipment and facilities on the ground used to operate the hardware in space and receive its data transmissions; and*
- *the downstream applications and services segment uses the data generated by the equipment in space to provide a number of services, such as Global Positioning System data and mapping images.*

The burgeoning global interest in space arises from a simple but compelling calculus: designing, manufacturing, and controlling satellites and participating in space exploration and science missions make nations richer, safer, smarter, and better-respected. These activities fire the imagination, instil pride, save lives, and enhance quality of life in countless, sometimes invisible, ways.

Canada's natural endowment of geography, resources, and northern location gives rise to powerful reasons to get it right when it comes to space. Our economic prosperity, our national security, and the management of our environment depend fundamentally on how space priorities are shaped and executed in pursuit of practical outcomes.

Against this backdrop, the government announced that it would initiate "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."[1]

The Aerospace Review was formally announced on February 27, 2012. David Emerson was appointed Review Head, and was joined by a three-person Advisory Council comprising Sandra Pupatello, Jim Quick, and Jacques Roy.

From the outset, a commitment was made to a review that would be independent, evidence-based, grounded in a long-term perspective on global and industry trends, open to innovative but practical approaches and solutions, and aimed at producing concrete, fiscally neutral recommendations. This volume provides the Review's findings and advice with respect to the space sector; a companion volume covers the aerospace sector.

In conducting its research and analysis, the Review relied on four sources of information and advice.

First, working in close consultation with the Aerospace Industries Association of Canada, it established industry-led working groups in the following areas:

- technology development, demonstration, and commercialization;
- market access and market development;
- aerospace-related public procurement;
- small business and supply chain development;[2]
- people and skills; and
- space.

The working groups brought together representatives of industry, academic and research institutions, and unions, as well as federal government officials participating as observers. The working groups were given specific mandates, including questions for consideration, and each held a series of discussions that led to the preparation of reports with findings and advice to the Review Head. While working group chairs and vice-chairs were not obligated to achieve consensus, they were encouraged to strive for the widest possible agreement among participants and to ground their counsel in sound evidence and analysis.

Second, the Review Head and Advisory Council members conducted a series of roundtables, meetings, and site visits in Canada and major aerospace nations. Domestic meetings were aimed primarily at understanding the state of the Canadian industry and its views on which policies and programs have been working well or falling short. International meetings were aimed at learning about best practices in other countries with vibrant aerospace and space sectors, and assessing both emerging competitive challenges and opportunities for increased collaboration and market success.

Travelling mainly as a group, the Review Head and Advisory Council members visited Montreal, Toronto, Winnipeg, Vancouver, and Halifax. Travelling for the most part individually, they visited the United States, the United Kingdom, France, Germany, China, Japan, Russia, and Brazil.

1 Government of Canada, *Budget 2011: The Next Phase of Canada's Economic Action Plan,* (Ottawa: Public Works and Government Services Canada), 2011. **budget.gc.ca/2011/home-accueil-eng.html**

2 This working group ultimately submitted two separate reports: one on small businesses and one on supply chain development.

Third, the Review commissioned 16 studies from independent experts (see Appendix A) on a range of topics, including the impact of global trends on Canada's space and aerospace sectors; export control regimes in Canada and abroad; a comparison of the structure and budgets of space programs in Canada and other major space-faring nations; and the potential role of space assets in advancing Canada's Northern Strategy.

Finally, the Review invited written submissions (see Appendix B) from interested parties through its website, ultimately receiving some 25 documents from a variety of organizations, companies, academics, and private citizens.

Most of the material and analysis generated through these four streams of information and advice are available through the Review's website (**aerospacereview.ca**) and, it is hoped, will continue to serve for some time as an important source of information and ideas for those interested in the shape and future of the aerospace and space sectors.

Drawing on all four streams, the Review examined current conditions and long-term trends and considered the roles and perspectives of all players.

The Review's analysis was guided in part by the principle that in a market economy, industry has the primary responsibility for its own fate and the role of government must be carefully delimited. In the space sector, this principle has been tested because government has historically been the dominant sponsor and consumer of space assets and applications. Going forward, fiscal constraints, advancing technologies, and the ingenuity of the private sector will inevitably lead to a more balanced and diverse range of activities and actors in space.

The role of government in supporting Canadian industry is concentrated in a number of key areas:

- Supporting research and development (R&D) that might take years to produce marketable results but has the potential to generate substantial benefit to the public good, in part through risk sharing.
- Improving the functioning of markets and business performance by facilitating communication between firms whose needs and capacities may be complementary, and between industry and academic and research institutions.
- Making procurement decisions that strengthen domestic industries, and therefore the national economy, while respecting international trade rules and acquiring the best product for a reasonable cost.
- Protecting the public – and the industry – by ensuring that Canadian products are safe and that sensitive technologies do not fall into the hands of hostile states or interests.
- Improving labour market efficiency by supporting vibrant academic institutions that understand the needs of industry and by facilitating recruitment of talent from abroad where serious domestic skills shortages exist.
- Levelling the global playing field for Canadian companies by negotiating equitable rules of the game, ensuring that these rules are respected in practice, and providing companies with information about foreign markets.
- Providing financing to support the purchase of Canadian products, as long as the terms of such financing produce a benefit to taxpayers and the economy, and fall within the bounds of international agreements.

Though the role of government must have clear limits, there has been historical recognition in Canada that space-related public investments are essential for the achievement of fundamental imperatives of nationhood, including guarding the country's borders and coastlines, raising its global standing, linking together and serving a small population spread across a huge land mass, spurring economic growth, protecting the environment, advancing the development of new technologies, and pushing the boundaries of knowledge.

Those imperatives will become more relevant than ever in the coming decades – and will severely test any constraint of "fiscal neutrality." While success over the next few years does not require a huge infusion of additional public resources, we are approaching a time when unlocking Canada's full potential will require major investments in space infrastructure.

For now, clarity of purpose and concrete action plans – supported by a robust governance and management framework, smart public procurements, and a focus on developing technological and commercial capacity – can go a long way toward keeping Canada among the global leaders in space.

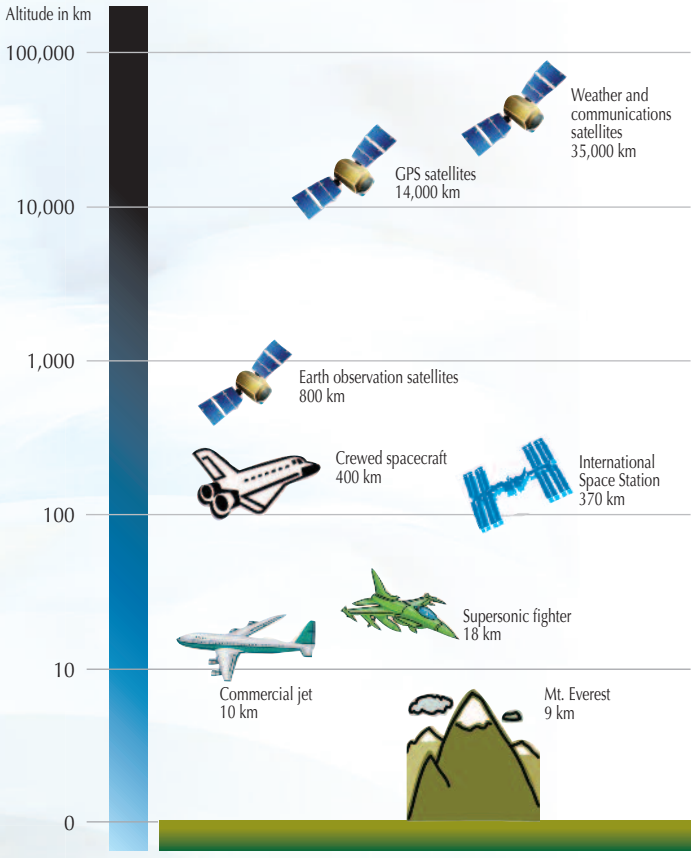
Context

Chapter 2.1
Why space?

In the popular imagination, "space" is most commonly associated with bold historical accomplishments and technological breakthroughs, from the Soviet success with Sputnik in 1957 to Neil Armstrong's first step on the moon; from the construction of the International Space Station to the rover Curiosity analyzing the surface of Mars; from the Canadarm at work to the startling pictures of distant galaxies captured by the Hubble telescope. Space is indeed a theatre of exploration and discovery, but at the most practical level, it is simply a domain like air, land, and sea where we place equipment to deliver services that could not be efficiently provided in any other way.

Space is typically deemed to begin around 100 kilometres above the planet's surface. By comparison, a commercial aircraft rarely flies higher than 12 kilometres.

Figure 1: Typical altitudes of space assets and aircraft



GPS = Global Positioning System

The things humans do in space fall into three categories.

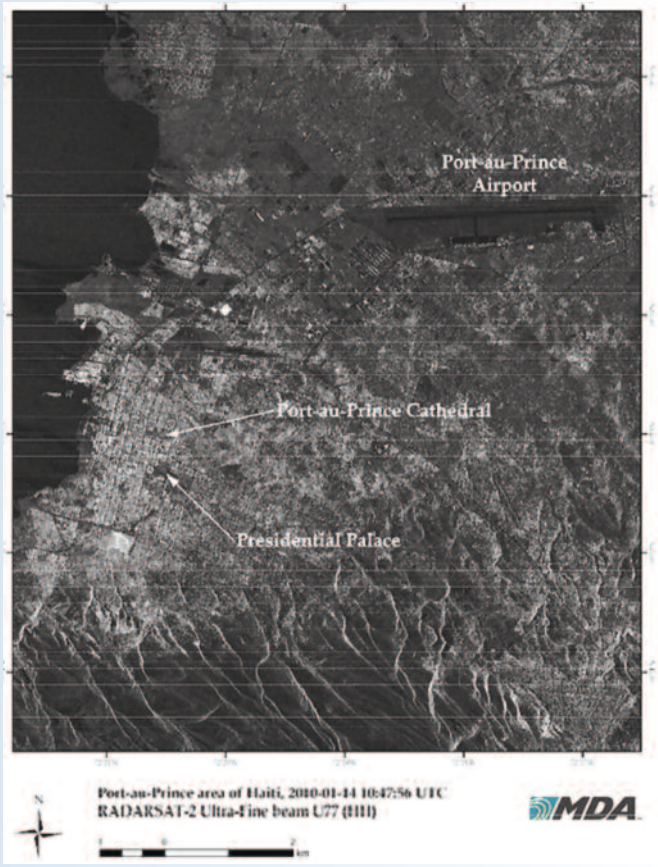
The first is provision of public services using satellites and associated ground stations, which are usually purchased by governments, but may be largely designed, built, and operated by private companies. Satellites have become indispensable to modern nations. Although individual satellites can cost tens or hundreds of millions of dollars, they are the cheapest – and sometimes only – way of delivering a wide and ever-growing range of services. Among their many applications, they allow us to:

- track and predict the weather;
- find natural resources and monitor how they are extracted and harvested;
- monitor the effects of climate change;
- increase agricultural yields;
- respond quickly to natural disasters and other emergencies;
- communicate with, and provide education and health services to, isolated communities;
- identify hostile attempts to penetrate our coasts and borders; and
- operate drones and support military deployments around the globe.

The use of satellite imagery for disaster relief

Canada's RADARSAT-2 satellite can collect imagery despite darkness and inclement atmospheric conditions, which is particularly valuable in the event of earthquakes, floods, landslides, or other natural disasters. Imagery taken before and after a natural disaster can be compared to determine the areas that have been hit hardest, and find passable routes for aid workers and safe locations for medical facilities and shelters.

Following the January 12, 2010, earthquake in Haiti, imagery from the RADARSAT-2 satellite was used to assess the extent of the damage and direct relief efforts effectively. Canada provided the imagery pursuant to the International Charter on Space and Major Disasters, an international program that harnesses space data in support of disaster recovery and reconstruction efforts.



The first imagery covering the main stricken areas of Port-au-Prince, January 14, 2010.

Source: Satnews Daily, "MacDonald, Dettwiler and Associates – RADARSAT-2's contribution to Haitian imagery," January 21, 2010.

Satellite applications

The Canada Centre for Remote Sensing (CCRS), along with federal and provincial regulators and the Canadian Space Agency, is developing a new technology using imagery from RADARSAT-2 to monitor land deformation caused by underground mining of Canada's oil sands, which can endanger workers and damage operating facilities. The CCRS technology will enable oil sand developers to identify problem areas and take measures to prevent accidents.

The CCRS is also developing an automated system for monitoring the environmental impacts of oil sand infrastructure development using multi-sensor, fine-resolution satellite imagery. This technology will allow for better assessment of impacts on the environment, and, in turn, ensure that regulations to control adverse effects are well-designed.

Farther north, the Canadian Ice Service at Environment Canada analyzes more than 7,000 RADARSAT-1 images per year to ensure navigation in ice-covered waters is safe, efficient, and sustainable. The use of satellite imaging resulted in cost savings of about $7.7 million annually in the first five years, through the elimination of extensive aircraft reconnaissance. RADARSAT-1 monitoring is unaffected by weather conditions and provides observations over a wider geographical area than was possible with aircraft. The newer RADARSAT-2 satellite allows for even finer discrimination of ice features.

