

# **Aerospace Industry Review Paper**

## **Canadian Space Society**

### **Introduction**

In 1962, Canada became the third country in space with the launch of Alouette-1. Since then, Canada has had a proud history of significant contributions in science and technology through space research and development. In 1967, the Chapman Report provided a series of recommendations that helped guide Canada's original focus and investments in space technology. The Chapman Report also provided a practical plan that outlined how space can address the areas of greatest need for Canadians. Given our large geographic area and disperse population, satellite communications and remote sensing (including space-based earth observation) was, and still is, a practical and cost effective means to address Canada's needs. As such, space technology has helped Canadians stay connected, coast to coast to coast, and has given us a higher vantage point to monitor our large country. In addition, research and development into space technology has provided us the Canadarm, an iconic symbol of Canada's innovative and imaginative ability.

50-years have now passed since the launch of Alouette-1 and Canada's space program is at a crossroads. The global community has yet to chart a course for space exploration and NASA has ended its Space Shuttle program. India and China have entered the space arena with significant strides in rocketry, satellite manufacturing, human space flight and has set its targets on the Moon. The private sector in the USA has entered the arena providing its own space transportation systems (SpaceX), and is setting ambitious targets to mine space resources (Planetary Resources). Canada has been without a new Long-Term Space Plan for over a decade, during which time Canada has completed several major projects such as Radarsat-2 and Dextre. However, without a clear direction on the path forward for Canada's space program, the space industry and Canada's next generation of space scientists and engineers are left in the dark about the future of Canada's Space program.

The Aerospace/Space review, announced in the 2011 Federal Budget, provides an opportunity to discuss the current state of Canada's space industry and where it's headed. This submission is the Canadian Space Society's contribution to the review.

### **The Canadian Space Society**

The Canadian Space Society is an association of space-interested individuals; professionals and students from across the country. Its members come from all walks of society and all share a desire to see Canada's space ventures flourish. The thoughts and opinions expressed in this paper are a culmination of shared ideas among members of the Canadian Space Society. It proposes a series of recommendations for a strong Canadian presence in this strategic area.

To benefit the Canadian Space program, the context of the review must consider that Canada has lacked both short- and long-term direction of the future to guide Canada's involvement in Space. Canada lacks both a new Long-Term Space Plan and a National Space policy. Without the creation of such direction, the space industry is rapidly losing

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its competitive advantage, lacking government investment and procurement. Consequently, scientists and engineers are leaving the country for better opportunities and research projects. As a result, Canada will quickly become outdistanced by the investments and space activities occurring around the world. This paper focuses on the policies necessary for the space industry in Canada to get back on track, while at the same time highlight some of the technologies that other agencies/industries will likely provide as the means of meeting short-term milestones.

### Multi-purpose missions

Recommendation: Multi-purpose technologies should have priority when investing in any space asset for Canadian use.

Unlike the US, Canada cannot afford to have separate budgetary streams for all the individual interests in space. No single interest should dictate the development of any single asset built for space operations. To achieve this objective, significant effort is required to bring all interested parties together and lay-out the needs of all. Significant openness, coordination, prioritization and budgetary planning would be required to reap the maximum benefits from this approach.

It is fiscally irresponsible to ignore the possible synergy of combining all government departments, and even Canadian industry, interests/efforts in fields such as Telecommunications, Earth observation and robotics.

Canada should continue to actively search out and merge the requirements that various government and industry agencies have to capitalize on the investment in space assets. Fiscal responsibility is shown by sharing investment strategies into a single, multi-purpose space asset.

Technologies: RadarSat, Sapphire, Mercury-global, NeoSat, M3M Sat

Strengths	Weakness
<ul style="list-style-type: none"> <li>- May provide the opportunity for collaboration amongst interrelated space industry players across Canada</li> <li>- Fosters collaboration between stakeholders assuming that a multipurpose mission has a higher likelihood of being funded</li> <li>- Create applicability across Canadian departments</li> <li>- Allows 'pooling' of resources</li> </ul>	<ul style="list-style-type: none"> <li>- Funding and planning these micro and nano satellite missions</li> <li>- Good projects may be overlooked, or compromised to accommodate multipurpose missions</li> <li>- Larger more complex scope may negatively impact project success</li> <li>- Achieving consensus can be difficult and slow and thus retarding program development</li> </ul>

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<ul style="list-style-type: none"> <li>- Canada has many niches that could be part of multi-purpose missions</li> <li>- Micro satellite missions demonstrate flight heritage in instruments that could be further advanced through multi-purpose missions</li> </ul>	<ul style="list-style-type: none"> <li>- Canada does not have many large-scale satellite missions or satellite constellations in its plans</li> </ul>
<p><b>Opportunities</b></p>	<p><b>Threats</b></p>
<ul style="list-style-type: none"> <li>- Several Canadian organizations have expertise to enable strategy implementation (e.g. Space Flight Laboratory at University of Toronto, Microsat Satellite Systems Canada, NRC-HIA, etc. have the expertise in developing and operating micro-satellites and their attitude control systems)</li> <li>- Leveraging limited funds to accomplish multiple goals reduces mission costs (e.g. by sharing costs related to launch, testing, project management, etc.)</li> <li>- Create awareness across Canadian government departments and industry professionals of the application of space assets</li> <li>- Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring contains reference to space-based satellite role, as well as a budget. This could encompass a multi-use payload strategy.</li> </ul>	<ul style="list-style-type: none"> <li>- International competition</li> <li>- Difficult to manage multiple stakeholders and varying interests</li> <li>- May end up being a combination of mediocre results instead of one quality mission</li> <li>- Missions may be held up indefinitely until a suitable mission is found to be paired with</li> <li>- Jack of all trades and master of none syndrome. Programs able to devote resources to single focused missions may develop a reputation as experts.</li> </ul>

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## Earth Observation and Remote Sensing

**Recommendation:** Advance the demand for Earth Observation (EO) products by developing a market strategy to increase the dissemination and use of value-added space-based EO information and services for Canadian concerns. The strategy could include opportunities to train more Canadians in the use and develop of EO applications.

Earth observation data is becoming more accessible thanks to the internet. Almost everyone in Canada has seen Google maps, and benefitted from “Free of charge” providers of EO value-added products. Enhancing the value of the images readily available, with tailor-made Canadian content would be of enormous value, and should be a priority for Canadian investment. The existing imagery provides a readily accessible base map, over which “special interest” information (crop dispersion, water flows, weather (space and atmospheric), mineral deposits, pollution tracking, etc.) can be added in layers. In addition, Canadian source imagery could be provided to a larger community, thus creating a greater demand for similar information.

Technologies: - RADARSAT I & II and Constellation

Fiscally neutrality in terms of EO information could be in the direct form of the distribution of the layers of information sought by specific user groups, but more likely is the secondary benefit of enhancing the yield of existing services, such as crop production, mining endeavours or tracking environmental concerns. The latter is much harder to assign a numerical figure, but likely to much more significant than the direct benefits of selling data.

Strengths	Weakness
<ul style="list-style-type: none"> <li>- Canada is a world leader in space-based SAR</li> <li>- Higher productivity of a wide range of user communities</li> <li>- Industry and Government are developing new applications for EO data</li> <li>- Industry is in place to develop and deliver remote sensing products and these are used extensively in the Oil and Gas Industry, transportation, etc.</li> <li>-</li> <li>- Research groups at Universities in Canada (Royal Military College of Canada, Toronto, Waterloo, Quebec City, etc) have expertise in data and scientific analysis.</li> </ul>	<ul style="list-style-type: none"> <li>- Government is not expanding its satellite capacity as fast as other governments and as such will have to rely on their resources to monitor Canada</li> <li>- In the absence of Canadian launch capabilities, Canada has to depend on NASA, ESA, ISRO, etc. for launch of these satellites</li> <li>- Providers of remote sensing data are increasing especially when airborne (vs. spaceborne) platforms are included</li> <li>- Unavailability of the desired data resulting in a customer base that goes elsewhere, or loses interest.</li> <li>- Costs of using SAR data can be</li> </ul>