The second category is the use of satellites and ground stations to provide services for which there is a commercial market, such as the delivery of telecommunications, information, and entertainment, and the collection of raw data that are then processed into popular applications such as Google Earth and the Global Positioning System (GPS). With respect to such business activity, the role of governments relates mainly to regulatory oversight and securing orbital slots for private companies' satellites.

The third category of space activity is space exploration and science, which focuses primarily on satisfying our thirst and need for fundamental knowledge. The inspiring feats of astronauts, missions to the moon and other planets, space labs, and deep-space telescopes expand our understanding of the universe and our place in it. They are wellsprings of national pride and prestige, and generate technological and economic spinoffs. Such activities are almost always government-funded and, given their scale and complexity, usually carried out through international cooperation.

Space technologies at work on Earth

Canada's investment in space technologies, such as the Canadarm, has yielded technological advancements in other sectors, notably health and mining.

The neuroArm, a direct spinoff from the Canadarm technologies, has revolutionized neurosurgery and other branches of operative medicine by liberating them from the constraints of the human hand and the operating environment. The neuroArm was developed in a partnership between the University of Calgary, the National Research Council, and MacDonald, Dettwiler and Associates (MDA). More than 50 neurosurgeries have been successfully performed with this technology since 2008 and a commercial version is being developed for international sales. Similar technologies are under way for breast cancer detection and treatment, as well as paediatric care.

Using space-based technologies, workers in the mining industry can now remotely operate heavy equipment above and below ground, and use robotics to prepare mines for drilling or blasting in dangerous areas with unstable rock. Penguin Automated Systems of Sudbury, for example, developed robotic vehicles to survey Xstrata Nickel's Montcalm Mine, which closed in March 2009 after a major ground collapse. Equipped with robotic arms derived from Canadarm technologies, these vehicles allowed Xstrata to survey the mine and determine whether operations could safely resume. In a further application, mining robots developed by Penguin were used to aid in excavation efforts following the Elliot Lake mall collapse in Ontario in June 2012.

Sources: MDA; Penguin Automated Systems; *Sudbury Mining Solutions Journal*, "Penguin ASI robots assess Montcalm instability," December 1, 2010; *Northern Ontario Business*, "Sudbury-born mine tech assists in Elliot Lake mall excavation," July 17, 2012.

The significance of space will only increase as technological advances expand the number of space-based applications and reduce costs. Space activities have become critical for developing strong economies, weaving the fabric of societies, and protecting national security and sovereignty. That is why so many countries are endeavouring to secure a position in space. Canada was a pioneer in this regard, quick to recognize the potential and value of space for its national interest.

"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."

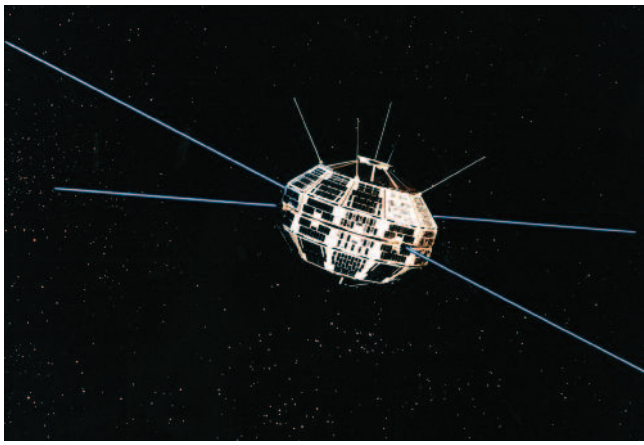
Final Report of the Space Working Group, September 2012.

Chapter 2.2
Canada in space

Humanity has been reaching into space for 55 years, since Sputnik first circled the globe. Canada has been there for 50. With the launch of the Alouette-I satellite on September 29, 1962, Canada became the third nation to have a domestically built satellite in space. While the United States and Soviet Union pursued a space race fuelled by geopolitical rivalry, Canada was motivated by the astute insight that satellites could play a critical role in linking together and developing a vast and sparsely populated country.

That insight is more relevant than ever.

Alouette-I



Launched on September 29, 1962, the Alouette-I scientific satellite marked Canada's entry into the space age.
Source: Canadian Space Agency.

As Alouette-I began to orbit the Earth, Prime Minister John Diefenbaker praised the scientific achievement of the engineers and workers who had designed and built the satellite, emphasized the peaceful and practical uses to which Alouette would be put, and underscored the cross-border collaboration – with the United States providing launch services for the Canadian asset – that had allowed the project to succeed. These elements – scientific progress, practical applications, and international cooperation – have remained building blocks of Canada's space program ever since.

Alouette-I was designed to gather information and perform research for improving communications between northern and southern Canada. It was followed by successors Alouette-II in 1965, ISIS I in 1969, and ISIS II in 1971. These satellites paved the way for the launch of Anik A1 in 1972, which made Canada the first country to have a domestic satellite communications system, and Hermes in 1976. Hermes was the most powerful communications satellite in existence at the time, and was the first to beam television signals directly to homes equipped with small antennae, provide emergency medical services in remote areas through telemedicine, and facilitate teleconferencing. Hermes' impact on communications in Canada's North was especially significant, as it gave citizens there the same access to telephone and television as that enjoyed by their counterparts in the rest of Canada.

Alongside communications, Earth observation was an early focus for Canada's efforts in space. Canada's first activity in this area was provision of a receiving and processing ground station for the early versions of the U.S. Landsat satellites, which allowed Canadian industry to become leaders in satellite data processing and applications development. Later, Canada developed radar-based Earth observation technology tailored to its specific needs – observing and monitoring vast landscapes and ice-laden waterways during long, dark, and cloudy northern winters – leading to the launch of RADARSAT-1 in 1995 and RADARSAT-2 in 2007. These radar satellites are among the most sophisticated in the world and provide detailed ground images day or night, under any weather conditions.

Canada's collaboration with the United States on space ventures deepened over the years. In the 1960s, Canada's Héroux Inc. produced the landing gear for the Apollo program's lunar modules. And in the 1970s, the National Research Council (NRC) in partnership with Spar Aerospace (later purchased by MacDonald, Dettwiler and Associates) designed and manufactured the iconic Canadarm, a robotic manipulator that eventually equipped all American space shuttles and led to Canada's robotic contributions to the International Space Station: the Canadarm2 in 2001 and the servicing space manipulator, Dextre, in 2008.

On the science and research front, Canada launched the small satellites SCISAT and MOST in 2003, the former to monitor the thinning of the ozone layer and the latter to provide astronomical observations. Canadian firms – especially COM DEV – have also provided scientific instrumentation for American, Japanese, Swedish, and European satellites.

The Government of Canada and the National Aeronautics and Space Administration jointly won an Emmy Award in 1987 for their role in developing the Ku band satellite technology through the Hermes program. Communications Minister at the time, Flora MacDonald, accepted the Award, describing the Hermes satellite as "one of the most important milestones in Canadian space history."

Source: Communications Research Centre Canada.

Canada's participation in the International Space Station

Along with the United States, Russia, Europe, and Japan, Canada is a partner in the International Space Station (ISS), a unique, orbiting research laboratory. Canada's investment in the ISS provides Canadian scientists with access to the ISS to conduct research for the benefit of Canadians.

Since the first module of the ISS was launched in 1998, the ISS has circled the globe 16 times per day at 28,000 km/h at an altitude of about 370 km, covering a distance equivalent to the moon and back daily. The ISS is as long as a football field, and has as much living space as a five-bedroom house.

The Mobile Servicing System (MSS) – a sophisticated robotics suite that assembled the ISS in space, module by module – is a critical aspect of Canada's contribution to the ISS. Developed for the Canadian Space Agency by MacDonald, Dettwiler and Associates in Brampton, Ontario, the MSS comprises the following:

- *Canadarm2, a 17-metre-long robotic arm, which has played a crucial role in the assembly and maintenance of the ISS;*
- *Dextre, the ISS's two-armed robotic "handyman," which astronauts and cosmonauts can use to manipulate delicate objects and remove or replace components of the ISS; and*
- *the Mobile Base, a moveable work platform and storage facility.*

Finally, Canada has sent astronauts into space more often than any country except the United States and Russia, in part in recognition of its important contribution to the space shuttle program and the International Space Station. Canadian astronaut Chris Hadfield, the first Canadian to walk in space, will also be the first Canadian commander of the International Space Station in late 2012.

International Space Station

Source: Canadian Space Agency.

Canada's public space program has always involved commercial expertise and collaboration. Early satellites were sponsored and designed by federal departments, but mostly assembled by private companies. The first telecommunications satellites were operated by a private-public partnership, Telesat Canada, which was fully privatized in 1993 and has since become a global leader in the provision of satellite communications services. The development of satellite data processing and applications to meet government mapping and surveying needs was led by the private sector, as was the later development of radar satellites. And, of course, the robotic systems that Canada contributed to the space shuttle and the International Space Station were arranged and funded by the government but designed and built by industry.

Symbolic importance of space to Canadians

An Ipsos-Reid survey, reported by the CBC in June 2008, found that the Canadarm was viewed as the top Canadian accomplishment of all time, ahead of universal health care, insulin, and the telephone.

By 2013, the Canadarm2 and Dextre will be featured on five-dollar bills, along with other themes emblematic of Canadian identity and achievement, such as innovation in medicine and the linking of the eastern and western frontiers by rail.

In January 2011, Canada Post issued a set of five stamps celebrating Canadian pride, including one depicting the Canadarm.

In April 2006, the Royal Canadian Mint issued a commemorative coin depicting the Canadarm and Canadian astronaut Colonel Chris Hadfield.

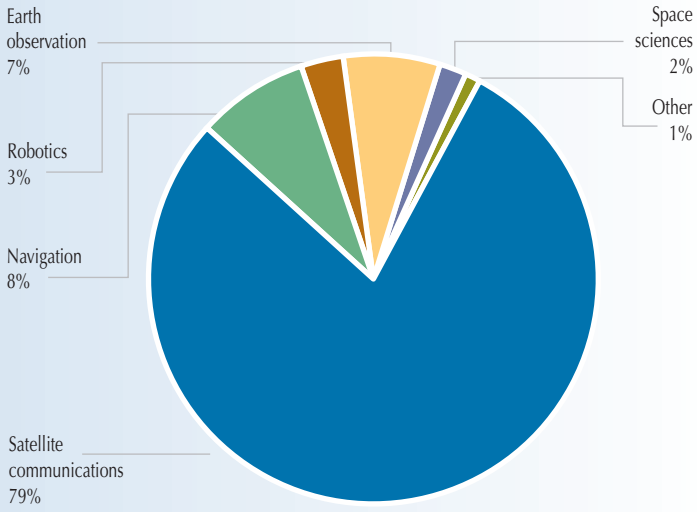
Canadarm2 and Dextre

Canadarm2 (left) and Dextre (right), the Canadian robotic handyman, on December 26, 2010.
Source: National Aeronautics and Space Administration (NASA).

Canada's space program, then, has been a primary driver for the creation of a $3.4 billion indigenous space industry that now employs some 8,000 workers across Canada. Eighty per cent of the industry's revenue comes from satellite communications services, and half from sales abroad – primarily to the United States and Europe – making Canada's space sector one of the most export-oriented in the world.

Figure 2: Canadian space revenues by sub-sector – 2010

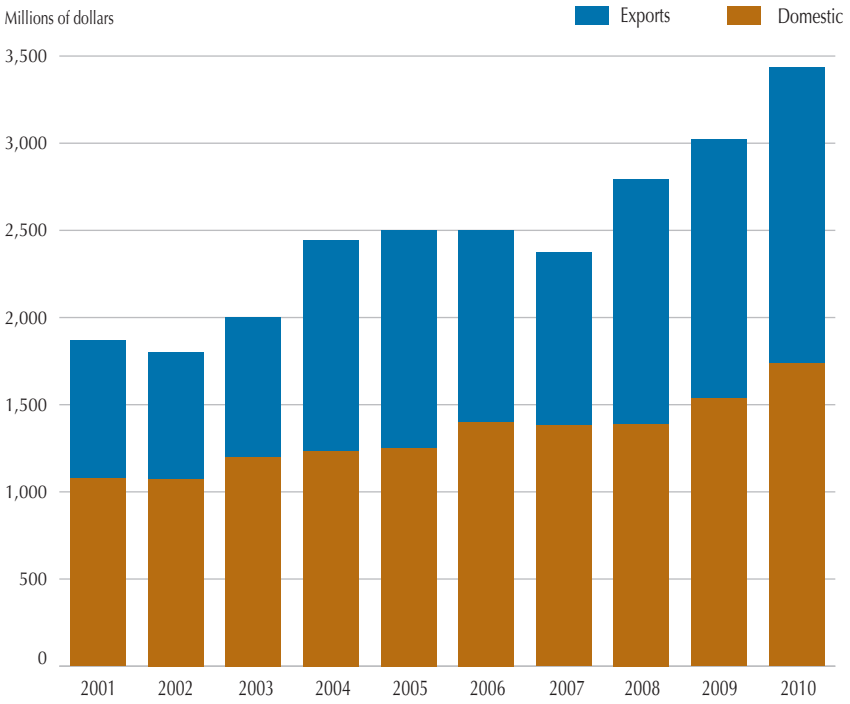
- *Satellite communications services include voice, data, television, and radio telecommunications services.*
- *Global navigation satellite systems provide positioning, navigation guidance, and timing information to users with the appropriate receivers.*
- *Earth-observation satellites are used to monitor and protect the environment, manage natural resources, and ensure safety and security.*
- *Space robotics equipment is used to support manned and unmanned activities in space, such as terrain exploration and the retrieval, inspection, and repair of satellites.*
- *Canadian scientists and companies have been involved in a number of satellite missions that have space sciences objectives related to space weather, astronomy, and environmental science, advancing Canada's space technology capabilities.*



Source: Canadian Space Agency, *State of the Canadian Space Sector 2010.*

Text adapted from: Hickling Arthurs Low, *The State of the Canadian Space Sector*, August 2012. Research report commissioned by the Aerospace Review.