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	<p>prohibitive to SMEs</p> <ul style="list-style-type: none"> <li>- Canada does not have high capacity to use or develop EO products/services both within government and outside</li> <li>- Users may prefer hyperspectral data which Canada has no expertise or hyperspectral satellites</li> <li>- The use of EO data, information, services and products are still relatively new and awareness is low on how to incorporate EO data to benefit government, businesses and academia</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- New growth sectors that currently don't exist.</li> <li>- Potential marketing venue, similar to Google/Facebook, through user base.</li> <li>- The Government could invest in purchasing more EO data, services, information and products from Canadian businesses to help grow the market</li> <li>- Government could provide more data in an accessible fashion, e.g. the next EO</li> <li>- Remote sensing technology can allow for efficient up-to-date monitoring of many aspects of Canada – oil sands, road footprints, urban sprawl, ice monitoring, etc.</li> <li>- Various opportunities in remote monitoring of Earth's atmosphere, weather predictions, environmental profiles, estimate green house gases, etc</li> <li>- Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring contains reference to space-based satellite role, as well as a budget. This could encompass a multi-use payload strategy.</li> </ul>	<ul style="list-style-type: none"> <li>- Other countries have strong space programs and as such might be capable of remotely monitoring parts of Canada that we are not capable of monitoring, providing them with possible competitive, security and strategic advantages.</li> <li>- The people with the knowledge are moving away because there are fewer opportunities for them to stay in Canada</li> <li>- Reduced funding for the space missions</li> <li>- Advancements in airborne remote sensing applications</li> <li>- Sometimes easier to fly a plane to capture images than to launch a satellite.</li> <li>- Not being able to reach/educate possible customer base</li> <li>- Without further investments from Government, there will not be sufficient demand to support a sustainable and competitive EO industry.</li> </ul>

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<ul style="list-style-type: none"> <li>- Provinces, and municipalities are increasingly relying on remote sensing data to support their planning and development, infrastructure maintenance, and environmental conservation initiatives. Understanding their data needs will lead to opportunities.</li> </ul>	
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**Navigation**

Recommendation: Invest in space-based systems that enhance the current world-wide navigational systems and provide a global coverage.

In addition to the value-added layers of EO information, existing open sources of navigational information should be added as a separate layer, with a range of increasing resolution for a multitude of users, both public and private.

The Polar Regions currently pose major obstacles in terms of reliable navigational references that could easily be addressed by space-based assets. Given Canada’s large polar region, surveillance and sovereignty of the area is almost impossible without reliable navigational aids and communications systems.

Strengths	Weakness
<ul style="list-style-type: none"> <li>- Providing services in the Northern regions would, by design, provide the same benefit to the Southern polar regions.</li> </ul>	<ul style="list-style-type: none"> <li>- low population density means small user groups</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- New growth sectors that currently don’t exist.</li> </ul>	<ul style="list-style-type: none"> <li>- Not being able to reach/educate possible customer base</li> </ul>

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**Telecommunications**

Recommendation: Invest in a coordinated effort to supply high bandwidth communications, and navigational information, to areas north and south of the 70<sup>th</sup> parallels, possibly including some space elements to the overall solution.

Given our long history of satellite communication use, Canada should continue its technical leadership in this area. Of particular interest today is the lack of reliable communications in the Northern regions of the country. More and more government and industrial interests are based in the North, and they all suffer from a lack of connectivity that they'd expect in other areas of Canada. Communications for maintaining sovereignty and emergency response is a fundamental requirement in the Arctic. So too, is the need for 21<sup>st</sup> century communication services for Arctic communities. Therefore it is recommended that the Government, Industry and Academia work together to implement the recommendations listed in the Arctic Communications Infrastructure Assessment Report in order to supply high bandwidth communications to areas north of the 70<sup>th</sup> parallel.

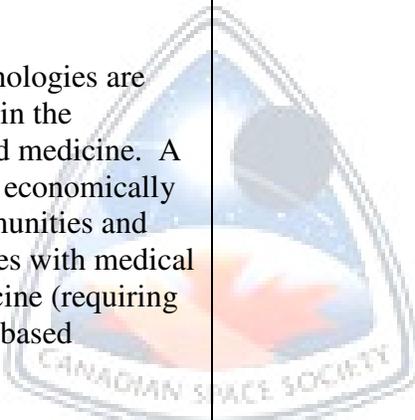
Technologies: Spot beam from GEO, and Mercury-Global constellation

Financial benefit would apply to any company providing these services to the growing resource-based business working in the polar areas. In addition, communication needs by transient ships would be potential customers of enhanced polar communications systems. A secondary benefit to Canada would be the potential reducing the “digital divide” that is currently occurring in our Northern communities. Without access to equivalent high bandwidth internet and communications, Northern communities are at a disadvantage.

Strengths	Weakness
<ul style="list-style-type: none"> <li>- Delivery of satellite based telecommunications require less terrestrial infrastructure (cable, etc.) to deliver the service to remote locations</li> <li>- Delivery of satellite based telecommunications is less intrusive and potentially more reliable in a rapidly changing northern environment</li> <li>- Telesat is the 4<sup>th</sup> largest provider</li> <li>- Canada has had a long history of making public investments in satellite communications and later allow for the commercialization of this industry</li> </ul>	<ul style="list-style-type: none"> <li>- Traditional northern communities and lifestyles may not require or utilize resulting services</li> <li>- Polar populations may not be enough of a driver</li> <li>- The market for fibre optic cables and/or wireless technologies in the North is uncertain and may provide direct competition to satellite communication solutions.</li> </ul>
Opportunities	Threats

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<ul style="list-style-type: none"><li>- Improved communications could improve the northern economy and responses to northern threats (oil spills, security, etc)</li><li>- Develop greater expertise in constellation planning, design, deployment and maintenance</li><li>- With climate change, Canada should expect and be prepared for greater activity in the north</li><li>- Globally, such services could be offered to paying customers in the south 70 deg</li><li>- Increased demand for communications in Northern Canada</li><li>- Telecommunications technologies are playing an increasing role in the provision of healthcare and medicine. A large opportunity exists to economically provide both remote communities and under serviced communities with medical services through telemedicine (requiring reliable and often satellite based telecomm. platforms)</li></ul>	<ul style="list-style-type: none"><li>- Faster development may occur at the expense of the environment.</li><li>- The markets for telecommunications in the North are not comparable to the south due to the regulatory regime and market failure.</li><li>- Other countries will have better communications in the North for their own activities in comparison to Canada.</li></ul>
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**Launch capabilities**

**Recommendation:** Canada must finalize current development of an indigenous launch capability for small and micro satellites, limited to polar and sun-synchronous orbits.

The Chapman report first made the recommendation that large satellite launch is an expensive business, but Canada should invest in small satellite launch. Small and micro-scale satellites now have as much or more capability as large satellites built in the Chapman era. Worldwide costs for launch of small scale satellites have reduced over the years, but that is because multiple payloads are loaded on the same launchers that were created for much bigger payloads. The logistics of coordination for all these smaller payloads creates a great deal of delay, and re-scheduling for the entire launcher. Delay of multiple years is not unheard-of in today's launch market.

Polar launch is ideal from Canada. Latitude is our benefit. This is one of many areas where Canada's military and civil interests should be combined to create and retain its

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own access to space. Communications and space surveillance are two areas today that would benefit from Canada being able to launch their own assets into space.

In addition to potential savings for existing Canadian expenditures, space launch could reap dividends by competing with the existing, high-priced, global market.