Figure 3: Revenues of the Canadian space sector – 2001 to 2010



Source: Canadian Space Agency, *State of the Canadian Space Sector 2010.*

The Canadian space industry is highly concentrated, with the 10 largest firms accounting for almost 90 per cent of total revenues, relatively few mid-sized companies, and about 200 smaller players. A signature strength of the industry has been its ability to establish niche areas of global technological leadership, often by leveraging innovations developed through government programs.

Canada's space program is led by the Canadian Space Agency (CSA), which was established in 1989 with a legislated mandate "to promote the peaceful use and development of space, to advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits for Canadians."[3] The CSA's annual budget in 2011-12 was $425 million, of which approximately one-third was temporary funding related to Canada's Economic Action Plan and specific projects.

Government departments that are major users of space include National Defence, Environment, Natural Resources, Agriculture and Agri-Food, Fisheries and Oceans, and Aboriginal Affairs and Northern Development. The government also funds two public research institutions – the NRC, and Defence Research and Development Canada – whose mandates include space-related activities.

Finally, a number of academic institutions are involved in space research and education. These institutions help ensure that Canada is able to nurture the minds that will imagine, design, and manufacture the advanced technologies needed to meet the country's future needs in space.

This array of institutions and companies has been both a cause and effect of Canada's half-century of success in space, and gives the country a solid foundation for securing and strengthening its position at a time when space assets are becoming ever more important to our long-term prosperity and security. But at a time when the number of space-faring nations is expanding rapidly and competition is stiffer than ever, Canada's space-related policies and programs lack clarity, focus, and managerial rigour.

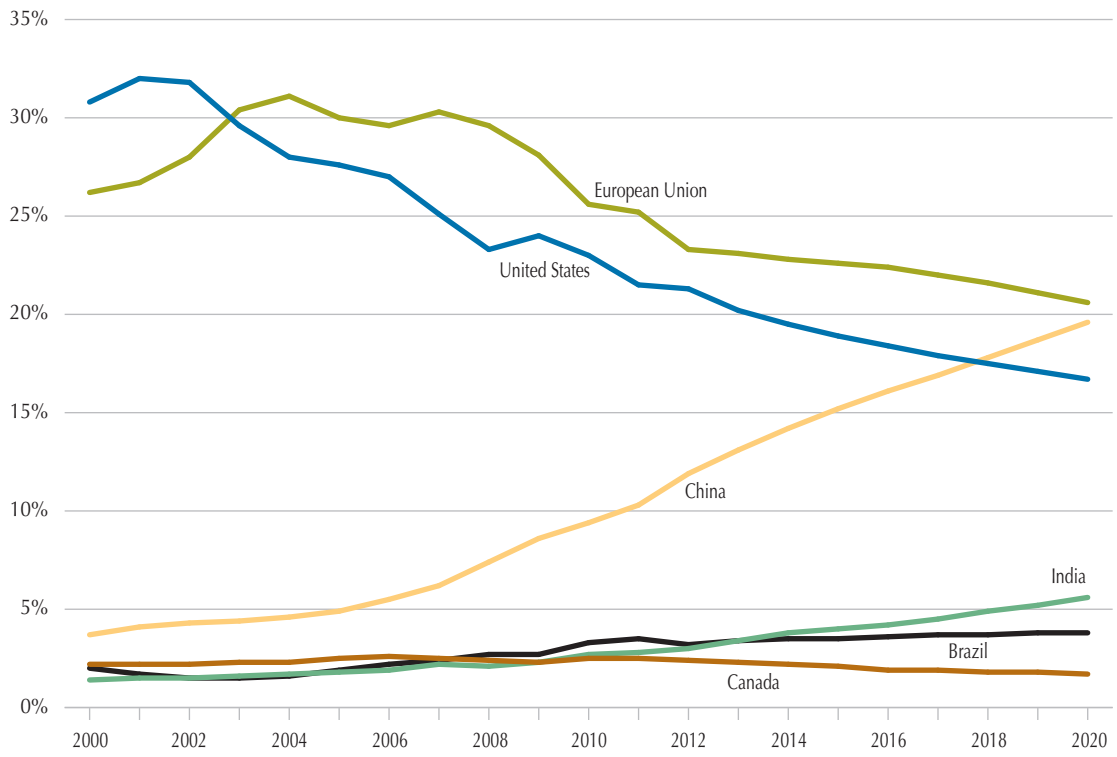
3 *Canadian Space Agency Act*, section 4. **http://laws-lois.justice.gc.ca/eng/acts/C-23.2/index.html**

Chapter 2.3
Global trends

The space sector, like the aerospace sector, is profoundly affected by the following changes in global conditions:

- *Global rebalancing*. We are witnessing a rapid rise in the economic and geopolitical power of regions and countries other than those that dominated during the second half of the 20th century. North America, Europe, and Japan are being joined by China, Russia, Brazil, India, and other rising powers across Asia, the Middle East, Latin America, and Africa. Many of these countries are populous, geographically large, geopolitically ambitious, and willing to use state power and resources to build sectors considered to have strategic importance.

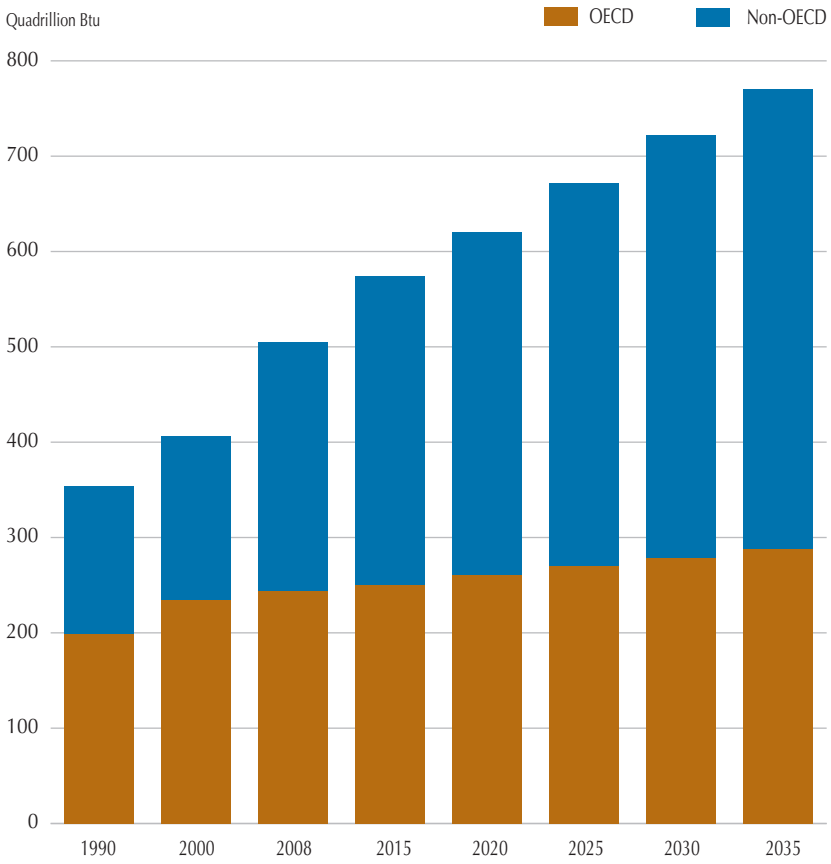
Figure 4: Share of world GDP – 2000 to 2020



Source: IHS Global Insight.
GDP = gross domestic product

- *The hunger for natural resources and agricultural production.* As hundreds of millions of people move from a rural, subsistence existence to more urban, middle-class lifestyles, there are significant increases in the demand for fuel, the raw materials from which consumer goods are manufactured, water, and food.
- *Climate change and environmental concerns.* As the day-to-day effects of climate change are felt, and as potential environmental impacts related to economic development and resource extraction gain visibility, citizens and political leaders are seeking effective means of monitoring developments and designing responses to them.

Figure 5: World energy consumption – 1990 to 2035



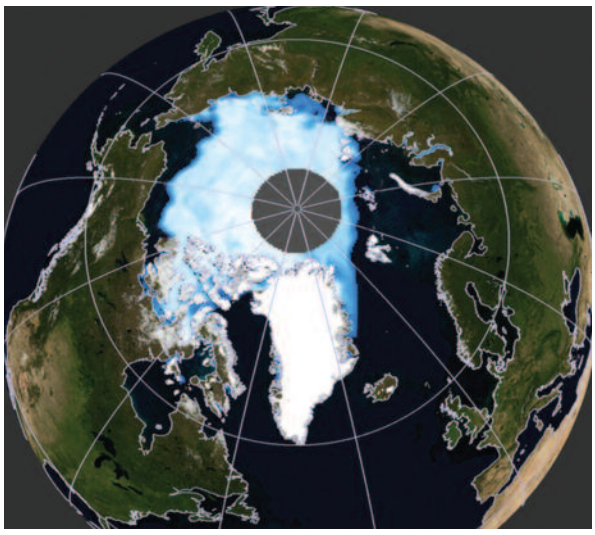
Source: U.S. Energy Information Administration.

OECD = Organisation for Economic Co-operation and Development

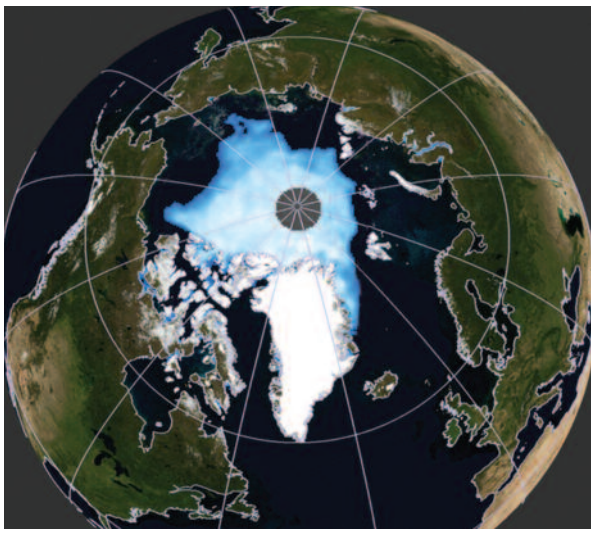
Decrease in Arctic sea ice, 1979 and 2011

Sea ice extent

September 1979 (7.2 million km^2)



September 2011 (4.6 million km^2)



Source: Adapted from an image by Matt Savoie, National Snow and Ice Data Center, University of Colorado, Boulder, using SSM/I data overlaid onto the NASA Blue Marble.

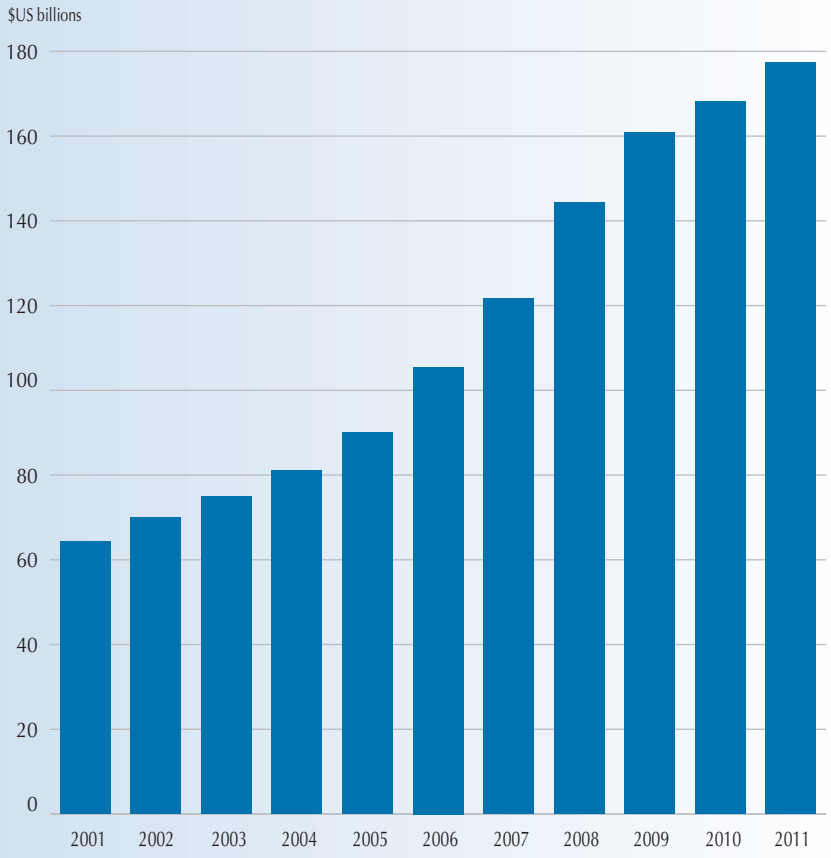
- *The decline in military expenditures and advent of non-conventional security threats.* In a climate of fiscal restraint, Western countries are reducing defence budgets while national security planners focus increasingly on managing non-conventional threats as well as the risks of traditional war.
- *The digital revolution.* We are in the middle of an epochal communications transformation driven by exponential increases in computing power, the advent of wireless technology, and an explosion of social media. The economic, social, and political impacts are already profound – and they are just beginning.
- *An aging population.* Shifting demographics are creating new challenges – and necessitating new strategies – for companies that rely on a highly educated, highly skilled workforce.

These general trends underpin and will continue to shape developments in the global space business. Perhaps most significant is the rapidly expanding use of space for civil purposes. As a result of technological advances – in particular, the increasing precision of satellite-based observation – and rising demand in both developed and emerging countries for natural resources, food, water, environmental oversight, and broadband telecommunications, the civil space economy continues to grow. Satellites and space-based applications have become essential tools for governments and private companies to satisfy this demand.

Figure 6: Global revenues of the satellite industry – 2001 to 2011

"Global satellite industry revenues grew by 175% for the period from 2001 through 2011, an average of 10.7% growth per year."

Satellite Industry Association, *State of the Satellite Industry Report: September 2012.*

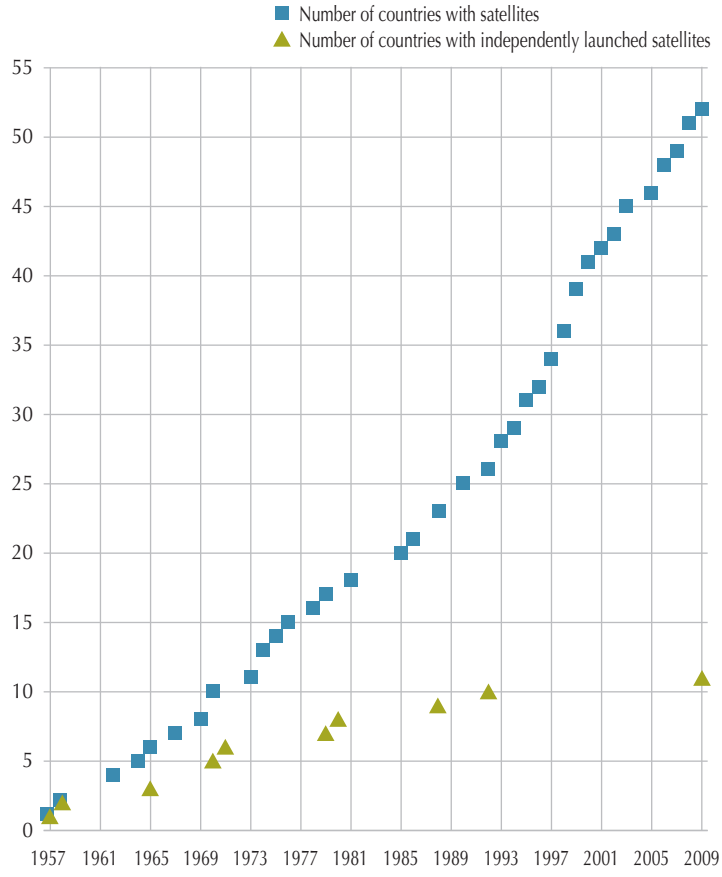


Source: Satellite Industry Association.

A similar set of factors is contributing to the expanding use of space for military purposes. Satellites have become critical hardware in the arsenals of modern armed forces, particularly in the face of unconventional threats from small, secretive, militant groups. Satellites are used, for example, to gather intelligence through high-resolution ground observation and signals surveillance, to monitor borders and sovereign waters, to operate drones over unfriendly territory, and to support far-flung military deployments.

> *"Surveillance satellites are used on a daily basis for military planning and intelligence. The military operation against Osama Bin Laden in 2011 is a prime example of how these space assets are used. After the [Central Intelligence Agency] and U.S. military determined the potential location of Osama Bin Laden's compound in Abbottabad, Pakistan, satellite images were used to create a detailed map from above. The map was likely developed using assets belonging to the National Geospatial-Intelligence Agency, though a number of military and commercial satellites may have also provided relevant mapping data. This information included not only visible spectrum images, like those commonly seen on Google Earth, but also imagery in a variety of wavelengths. Using satellite imagery of the target over time can show the development of the site. In the case of the Bin Laden compound, images show an empty lot in 2001, a new building in 2005, and an expanded compound in 2011. When the operation was actually carried out, secure satellite communications were essential to connecting warfighters in the field with experts directing the operation."*
>
> Space Foundation, *The Space Report: The Authoritative Guide to Global Space Activity*, 2012, p. 25.

Figure 7: Number of countries with satellites (launched independently or via a third party) – 1957 to 2009



Source: Organisation for Economic Co-operation and Development, *The Space Economy at a Glance 2011*.
Note: Data points are provided only for years in which an increase took place.

The expanding range of space-based applications – and the drive for national prestige and geopolitical leverage – is producing an influx of new sovereign players. Globally, government expenditures on space have increased, even as the world's largest space agency, the National Aeronautics and Space Administration (NASA), has had to cut spending. Russia is investing billions in revitalizing its space program. China is spending billions to turn itself into a major space power. The United Kingdom, Japan, and Brazil have re-engineered the governance of their space programs to advance national priorities. And dozens of other countries – among them, Israel, India, Iran, South Korea, Indonesia, Ukraine, Turkey, and Australia – have launched their own satellites or created national space programs where none existed.

Accompanying the growth in the number of nations in space has been an appetite for international cooperation. Collaboration allows participating countries to share the substantial risks, costs, and benefits of developing, manufacturing, and operating space assets, whether for the delivery of public services or for exploration and science. Collaborative efforts are also driven by the need to manage an increasingly congested operational space environment.

The number of satellite-based applications used to deliver public services and support military operations means that most space activity is still funded by government budgets. Nevertheless, a key trend in the global space sector is the growth of private sector activity. The construction and operation of satellites for telecommunications purposes have long been commercially viable. Recent years, however, have witnessed an increase in the number of satellite-based applications for which private companies and citizens are willing to pay – notably in the areas of remote sensing, mapping, and navigation – and the development of small satellites that substantially lower the cost of entry into space for private businesses.

" "Commercial Space" … refers to a paradigm that is gaining significant traction in both the US and internationally. Frequently also referred to as "NewSpace", it refers to the broadening of space-based businesses and industries beyond the traditional sphere of government space activities to develop significantly lower cost spaceflight technologies and open new markets that capitalize on the significant opportunities afforded by spaceflight. Accompanying this new trend is a rapidly growing community of relatively new, small to medium-sized aerospace companies working to minimize their overhead and streamline their business to achieve a large reduction in the cost of technologies for accessing and operating in space, and advocating progressive policies to facilitate the growth of the industry.

"… Commercial space or NewSpace refers not necessarily to new technologies, but rather to new applications, new markets, and non-traditional ways of funding and conducting space activities, and to the rise of a large number of small companies seeking to competitively pursue these activities."

Canadian Space Commerce Association, *Fostering Innovation, Creating New Markets: Novel Approaches to Space Policy and Programs*, submission to the Aerospace Review.

This period has also seen the establishment of private sector launch companies – in part in response to NASA's push to outsource the delivery of crew and cargo to low Earth orbit – and the emergence of investors ready to dabble in space tourism and space mining. Alongside their move into for-profit space activities, private companies are increasingly commercializing technologies developed for space through non-space applications in areas such as natural resource management and medicine.

These trends underscore the growing importance of space activity, and hint at the challenges and opportunities facing Canada.

Chapter 2.4
Opportunities and challenges

The space sector is entering a period of tremendous dynamism, and the next 20 to 30 years will present both the private sector and government with a range of opportunities to advance national security, resource development, and a broad range of public and private services using space assets, technologies, and applications.

Among the most important of the opportunities is the role satellites and associated ground infrastructure can play in propelling and managing the opening of the North. Satellites will facilitate the identification of mineral deposits; help us monitor the impacts of mines and oil and gas wells; allow us to better apply environmental standards and to monitor and understand the pace and effects of climate change; permit safer navigation through northern sea and air routes; and support the delivery of education, health, and emergency response services to small, dispersed northern communities, whether they have been there for centuries or are established in response to new economic activity.

> *"In light of the effects of global warming on the Arctic climate and the associated sovereignty issues, expected boom in resource exploration and development, increased maritime traffic, and socio-economic development needs of the North, a clear and compelling argument can be made that investment in the space sector is a cost-effective solution to the needed infrastructures that will contribute to positive developmental outcomes.*
>
> *"In some instances, the business case for those investments will appeal to and be embraced by industry. These generally relate to the direct support of resource exploration and development in the North, and in support of secondary industries including transportation and logistics…*
>
> *"However, in other cases, the sparse population of the North or current public policy makes pure commercial investment in space infrastructure uneconomical. Examples include large private investments in telecommunications infrastructure in the North instead of more lucrative, populous regions; or in building weather forecasting infrastructure when weather forecasts are provided for free to the general public… The responsible development and protection of Canada's North is not just a short-term development need, but rather…long-term, highly strategic and vitally important… "*
>
> Norstrat Consulting, *Canada's Space Sector: The Essential Enabler of Canada's Northern Strategy*, July 2012. Research report commissioned by the Aerospace Review.

Through a vigorous presence in the North, using satellites as a key instrument of policy, Canada will be able to accelerate wealth creation, protect the environment, and assert its sovereignty. Given the intensification of multiple, conflicting national claims in the Arctic, both international law and pragmatic geopolitics demand that Canada be active in the region if it wants to secure its interests there.

"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 land mass. Protecting and managing such an enormous zone is a major challenge. Seventy-five percent of our population lives within 160 km of the U.S. border, leaving the majority of our land mass scarcely populated and difficult to access. We are an Arctic nation with a northern territory that comprises more than 40% of our total land mass. 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 … 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."

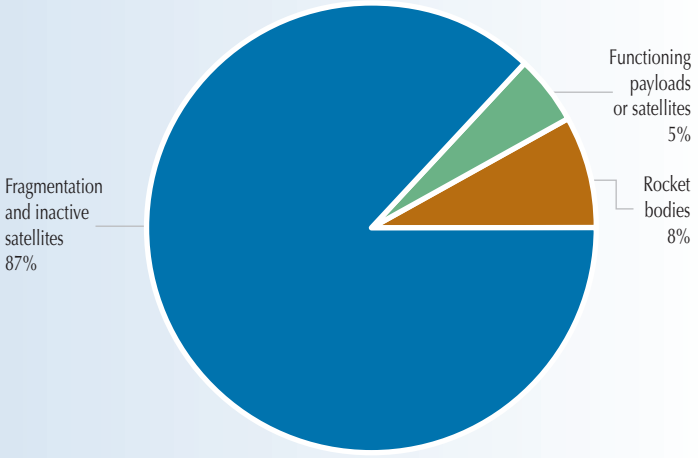
Final Report of the Space Working Group, September 2012.

Beyond the North, the designers, manufacturers, and operators of satellites, satellite components, ground stations, and data processing services have the opportunity to meet rising demand in areas as diverse as precision farming that optimizes the use of equipment, irrigation, and fertilizers; transportation and urban planning; meteorology; and the delivery of information, entertainment, and many other applications to a constantly expanding customer base.

Finally, there is an emerging set of opportunities that are a by-product of the dramatic expansion in the use of space. There is, for example, an increasing interest in extending the lifespan of functioning satellites through refuelling and maintenance missions. And as more and more countries and companies put assets in space, there is a growing recognition of the need to track space debris and reduce the congestion caused by defunct space assets. This protects operational satellites and makes room for new

Figure 8: Status of man-made objects in orbit – 2012

Only a very small proportion of the man-made objects in orbit represent operational satellites or spacecraft. The rest – including fragments of destroyed equipment, spent booster rockets, and inactive satellites – is considered debris. Since these objects circle the Earth at almost 30,000 kilometres per hour, any collision with satellites or manned spacecraft can be catastrophic. Space-faring nations recognize the challenges posed by rising amounts of orbital debris and are actively discussing remediation strategies, notably through the 11-nation Inter-Agency Space Debris Coordination Committee, of which Canada is a member.



Source: Joint Space Operations Center (JSpOC) of the U.S. Space Surveillance Network. Data as of May 2012.

Includes objects that are 10 centimetres and larger – about 22,000 in all.