Strengths	Weakness
<ul style="list-style-type: none"> <li>- Produces some assurance for Canadian small satellites to be launched (if economical enough)</li> <li>- Canada ideally suited for polar launches</li> <li>- Knowledge is available in Canadian Universities, Industries, and research institutes</li> </ul>	<ul style="list-style-type: none"> <li>- May not be Canada's core strength at the moment</li> <li>- Does nothing to support our GEO comms expertise</li> <li>- Still expensive – high potential for fiscal failure</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- Increase in the number of micro satellites and their capabilities</li> <li>- Open a new market for other smaller nations to launch with us</li> <li>- Currently highly dependent on others</li> <li>- Lower global launch costs</li> <li>- Cost neutrality can come from barter opportunities or hosted-payloads</li> </ul>	<ul style="list-style-type: none"> <li>- Negative perception that polar launches require more delta to be effective, which is not the case if you are launching into a polar orbits.</li> <li>- Environmental concerns for launch areas, mishaps etc</li> <li>- May cause former providers to become closed to Canadian participation and technology-sharing</li> <li>- Other countries may see this as a strategic niche to develop</li> </ul>

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### Space tourism/travel

Recommendation: Canada should explore the feasibility of attracting industry to build a spaceport in Canada. This could potentially be done through a public-private-partnership. The CSA and the Canadian Tourism Agency could jointly develop a policy position to support space tourism/travel

Since the successful completion of the first X-Prize which saw Scaled Composites walk away with the \$10 million purse, space tourism has begun to attract a great deal of attention. Currently seen as a means for wealthy patrons to explore the upper atmosphere, it is positioned to challenge the airlines for high-speed business travel. The termination of the supersonic fleets of Air France and British airways have left an opening for high-speed, prestigious travel, the likes of Virgin Galactic and Space Adventures are poised to profit from this demand. Many of their future clientele are Canadians. Canadian-based technology, for both the sky and the ground components of this new industry, is a key strategic investment for the future of the country.

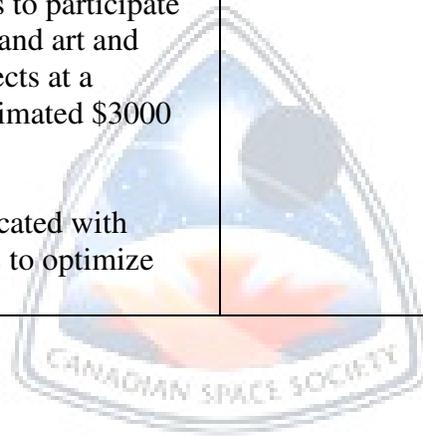
Technologies: Canadian Arrow, Cape Breton spaceport development proposal.

The development of a space tourism sector in Canada could create untold revenues, potentially on par with traditional tourism or transportation sectors.

Strengths	Weakness
<ul style="list-style-type: none"> <li>- Canadian industry already has some vested interest (see technologies above)</li> <li>- Canada has lots of space</li> <li>- A 'polar' view might be as attractive as an equatorial one</li> <li>- Canada already has one celebrity space tourists: Guy Laliberté</li> <li>- The modifications needed to enable a plane to handle parabolic flights are well understood and have been implemented before.</li> </ul>	<ul style="list-style-type: none"> <li>- Space tourism market is relatively new starting in with Dennis Tito's flight in 2001. Since then, less than 20 customers have become space tourists.</li> <li>- low cost, long range air carriers are becoming more numerous (competition)</li> <li>- Venture capitalists may not want to invest</li> <li>- No 'sweet spot' to be found for potential market demand</li> <li>- There is currently no regulations by Transport Canada on suborbital launches</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- X prize award created a great deal of interest around the world</li> <li>- Several private companies have announced investment and development in space tourism including Virgin Galactic, Blue Origin, Excalibur Almaz,</li> </ul>	<ul style="list-style-type: none"> <li>- X-prize winners have not had much success in taking tourists to space (to date)</li> <li>- High cost of space tourism (~\$20M for orbital flight and \$200K for suborbital flight)</li> </ul>