Removing debris and inactive satellites requires both an accurate identification of objects in orbit and a capacity to gather them for proper disposal. Regarding the former, Canada is preparing to launch its first military satellite, called Sapphire, which will provide timely tracking of objects in space. For the latter, Canada possesses world-renowned expertise on space robotics that can be mobilized to develop equipment to retrieve space objects.

assets to be placed in orbit without a major risk of being damaged or disabled by other floating objects. Even healthy space assets will need to be carefully managed and coordinated in the increasingly crowded global commons that is near-Earth space.

Reflecting the transformational opportunities emerging in space-related technologies and applications, substantial growth is taking place in both global public spending on space activities and the commercial space industry. Neither market should be ignored.

The Canadian space industry is well-positioned to profit from these opportunities. One of the sector's comparative advantages is its proficiency with respect to a number of niche technologies, each of which is relevant in its own way to the constellation of emerging demands:

- *Satellite communications* are essential to satisfying consumers' demand for broadband communications and information services, and government requirements related to service provision and military deployments.
- *Space robotics* will continue to be critical for publicly funded exploration and science missions, as well as initiatives to deal with space congestion and to extend the operations of existing assets.
- *Radar-based Earth observation and optical instrumentation* will both be increasingly important in the context of natural resource management, environmental monitoring, and intelligence gathering.
- *Small satellites* are more and more attractive to governments and private companies as a way of carrying out key activities in space with lower costs and shorter timelines than larger satellites.

In addition, the fact that Canada is a global leader in mining techniques positions Canadian firms to participate in potential long-term initiatives to mine in space and to use space assets to further resource extraction on Earth. While mining rare minerals in space remains largely speculative, it is attracting private investor interest and, in another quarter or half century, could conceivably become lucrative. Meanwhile, the number of space-based applications that facilitate mining and other natural resource activities on Earth is multiplying rapidly.

> *"Increasingly, complex data and communications services requirements are being met with nimble, low-cost, small and micro-satellite systems. The proliferation of small satellite solutions is evidence of this trend throughout the world and many are real success stories ... Other advantages of pursuing a greater number of smaller missions are:*
>
> - *Affordability, making it possible to distribute mission activities to a larger number of Canadian stakeholders; both to industry and academia*
> - *More spending goes to technology development that contributes to the creation of new niche capabilities for export markets*
> - *Risk is spread over a broader portfolio"*
>
> COM DEV International, *Aerospace Review: COM DEV's Recommendation for a Guiding Framework for Canadian Investments in Space*, submission to the Aerospace Review.

Canada's geography also has benefits for its space sector. In part, this is because the country's vastness and northern location require, and therefore stimulate, satellite-based technological solutions that can be sold internationally and often put to other uses. But it is also because the North is an ideal location for ground stations, given that most Earth observation satellites are in polar orbits and pass over the Canadian Arctic on every orbit. This natural advantage can be leveraged both by companies seeking commercial gain and public agencies looking to enhance cooperation with other countries by having facilities that receive satellite data and can be used for command and control of satellites.

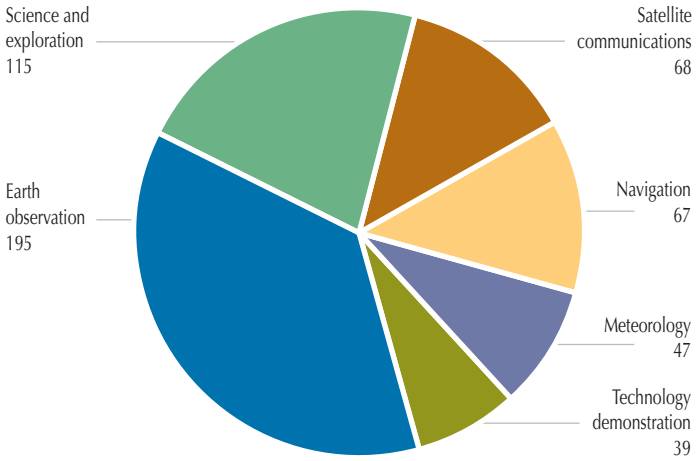
Finally, Canada's space sector has a strong set of global networks and a positive reputation built on a history of success. Consider, for example, the extensive "flight heritage" and export achievements of the industry; highly visible technologies such as the Canadarms, which serve as global advertisements for Canadian expertise; the country's participation in international space initiatives, cementing its reputation as an advanced and reliable

collaborator; the web of linkages the CSA has built with other space agencies, particularly NASA and the European Space Agency (ESA); Canada's highly successful astronaut program; and Canada's membership in the Arctic Council, whose members share common interests in the North and may be partners in joint space-based efforts.

Against these technological, geographic, and reputational strengths, the Canadian space sector has a number of challenges that, if left unaddressed, will likely compromise its ability to take advantage of opportunities and serve the country's needs.

Figure 9: Civilian satellites to be launched, by sub-sector – 2011 to 2020

Total civilian satellites to be launched: 531



Source: Euroconsult.

The first lies within government: inadequate clarity of purpose with respect to Canada's space program and its role in providing services and advancing national priorities. This lack of focus appears to go back at least a decade and has been manifested in weak planning, unstable budgets, and confusion about the respective roles of the CSA and those government departments that are major space users. In a sector whose undertakings are, by definition, long-term, expensive, and complex, it is especially important to have concrete goals, predictable funding, and orderly implementation.

The second challenge lies with the private sector: limited competition and, in some cases, excessive reliance on public spending. In part, this reflects the realities that the Canadian space market is too modest to support a large number of major players and that governments around the world remain major purchasers of space assets. As a result, Canadian firms have tended to specialize in and depend on government contracts. But it is also a function of approaches dating back to the early days of Canada's space program, when federal officials worked with Canadian companies to allocate activities related to space procurements. While it is important to be pragmatic about the scale of the industry and encourage collaboration, it is also necessary, as the sector matures internationally, for private firms to contend with the discipline of competition.

This brings us to a third challenge: the widespread interpretation of security-based exceptions from international trade rules as applying to space programs, which has allowed governments in countries with large space budgets and markets to give explicit preference to domestic companies. Such practices impede the ability of Canadian space companies to diversify their markets, but may be partially overcome through bilateral, government-to-government agreements. A related issue is export controls and legislated American restrictions on space collaboration with China, which can present Canadian companies with a difficult decision: continue to seek business in the United States, which remains the world's largest player in space and the Canadian industry's best customer, or try to access the rapidly growing market in China and elsewhere.

A final challenge is the lack of launch capacity in Canada, which means the CSA and Canadian firms must turn to other countries' launch systems to place satellites into orbit, a dependency that can result in delays, operational complications, and cost overruns. This issue may become more serious if the use of small satellites continues to grow at a rapid pace.

The opportunities and challenges facing the Canadian space sector offer guidance to the way forward.

Analysis and recommendations

Many of the recommendations in volume 1, the companion report on the aerospace sector, apply to the space sector as well. These include the following recommendations for the government:

- Expand the list of strategic sectors under the government's Science and Technology Strategy to include aerospace and space.
- Maintain Strategic Aerospace and Defence Initiative (SADI) funding at current levels – less reallocations recommended in the companion volume on the aerospace sector – and modify SADI's terms and conditions to make it a more effective program for stimulating the development of the aerospace and space technologies of the future.
- Co-fund a Canada-wide initiative to facilitate communication and collaboration among companies, researchers, and academics.
- Simplify and streamline application and reporting procedures for programs used by the industry, especially for smaller companies seeking modest levels of support, and use a "one-stop" internet portal to provide information on, and links to, those programs.
- Negotiate bilateral agreements with countries where potential market and partnership opportunities are likely to benefit Canada and the Canadian aerospace and space sectors.
- Review export and domestic control regimes to ensure that they are not unnecessarily restrictive and that export permits are issued expeditiously.
- Use federal programs – in collaboration with industry, academia, unions, and provinces – to promote science, technology, engineering, and mathematics studies generally, and aerospace and space careers specifically, among youth; to help college and university students acquire relevant expertise; to bridge new graduates into the aerospace and space workforces; and to bring skilled aerospace and space workers from abroad when efforts to develop labour supply in Canada do not keep up with demand.
- Develop mechanisms to support the efforts of companies to keep their workforces technologically adept and adaptable through continual up-skilling.
- Co-fund – with industry, provinces, and academic and research institutions – the purchase and maintenance of up-to-date infrastructure required for training and research purposes.

Details on the analysis underpinning these recommendations and suggested steps for implementing them can be found in volume 1. The rest of this report will focus on analysis and recommendations specific to the Canadian space sector.

Chapter 3.1
Establishing clear priorities and plans

Public programs related to space must be grounded in carefully considered priorities that reflect the needs and advice of a wide range of users and stakeholders, and are advanced through rigorous plans and stable funding.

Effective priority-setting and implementation are, of course, always necessary when governments make choices about the use of finite public resources – but they are doubly so when every project involves multiple players and requires a significant investment of time and resources, a unique design, a dedicated manufacturing process, and repeated, rigorous testing along the way. A lack of clear priorities and plans increases the chances that substantial public monies will be spent without realizing sufficient positive impacts on the national economy, security, and delivery of public services. In an area as important and complex as space, ad hocery is costly, inefficient, and counter-productive.

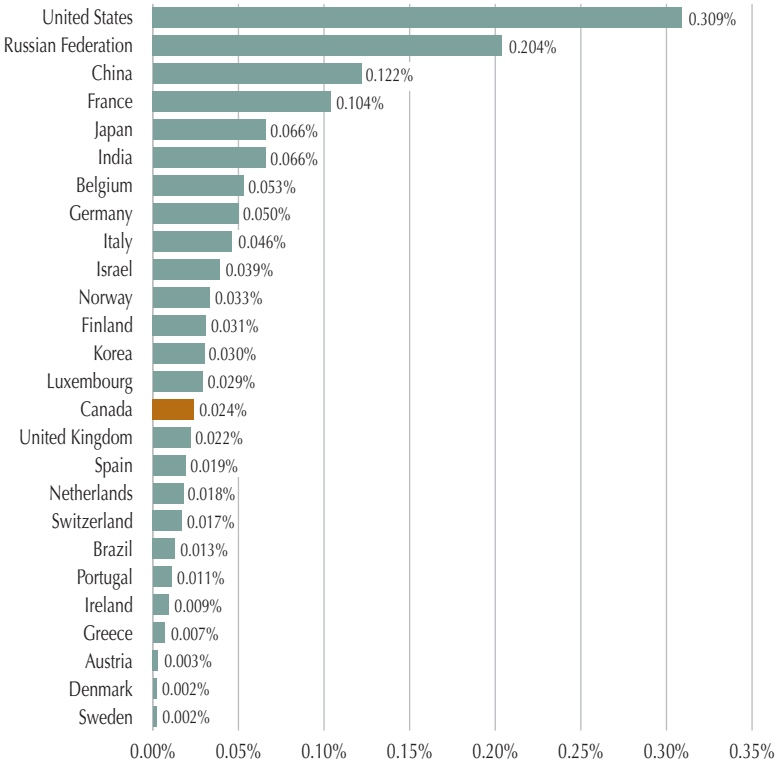
A clear sense of direction in the public space program is also important for the space industry, given that government remains the largest customer for space assets outside of commercial satellite communications. Companies need a reasonable level of predictability in their markets in order to make sound business decisions and properly deploy the substantial capital and resources involved.

> *"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 [research and development (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 …*
>
> *"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."*
>
> *Final Report of the Space Working Group,* September 2012.

For a number of countries with space programs comparable in size to Canada's, these considerations have led to revisions in governance arrangements for space-related activities. These changes have been designed to increase the involvement of the highest levels of government in setting overall program priorities, foster coordination across ministries, clarify the roles of national space agencies, and better engage the private sector. For example:

- The United Kingdom has established a space agency for the first time. The agency reports directly to the Minister of State for Universities and Science, and has overall responsibility for all of the country's publicly funded civil space activity. Government departments, research institutions, industry, and publicly funded non-governmental bodies with space-related activities sit on a Space Leadership Council that advises the Minister and agency on national space priorities.
- Japan has created a Cabinet-level committee, chaired by the Prime Minister and supported by a dedicated secretariat in its Cabinet office, with a mandate to establish national space-related priorities, coordinate space-related activities across government, and strengthen the role of the private sector in Japan's space program. The role of the country's space agency, JAXA, has been clarified as one of research, advice, and implementation, not policy-setting.
- Brazil has set up a national council for space policy at the ministerial level, chaired by the President, and has strengthened the mandate of its space agency to support the establishment of priorities for the country's space program and coordinate their implementation. Similar to the situation with Japan's JAXA, the role of Brazil's National Institute for Space Research has been focused on research and implementation.

Figure 10: Space budgets of selected OECD and non-OECD countries as a share of GDP – 2009



Source: OECD.

GDP = gross domestic product
OECD = Organisation for Economic Co-operation and Development

Although Canada's public space program has had many successes and is well-regarded internationally, the steps other countries have taken to elevate the priority of space, more clearly delineate responsibilities, and better manage across multiple programs and departments are instructive.

The reality is that over the last decade or so, while other players have modernized their space programs through national strategies and stronger governance, Canada's priorities have been ambiguous and implementation has been below the necessary standard. There is no over-arching articulation of what we want to do in space or how we want to do it. There is no clear mechanism to manage space activities across government. Individual projects such as the RADARSAT Constellation Mission have been announced, only to disappear from view and then reappear later. The CSA's budget has been reduced even as Canada has entered into new commitments, such as extending its participation in the

International Space Station until 2020. And Canada's lead with respect to key technologies like space robotics and optical instrumentation is being eroded, in part due to the greater determination other countries have brought to their space programs.

It is essential that there be a Canadian Space Program that is energized and focused through a clear sense of purpose, strong and consistent engagement of stakeholders, more rigorous planning and implementation, and stable funding.

Recommendation 1: Canadian Space Program priorities

Canada's space program will be most effective at promoting the national interest and providing services to Canadians if it is anchored in priorities set at the highest levels after appropriate consultation across government and with industry and researchers. In the main, these priorities should be stable, given that the development and deployment of a space asset is a multi-year process that requires sustained commitments of public and private resources.

It is recommended that the government explicitly recognize the importance of space technologies and capacity to national security, economic prosperity, and sustainable growth, and that the Minister of Industry bring 10-year, 5-year, and annual government-wide priorities for the Canadian Space Program to the Cabinet Committee on Priorities and Planning, which is chaired by the Prime Minister, for discussion and approval each spring.

These priorities should:

- be developed on the basis of advice from ministers from all interested portfolios, along with provinces and territories, industry, and experts from research and academic institutions – this advice will come in part from the Advisory Council described in recommendation 2;
- reflect the areas in which space assets and activities can have the greatest impact in advancing Canada's national interests;
- cover both civil and military assets and activities;
- align with Canada's international partnerships and commitments;
- position the industry to take maximum advantage of emerging opportunities, for example, by extending Canada's lead in niche technologies; and
- be assessed annually in light of emerging circumstances.

Barring major developments that demand a change in course, 10-year and 5-year priorities should remain consistent over their lifespan, while annual priorities should reflect and build on 10- and 5-year priorities.

Once approved, priorities should be reflected in ministerial mandates, with the expectation that follow-through will occur in a timely manner. Where necessary, ministers should bring more detailed project proposals to Cabinet for approval. Approved priorities and projects should, of course, inform the government's budgeting process.

To help industry, researchers, and other interested parties plan their own work, a summary of approved Canadian Space Program priorities and projects should be released to Parliament and the public on an annual basis.

While there are many areas the government might wish to emphasize in its first set of Canadian Space Program priorities, the imperatives of development and security in the North should almost certainly be high on the list. Satellites and associated ground infrastructure are frequently the most cost-effective – and sometimes, the only – tools for unlocking the enormous wealth of the region; monitoring environmental conditions and impacts; allowing for communication among, and delivery of health and education services to, dispersed communities; ensuring that Arctic sea and air transportation are safe; protecting the northern perimeter; and asserting Canadian sovereignty.

In addition, the government should consider, when establishing priorities, how the country's launch capacity needs can be addressed. Canada's public and private sectors already face potential delays and extra costs as they wait in line for a spot on other countries' launch vehicles. Access to reliable launch capacity will become more important as increased use is made of space assets, including small satellites, to meet the country's economic, security, and public service delivery needs. While creating launch capacity alone is likely to be prohibitively expensive, joint efforts with close allies and/or nations confronting similar challenges may be a way of assuring that Canadian assets are near the front of the launch queue in the decades to come.

Finally, a first set of priorities should reflect how Canada will make full and strategic use of its right to access the laboratories and equipment of the International Space Station to advance cutting-edge Canadian research and technological development.

Recommendation 2: An Advisory Council

Space activities are like no other. They involve developing and deploying complex and often unique technologies into a hostile and forbidding environment where there is little or no possibility of second chances or repair and maintenance. As a result, determining what is feasible and desirable in the context of a national space program requires the experience and insights of a wide range of experts.

The most efficient way for government to gather this advice is to hear the unvarnished views of knowledgeable people around a single table. Such an approach can reduce the number of discussions that must take place, improve the quality of decisions, and offer invaluable input on the sorts of trade-offs that are essential in a resource-constrained world.

It is recommended that the government establish a Canadian Space Advisory Council, reporting to the Minister of Industry, with membership from industry, the research and academic communities, provinces and territories, and federal departments and agencies.

The Advisory Council should be mandated to advise the Minister of Industry on Canadian Space Program priorities and plans, taking into account factors such as:

- the current and potential niche strengths of the Canadian space industry and research community;
- emerging technologies with the potential for positive economic impacts through a wide range of applications in and beyond the space sector;
- public service delivery needs that can be efficiently met through the use of space assets; and
- opportunities for international cooperation on space-related initiatives.

It is important that the Advisory Council bring perspectives from outside government and across the country. It should, therefore, be chaired by a neutral, non-governmental appointee, and include among its members:

- industry representatives from large, medium-sized, and smaller firms;
- representatives of leading space-related research and academic programs;
- senior officials from the CSA and federal departments and agencies with space-related interests and activities, including those that use satellites to deliver their mandates and those that conduct or fund space-related research; and
- senior officials from provinces and territories interested in using space assets to deliver services in their jurisdictions.

It may be appropriate for senior government officials who participate in Advisory Council discussions to do so in an ex officio capacity, given that they have both an opportunity and obligation to provide policy advice to ministers through other channels.

The U.K. Space Agency's Space Leadership Council

The U.K. Space Agency's Space Leadership Council was created in response to a recommendation by the independent, industry-led Space Innovation and Growth Strategy (IGS). The IGS, which was launched by the Minister of Science and Innovation in 2009, resulted in a final report in 2010 that defined a 20-year strategy for the future growth of the U.K. space industry.

The Council is chaired jointly by industry and government and is composed of senior-level officials from across industry, academia, and government. Its duties include:

- *providing advice to the U.K. Space Agency on its workplan and future opportunities;*
- *offering advice on the areas of space activity in which the United Kingdom should seek to develop and maintain global leadership; and*
- *promoting the United Kingdom's space industry and scientific excellence in space research, technology, and applications.*

Source: U.K. Space Agency.

Recommendation 3: Disciplined governance and implementation

Overall direction is only meaningful if properly implemented. Because space projects are complicated and often break new technological ground, they carry an inherent risk of false starts and unexpected detours. Experience illustrates this risk: major space projects in Canada and abroad have been bedevilled by project management issues, cost overruns, and missed deadlines. In such a context, rigorous governance and planning are a must. Once Cabinet has pointed the way, government departments and agencies must be properly organized to follow through.

It is recommended that a deputy minister-level Space Program Management Board be created to coordinate federal space activities, project-specific arrangements be put in place to ensure disciplined project management, and all agencies and departments with a role in the Canadian Space Program be required to report on how they are implementing priorities set by Cabinet.

A deputy minister-level Space Program Management Board – with the Deputy Minister of Industry serving as Chair and the President of the CSA as Vice-Chair – should be mandated by the Clerk of the Privy Council to ensure the coherence and coordination of federal space-related activities, once Cabinet has approved priorities. Support and advice to the Board should come from the CSA as well as the deputy ministers' own departments.

This Board, in turn, should implement arrangements to ensure that major projects are planned and executed in the most rigorous manner possible. It could, for example, strike project-specific steering committees comprising representatives of the CSA, federal departments and agencies involved in the project or initiative, interested provincial and territorial governments, and research institutions. Participation in such steering committees would normally follow a "pay-to-play" rule: those funding a project or initiative should have a voice in how it is designed and implemented.

To provide information on these activities to Parliamentarians and the public and to strengthen accountability, the Reports on Plans and Priorities and Departmental Performance Reports for the CSA and all departments and agencies involved in the Canadian Space Program should specify, in detail, how those organizations are implementing Canadian Space Program priorities. Effective delivery of space-related commitments should be considered in assessing the performance of relevant deputy ministers and senior managers.

Proposed governance structure for the Canadian Space Program

Government Committee	Role
Cabinet	To establish 10-year, 5-year, and annual government-wide priorities for the Canadian Space Program on the advice of the Minister of Industry
Canadian Space Advisory Council	To advise the Minister of Industry on Canadian Space Program priorities and plans
Deputy minister-level Space Program Management Board	To ensure the coherence and coordination of federal space-related activities that reflect the priorities established by Cabinet

Recommendation 4: Predictable funding

In a field in which projects can take a decade to go from concept to operation, sustained funding commitments are essential. Budgetary uncertainty is a recipe for eroding value and increasing risk to the public purse, private industry, and the research community.

Funding stability requires an explicit assurance of continued support as long as activities and projects stay on track. It is not a blank cheque: where milestones are missed, the government must have the ability to use its financial authority as purchaser to compel better performance. Nor does it mean the federal government should be covering all required expenditures itself: given the cost and complexity of space assets, and the benefits of cooperation, multi-payer funding models will often be more appropriate than single-payer models.

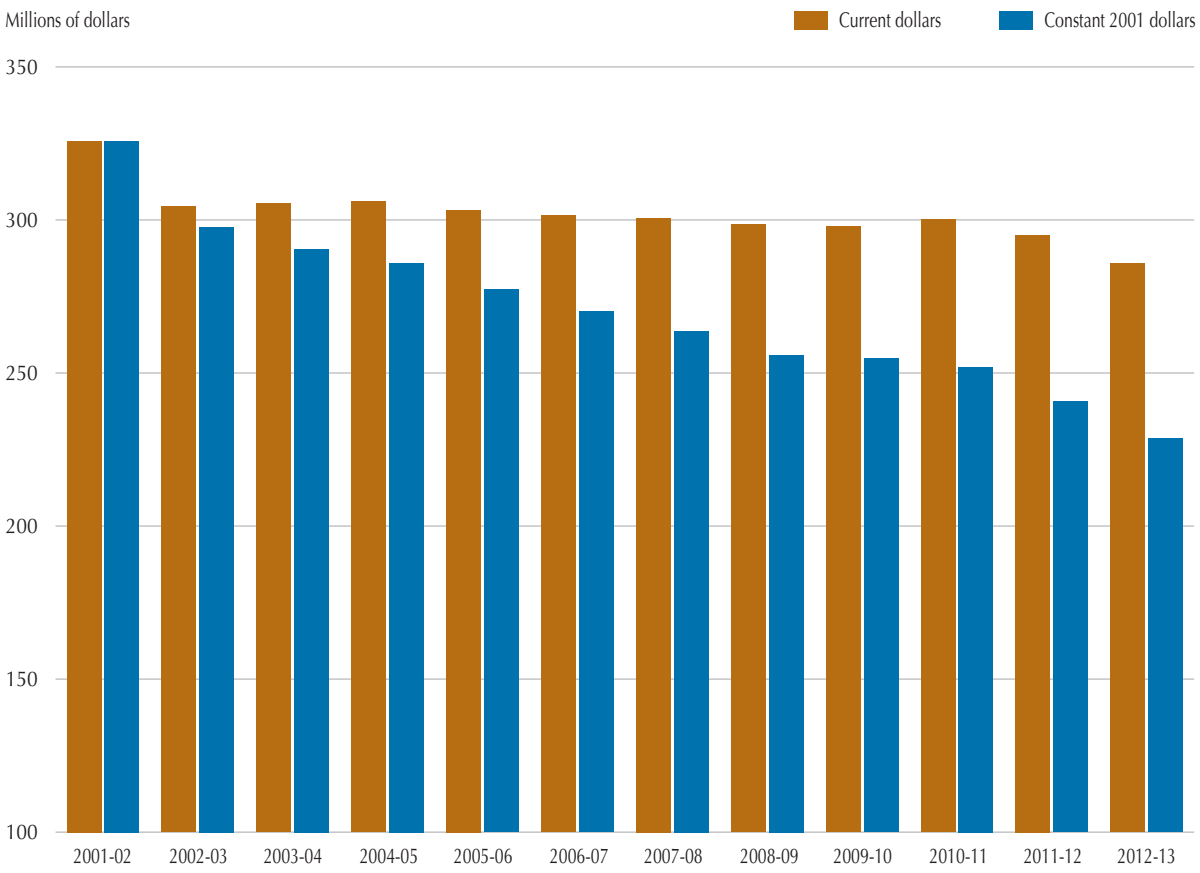
Within those limits, however, predictability in long-term funding is essential to effective management and the success of a national space program.

It is recommended that the Canadian Space Agency's core funding be stabilized, in real dollar terms, for a 10-year period; that major space projects and initiatives be funded from multiple sources, both within and beyond the federal government; and that increased international cooperation be pursued as a way of sharing the costs and rewards of major space projects and initiatives.

Canadian funding sources for major projects may include:

- the CSA, whose core budget should allow it to make a modest contribution to each major project;
- federal departments, agencies, and research bodies that will use the asset or initiative to support delivery of their mandates;
- provincial and territorial governments that will make use of the asset or initiative;
- research and academic institutions interested in using the asset or initiative as a platform for conducting research;
- the builders and operators of the asset, through public-private partnership arrangements; and
- special allocations from general government coffers, in the same manner as such allocations are made for infrastructure projects such as bridges and ports.

Figure 11: Core budget of the Canadian Space Agency – 2001-02 to 2012-13



Sources: Canadian Space Agency and Statistics Canada.

Note: Core budget does not include one-time funding for the Economic Action Plan or major capital projects.
Constant 2001 dollars are calculated using the Consumer Price Index, assuming annual inflation of 2% in 2012. They illustrate the purchasing power of the CSA's budget after accounting for the rising cost of goods and services over time through annual inflation.

The domestic funding formula for each project should reflect considerations such as the nature of the project itself, the capacity and willingness of potential users to make a contribution, and the overall fiscal situation. Special allocations from government coffers may be more appropriate in the early stages of a project's lifecycle, when required expenditures may outstrip users' ability to pay, but should decline over time. This would be consistent with funding patterns for many types of basic or developmental infrastructure.

In some cases, international cooperation will be critical to seeing a project to fruition and to its long-term operational success. Canada has a history of working closely with other countries on space initiatives – a history that has allowed it to strengthen its international visibility and relationships, establish a global reputation for niche technological strengths, and gain access to multi-billion-dollar assets, like the International Space Station and the Mars Curiosity rover, that it would never have been able to develop and build on its own.

Partnering with the European Space Agency

The Canada-European Space Agency Cooperation Agreement enables Canadian space companies to get contracts from the European Space Agency (ESA) based on the principle of "juste retour." For every dollar contributed by Canada to ESA programs, Canadian space companies can obtain one dollar's worth of contracts from the ESA.

This program fosters technology innovation and competitiveness by providing Canadian companies with exposure to the European space market, and providing spaceflight opportunities to test technologies. Overall, Canadian firms have benefited or are expected to benefit from $399 million in incremental revenues due to the ESA contracts and follow-up work.

An example of technology generated through the ESA Agreement is guidance, navigation and control software for satellites. This software, developed by NGC Aerospace of Quebec, was installed on the ESA's Proba-1 satellite. The software predicts when the satellite will fly over a specific target, then manoeuvres it into an ideal position for imaging. With ESA support, NGC subsequently developed second-generation software for the Proba-2 satellite. This software allows the satellite to compensate for environmental disturbances and avoid interference from the Earth. Through the ESA, NGC also had the opportunity to flight-test guidance, navigation, and control technologies for future Earth-observation and exploration missions. Proba technology is now being commercialized in both Canada and Europe.

Canada's reputation as a dependable and sophisticated collaborator positions us well for deeper cooperation with:

- traditional partners NASA and the ESA, which remain the world's largest space agencies;
- emerging (or re-emerging) space powers such as Russia, China, India, Brazil, and Japan – where export controls complicate cooperation with these countries, joint efforts can be focused on areas that are not security-sensitive; and
- Arctic Council members, who are likely to share Canadian interests in developing satellites, ground stations, and small satellite launch capacity to support economic development, safe transportation, public service delivery, and environmental stewardship in northern regions.

Chapter 3.2
Conducting procurements

Public procurements have been a catalyst for the Canadian space sector from its inception. Because government has always been a major client for space assets and expertise, the emergence and growth of the Canadian space industry – and of research and academic programs with a space focus – have been inextricably tied to purchases by the federal government, either for its own projects or for initiatives undertaken in cooperation with other countries' space agencies, especially NASA and, to a lesser extent, the ESA.

This does not mean that the majority of the industry's revenues come directly from Canadian governments; in fact, only about one-fifth of domestic revenues do, and the industry generates half its revenue from sales outside the country, making it one of the most export-oriented in the world. But most sales abroad involve proven products and services, particularly in the fields of satellite communications, Earth observation, and data processing.

When it comes to major technological advances and establishing market credibility, the role of public procurement remains key. Although the situation is gradually changing, few private investors are prepared to assume the costs and risks required to create something new for space, and none has the government's ability to demonstrate a new product's capability through the achievement of "flight heritage."

Testing space assets

Space is a hostile and forbidding environment where there is little room for error. Given the timelines and cost involved in putting technology into space, developers and buyers proceed step-wise, first testing space technology as rigorously as possible on the ground and then testing a small prototype or components in space to gain "flight heritage." This second testing phase is important because it can be quite challenging – and in some cases, impossible – to prove on the ground that a technology will work flawlessly in space at a high level of performance over a period of years with little to no maintenance.

For on-ground testing, industry and government can use the David Florida Laboratory (DFL) of the Canadian Space Agency, among others. The DFL provides specialized facilities, equipment, and support personnel necessary to assemble and check the space-worthiness of entire spacecraft, their subsystems, and major components.

The flight heritage phase generally involves obtaining a "ride" into space, often by piggybacking on an unrelated space mission. Governments often play a critical role in securing such opportunities through funding and international agreements.

The New InfraRed Sensor Technology (NIRST) instrument is an example of a technology that is in the flight heritage phase. It was put into orbit, together with seven other instruments, with the launch of an Argentinian satellite in 2011. NIRST is designed to monitor temperatures at the surface of the ocean and hot spots such as forest fires and volcanic activities. The sensors used in this technology were developed in partnership between the Canadian Space Agency and the Quebec-based Institut national d'optique.

That said, public procurement obviously cannot be predicated exclusively on strengthening the indigenous space sector. It also has to be about meeting the operational requirements of user organizations and getting the best value for taxpayers. These three broad goals – price, performance, and industrial capacity – are the same as those identified in the companion volume on aerospace when it examines public procurement of aircraft.

Attaining these goals demands that, once clear priorities and plans have been established for the Canadian Space Program, the scope of each specific project be established early and requests for proposals create incentives for lower costs, more innovation, and the involvement of Canadian companies and research institutions.

Recommendation 5: Early project scoping

Because space assets take years of sophisticated development, construction, and testing – and are often designed to accommodate multiple payloads for multiple purposes – there has been a tendency for original project scopes to expand, resulting in cost escalation and delays.

It is recommended that the scope of space projects, project timelines, and performance requirements be finalized as early as possible in the project definition phase.

The project scope should be:

- set at a level specific enough to ensure that the asset delivers required services, but general enough to give bidders flexibility to propose a range of approaches to meeting those requirements – in practice, this will mean specifications that are more performance-based and less detailed than those that have typically been used to date;
- approved by the senior executive officer of all organizations involved in funding and/or using the asset, for example, deputy ministers for federal departments; and
- fixed upon approval, unless extraordinary circumstances justify a later revision.

Scope and project management are critical for a successful space program. Any scope changes, timeline extensions, or draws on a project contingency should require approval at the senior executive officer/deputy minister level.

Recommendation 6: Competitive bids that encourage innovation, control costs, and build the Canadian industry

The conventional approach used to procure space assets and services for government purposes in Canada has seen limited competition and a relatively high degree of involvement by CSA officials throughout the design and manufacturing process.

When technologies were in their infancy and Canadian industrial capacity was limited, this may have been appropriate. It helped to build the Canadian space sector and ensure that the government got the assets it needed. But budgets have tightened, technologies have matured, and there is a deeper pool of industry capability, all of which warrant modernizing our approach to acquiring space assets.

Those assets could include more small satellites, which cost a fraction of what major satellites do, can be designed and built relatively quickly, and are increasingly capable of providing valuable data and services. While some applications will always require a larger platform, the goal of maximizing value for money when buying space equipment and services can be advanced by considering all technological and hardware options and determining the optimal mix for each project.

Arriving at that optimal mix will be facilitated by soliciting and considering a range of approaches each time the government contemplates a space-related procurement. In any sector – as the Competition Policy Review Panel[4] noted in 2008 – competitive intensity spurs innovation and produces better results at lower prices for customers. This is true not only when customers are individual citizens, but also when the federal government makes purchases on behalf of the people of Canada. While the number of major companies in the space business will always be relatively small – given the costs and complexities entailed in designing and manufacturing space assets – there are now enough players to generate healthy competition for the public's space dollars.

Competition need not mean an erosion in the commitment to leverage public procurements to strengthen the Canadian space sector. As long as the sector relies to a significant degree on such purchases – and as long as other countries treat space procurements as exempt from trade rules and use them to foster their own sectors – positive impacts on the Canadian space industry and research community should be a consideration when public resources are used to buy satellites and other space equipment and services.

Canada's space companies do not oppose competition as long as it is fair, balanced, and transparent. Indeed, properly managed, more competition should be of benefit to both the government as purchaser and the Canadian space sector, as it will spur innovation and give firms the opportunity to forge a range of partnerships as part of bid development.

It is recommended that space asset and service procurement processes be competitive in nature and that proposals be assessed on the basis of their price, responsiveness to scoped requirements, and industrial and technological value for the Canadian space sector.

To keep costs down, creativity up, and indigenous capacity strong, any company or consortium of companies that satisfies a significant Canadian content threshold should be permitted to bid for the federal government's space business. Bidders should be encouraged to propose innovative solutions to meet the government's requirements – something that will be helped by having those requirements scoped at a relatively general level, as described under the previous recommendation.

Each proposal should be required to include a detailed explanation of concrete industrial and technological benefits for the Canadian space sector. Benefits may accrue from the direct participation of Canadian companies and research institutions as leaders of, or partners in, the bid; from firm commitments to source systems and components from Canadian companies; and from investments in research and skills training related to the project. Projected benefits should be assessed for their impacts on the Canadian space sector's technological capabilities and ability to develop and sell products and services in Canada and abroad. Bid selection should consider these impacts, along with a bid's total cost and capacity to meet users' needs.

"Government space procurements should be based on needs to be met or problems to be solved.

"… Close consultation between industry and government on user requirements and industrial capabilities should occur at the outset and before the completion of any detailed technical specifications. This process will allow industry to propose, and the government to assess, alternative solutions to meet the identified user needs, which will promote innovation and reduce costs."

Telesat, submission to the Aerospace Review.

4 Competition Policy Review Panel, *Compete to Win: Final Report* (Ottawa: Public Works and Government Services Canada), 2008. **ic.gc.ca/eic/site/cprp-gepmc.nsf/eng/h_00040.html**

In instances where efforts to encourage increased competition do not bear fruit and there is only one bidder – due, perhaps, to the specific requirements of the project and the limited number of players in the industry – special measures may be required to ensure that costs are reasonable and the benefits to the Canadian space sector are meaningful. These measures may include benchmarking the price of the bid against the cost of comparable projects carried out in other countries and raising the Canadian content thresholds.

In all cases, the procurement process should be led by Public Works and Government Services Canada (PWGSC), the federal agency with the deepest expertise in major government purchases. The CSA should provide technical advice to PWGSC – in conjunction with all organizations involved in the project – and should liaise with PWGSC and the vendor during the design and manufacturing phases to ensure that milestones are being met. In most cases, however, the CSA should not be directly involved in those design and manufacturing activities. Less emphasis should be placed on continuous technical oversight by the CSA, and more on the establishment and enforcement of firm contractual obligations for product development and delivery, with meaningful penalties for under- or non-performance. The onus for proposing and delivering assets and services should rest with the companies that bring forward bids. The government should act as a savvy customer rather than an overweening supervisor.

Chapter 3.3
Fostering technological and commercial capacity

Although public procurements make important contributions to innovation and the competitive position of the Canadian space sector, they are not the only tool available to government to help the sector thrive. In fact, as technological progress and global trends make space a more and more commercially viable domain, the role of public policies and programs should turn increasingly toward creating an environment that helps Canadian space companies succeed not just in the context of government procurements, but also in the global marketplace.

> *"Without new technologies, international academic linkages and appropriately skilled people flowing from universities to industrial [research and development] labs, and finally to flight programs, Canadian companies will eventually fall behind the state-of-the-art and no longer be relevant or competitive on the world stage. A strong research capacity in groups of critical mass, well connected to industry and government, is an essential underpinning of a competitive sector."*
>
> Janet E. Halliwell, Tim Barfoot, Kieren Carroll, Gabriele d'Eleuterio, James Drummond, Gordon Osinski, and Andrew Yau, *The Academic Dimensions of Industrial Competitiveness*. Research report prepared for the Space Working Group, June 2012.

Such success will depend on the ongoing refinement of existing technologies and development of new ones that anticipate and respond to the needs of public and private sector customers in Canada and around the world. It will also require conditions that facilitate creativity and experimentation by entrepreneurs and researchers.

Recommendation 7: Support for technology development

Government plays a critical part in fostering innovation through funding for R&D. That is one reason why Budget 2012 tightened eligibility rules for the Scientific Research and Experimental Development tax incentive program (SR&ED) in favour of more direct support for promising ideas and projects. Such support is particularly important in a sector like space, where competitive advantage and technological advantage are so closely intertwined.

The main federal programs targeted to applied R&D in the Canadian space sector are the CSA's Space Technologies Development Program (STDP) and Earth Observation Application Development Program (EOADP). Over the years, the proportion of CSA funding devoted to STDP has dropped as budgets have become tight and resources have been reallocated to other activities: it provided $10-20 million annually in funding between 2003 and 2010, but had declined to $4 million by 2011-12. EOADP has remained relatively stable during the same period at about $5 million annually.

Space Technologies Development Program

The Space Technologies Development Program (STDP) provides financial support to industry and academia to foster innovation, enhance the competitiveness of the Canadian space sector and further the development of technologies that could be required for future Canadian space missions.

In the last 10 years, STDP has supported the development of over 50 new technologies ranging from self-healing carbon fibre materials to the automated vision systems used for inspecting the Space Shuttle in space.

For example, ABB of Québec City received $500,000 from STDP to help develop a miniature interferometer (called MINT), an instrument that modulates incoming light in a way that allows more detailed analysis of a scene under observation. This technology can be used in a wide range of applications, including remote sensing instruments for environmental, defence, and security monitoring, as well as industrial analyzers. With further research and development on this technology, ABB developed a new family of low-cost, high-performance industrial analyzers that now have significant export sales.

Given the significance of innovation to the long-term vitality of the sector, and the scale of other countries' investments in space-related R&D, the level of support for such activities must be raised and protected.

It is recommended that total funding for the Canadian Space Agency's technology development programs be raised by $10 million per year for each of the next three years, and that it be maintained at that level.

Half of the recommended funding increase should come from a reallocation of savings achieved as a result of the tightening of SR&ED criteria, and half should be reallocated from CSA business lines that will be less active as a result of recommendations in this report, including direct oversight of the space asset design and manufacturing process.

It is important that when public funds are spent with the aim of spurring ground-breaking technologies, support be focused in areas with the greatest potential to benefit the competitiveness of the industry and growth of the economy. To achieve this, the criteria for space-related R&D funding should give preference to proposals that:

- align with the Canadian Space Program priorities approved by Cabinet;
- are submitted by industry-academia consortia with agreements for sharing intellectual property;
- include technology demonstration as well as basic R&D;
- include a sound business plan showing how the proposed technology development activities will result in commercially viable and exportable products and services; and
- have a clearly articulated project management plan, ideally with some sharing of expense and risk by proponents.

Proposal assessments should be jointly conducted by the CSA and the NRC, which has expertise in space research, and in supporting small and medium-sized businesses with the development of technologies that have high potential for commercialization and sale in global markets. More formal management linkages in the NRC's and CSA's technology development programming should also be explored.

High-altitude science balloons

The Canadian Space Agency (CSA) is partnering with France's space agency Centre national d'études spatiales and municipal authorities to build and operate a base in Timmins, Ontario, from which high-altitude science balloons can be launched. Balloons can carry up to 1.5 tons of equipment into the stratosphere – an altitude of about 40 km – to collect data on the environment and the atmosphere, as well as peer into space using telescopes. This launch facility will provide cost-effective opportunities to conduct research and train the next generation of space scientists and engineers. Preparations for the first launch are expected to take place in 2013.

Recommendation 8: Encouragement of commercial space activity

The global space business is gradually opening to commercial activity beyond satellite communications. NASA's efforts to sponsor and, eventually, rely upon commercial launch services to low Earth orbit is one driver of this trend, but so are the growing popularity of applications based on data delivered by satellites; the development of new, cheaper technologies for getting to and operating in space; and the interest of serious researchers and investors in space tourism, space mining, satellite refuelling and maintenance services, space debris management, and the collection of solar energy in space for use on Earth.

Some of these ideas may prove fanciful, but others may be visionary and produce tremendous profits for their proponents and for the countries in which those proponents operate. The R&D support recommended previously will help stimulate development of the most promising proposals, but it is impossible to know with certainty whether a notion that appears unrealistic today might lead to tomorrow's breakthrough. Without endorsing specific speculative projects, public policies and programs can create the conditions for entrepreneurs and researchers to test and pursue creative approaches and, in so doing, jump-start Canada's private sector space activity at a time when the global commercial space business is gaining momentum.

Commercial space: present and future

For-profit private sector space activity, although still relatively modest in scale, is on the rise. Examples include:

In Canada, exactEarth, a subsidiary of COM DEV, has developed an automatic identification system (AIS) data service using microsatellite and nanosatellite technology. It can be used to monitor ship traffic and fishing in waters beyond coastal areas. This technology has a large potential market with surveillance and maritime security authorities, as well as shipping companies interested in better tracking their fleets. Recently, the Department of National Defence began using exactEarth's AIS to provide real-time intelligence and security data to the Canadian Forces.

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Solaren Corporation of the United States is currently developing a space solar power satellite system that would generate electricity from solar panels in orbit and beam it down to a receiving station on Earth using microwaves. Space-based solar panels have the advantage of being able to generate power continuously without interruptions due to night, cloud cover, or wind variances, while avoiding filtering effects from atmospheric gases. The company has already signed a contract with Pacific Gas and Electric Company, a large electricity transmission utility in California, to supply about 1,700 GWh of electricity per year for 15 years, or the amount used annually by some 250,000 homes. The cost of the electricity is expected to be competitive with that of other renewable sources. Solaren aims to begin delivering electricity by 2016.

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Virgin Galactic of the United Kingdom plans to provide suborbital spaceflights to space tourists, suborbital launches for space science missions and orbital launches of small satellites. Further in the future, it hopes to offer orbital and transcontinental human spaceflights.

To date, more than 540 customers have each placed deposits toward a ticket priced at $200,000 for a two-hour ride on Virgin Galactic's spacecraft, called SpaceShipTwo. The company aims to start launching space tourists to the edge of space by the end of 2013, pending the success of rocket-powered test flights.

It is recommended that where costs are modest and there is no risk to public safety, the government create conditions conducive to the expansion of space-related commercial activity.

A variety of measures will help to create such conditions, and those measures will need to evolve together with space technologies and business dynamics. Measures worth immediate consideration include:

- Intensifying efforts to secure geostationary orbital slots for Canadian-owned satellites. Because space is treated as a global commons, only the government can negotiate access to these slots and make them available to private firms.
- Simplifying regulatory regimes that cover high-altitude testing, suborbital and orbital launches, and human spaceflight. These regimes need to address the inherent risks associated with such activities, but some recalibration may be appropriate in light of technological advances and the desire to encourage safe experimentation.
- Making public infrastructure – from CSA and NRC laboratories in major cities to little-used runways in isolated locations – available at modest cost to companies for the purposes of safely testing new space-related technologies.
- Adopting an open data policy for non-security-sensitive raw data generated by publicly owned satellites, particularly those involved in Earth observation. This policy would be consistent with global trends and Canada's Action Plan on Open Government, and would allow creative individuals and companies to add value and generate economic activity by developing and selling a range of applications.
- Extending the favourable tax treatment currently afforded to investors in flow-through shares of mineral exploration companies to investors in commercial activity in space, whether or not that activity is mining-related. While this measure is unlikely to result in significant uptake in the short term, it has the potential to encourage private sector efforts over the long term.
- Negotiating bilateral sectoral agreements that increase the access of the Canadian space industry to global markets, including procurements by governments abroad, consistent with recommendation 8 in the companion volume on aerospace. Such agreements would help ensure that the application of any exceptions from normal international trade rules is carefully limited to space-related products and technologies that are genuinely security-sensitive.

Chapter 3.4
Next steps for the Canadian Space Agency

The CSA was created in 1989, pursuant to a recommendation made by the 1967 Chapman Report, which laid the groundwork for Canada's space program. The CSA's responsibilities, as laid out in the *Canadian Space Agency Act*, are very broadly defined.

Another 23 years have passed, and this report makes recommendations that will mean significant change for the CSA. Reflecting the experience of the last two and a half decades, the maturation of the Canadian space sector, and the evolution of the global space business, these recommendations will bring greater clarity to the CSA's core mandate.

If these recommendations are fully implemented, the CSA will focus on:

- Providing advice and support to the Minister of Industry, the Canadian Space Advisory Council, and the deputy minister-level Space Program Management Board, for which the President of the CSA will act as Vice-Chair.
- Acting as a technical advisor to project-specific committees and to Public Works and Government Services Canada in the context of major space procurements, as well as to government departments and agencies more generally on the uses of space assets and data.
- Negotiating cooperation agreements with other countries' space agencies and coordinating Canada's participation in international space projects.
- Co-managing, with the NRC, the allocation of increased funding in support of space technology development, as well as conducting its own research in collaboration with industry and academia.
- Continuing to operate public space assets and associated ground infrastructure in its inventory.
- Running the Canadian astronaut program.

In addition, consistent with recommendation 15 in the companion volume, *Beyond the Horizon: Canada's Interests and Future in Aerospace*, the CSA will help to promote space-related studies and careers among Canada's youth.

Better delineated roles for the CSA mean that it will not, itself, be a policy-making body, nor, as a rule, will it be directly involved in designing and manufacturing space assets purchased by the government.

A clear mission helps ensure the success of any organization. The CSA will benefit from having a well-defined mandate, as well as the right number of staff, with the right mix of competencies, to deliver that mandate.

Conclusion

Human endeavours in space have shifted increasingly from a focus on exploration to practical applications and commercial activity. For the foreseeable future, nation-states will remain the largest clients for space ventures – including scientific discovery, Earth observation, and the provision of public services – but more and more, they will be joined by companies selling space-related activities and services at a profit.

Technological advances, primarily in the capabilities of satellites, have made space indispensable to the functioning of contemporary societies. Space-based assets make life on Earth more productive, prosperous, safe, and interesting. The value of space activity – both in commercial terms and in its contribution to the public good – will multiply in the future.

It is essential that Canada capitalize on its strengths in space and position its space sector to be at the forefront of what has become an international race for new ways to turn space to public advantage and private gain. Not to do so is to forfeit opportunities that can never be regained. Our national interests, including in the North and along our security perimeter, demand a range of space-based equipment and applications. Our space firms should be marketing cutting-edge designs and services to the world. Our economy should be benefiting from the rewarding jobs, investment opportunities, and technological innovations and spinoffs that come with space projects. And our researchers and youth should be inspired by the potential to contribute to fundamental knowledge and the betterment of humankind through space-related studies and careers.

Taking advantage of these opportunities requires, first and foremost, that clear priorities for the Canadian Space Program be established at the highest levels. Only then can the creative energies and resources of government agencies, industry, and the academic and research communities be effectively channelled. Robust management structures and plans are required to efficiently marshal efforts in support of these priorities. A carefully calibrated approach to public procurements must be used to balance emphasis on fostering the technological and commercial capacities of Canada's space sector with value-for-money considerations. And the competitive spirit of the Canadian space industry must be as great as its manifest ingenuity.

Canada has already accomplished great things in space. Renewed clarity of purpose and focused administration will allow us to eclipse even those successes. For the sake of future generations of Canadians, it's time to reach higher.

Appendix A
List of research reports

The research reports listed below were commissioned by the Aerospace Review to provide information and advice on key issues. The complete text of these reports may be found on the Review's website, **aerospacereview.ca**, under "Research and Consultations."

These reports are available only in the language submitted, and are not subject to official languages, privacy, or accessibility requirements.

The Aerospace Review is not responsible for the accuracy, reliability, or currency of the information supplied by external sources. Users wishing to rely upon this information should consult directly with the authors.

Aerospace Export and Domestic Controls Review, by Advantage Trade Controls Ltd.

Aerospace Small and Medium Sized Enterprises Financing, by Patrick Hum, MBA Candidate, Queen's University

Approaches to In-service Support (ISS), Optimized Weapon System Support (OWSS) and Single Point of Accountability (SPA), by Cogint

Brazil, Russia, India and China Governments' Aerospace Strategies and National Policies: Implications to Canada's Aerospace Industry, by Pravco Aviation Review L.L.C.

Canada's Aerospace Industry: The Impact of Key Global Trends, by the Conference Board of Canada

Canada's Space Sector: The Essential Enabler of Canada's Northern Strategy, by Norstrat Consulting

Current and Future Human Capital Needs in the Aerospace Industry and Strategies for Harnessing the Potential Workforce, by Prism Economics and Analysis

Defence Industrial Policy Approaches and Instruments, by Ugurhan Berkok, Christopher Penney and Karl Skogstad, Queen's University

International Overview of Space Governance and Policies for the Canadian Aerospace Review, by Euroconsult

Policies and Programs of Canadian Provinces and Territories: Mechanisms to Support SMEs and Established Aerospace Firms, by Acacia Policy Consulting Inc.

R&D Support for the Aerospace Industry: A Study of Eight Countries and One Region, by Dr. Jorge Niosi, Université du Québec à Montréal

A Report on the Development of a National Space Infrastructure to Support the Global Competitiveness of the Canadian Space Industry, by Lansdowne Technologies Inc.

A Research Assessment Report on Integrated Technology Demonstration and the Role of Public Policy, by Dr. Jeff Xi, Ryerson Institute for Aerospace Design and Innovation

Sectoral Structure Analysis, by PricewaterhouseCoopers

The State of the Canadian Space Sector, by Hickling Arthurs Low

Strategies for Attracting and Retaining a Skilled Workforce in a Cyclical Industry, by John O'Grady Consulting Ltd.

Appendix B
List of submissions

Written submissions were received by the Aerospace Review from the organizations and individuals listed below. The complete text of these submissions may be found on the Review's website, **aerospacereview.ca**, under "Research and Consultations."

These submissions are available only in the language submitted, and are not subject to official languages, privacy, or accessibility requirements.

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DreamSpace Group

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International Association of Machinists and Aerospace Workers

ISR Technologies

JMJ Aerospace

Lark, Eva-Jane

Montréal International

Prentice, Barry E.

SAR Corporation

Space 1 Systems

Telesat