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<p>etc. that are determined to make space tourism a reality. These organizations and those to follow will require a base of operations. Why not Canada?</p> <ul style="list-style-type: none"><li>- Announcing a Canadian spaceport enhances Canada's prestige as a developed nation, and provides Canadians with access to a service that they would otherwise need to fly to the US, Europe, or the Middle East (Dubai) further increasing the cost to Canadians.</li><li>- Assuming that parabolic flights are included as space tourism, and would depart from a spaceport, investing in a Canadian spaceport increases the opportunity for Canadians to participate in microgravity research, and art and culture development projects at a relatively simple cost (estimated \$3000 per person)</li><li>- Space port could be co-located with Canadian launch facilities to optimize resources</li></ul>	<ul style="list-style-type: none"><li>- International and personal legal issues in case of a disaster</li></ul>
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## Celestial Body/Planetary exploration

Recommendation: Canada must be a part of the international community's efforts to expand human presence beyond Earth.

Many members of the Canadian Space Society feel that the future of humanity lies in our ability to explore and inhabit other celestial bodies, be it for much needed resources, or alternate locations to live.

Mankind's ability to find extra-terrestrial planets that may hold life, as we understand it, is limited but growing. Planetary exploration is something that Canada must be a part of and actively invest in, but there is more to exploring a planet than sending humans to walk on its surface. Canada's current technological investments have poised it to excel in a number of means to explore planets in our universe, and they should be enhanced to continue the effort.

Ground and space based telescopes, designed and built in Canada, such as the Microvariability and Oscillations of STars (MOST), have had success and prove Canada's capability in performing world-class Astronomy with a modest budget. These telescopes and their Canadian astronomers should be considered the cartographers of the future. Much like earlier explorers, who charted the Canadian wilderness, both professional and amateur astronomers are charting the sky, creating maps for future exploration.

Immediate financial benefits of this activity would be limited to the realm of academia and research but would later pay off in terms of robotic and human activities in space.

Strengths	Weakness
<ul style="list-style-type: none"> <li>- Canada has contributed greatly to the on-going success of Herschel Space Observatory (HSO) which is an ESA mission.</li> <li>- Blue Sky Spectroscopy (BSS) hosts the data processing and scientific analysis software (DAPSAS) centre for one of the HSO instruments (SPIRE).</li> <li>- University of Lethbridge along with BSS is involved in the developmental phase of the SPICA mission (by JAXA)</li> <li>- Canada is a global leader in resource and mineral exploration, and extraction technologies especially in sever/harsh environments (far north, coastal, deep</li> </ul>	<ul style="list-style-type: none"> <li>- Industries or Universities/Institutes have to do a collaborative work to accomplish the results because a single entity doesn't have the capabilities to do the whole work.</li> <li>- Canada has never lead a mission that has rendezvoused/touched down with another celestial body</li> <li>- Aging population with insufficient junior people to take on the existing responsibilities, let alone grow the field.</li> <li>- Canada's investments in space exploration are ad hoc and not planned in a strategic manner. Industry does not know what types of technologies to</li> </ul>

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<p>ocean drilling, etc.)</p> <ul style="list-style-type: none"> <li>- Existing world-class scientific baseline to build from.</li> <li>- Canada has world leading astronomers</li> </ul>	<p>develop</p>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- The abundance of minerals and resources on the Moon, asteroids, comets, etc. are mines that have long since been discovered, and yet to be extracted.</li> <li>- Canada has developed expertise in various instruments for space exploration and has expert scientists and academia to conduct world leading S&amp;T in Space Exploration</li> </ul>	<ul style="list-style-type: none"> <li>- Reduced funding for these space missions</li> <li>- Limited, or no immediate fiscal return on investment</li> <li>- Continued lack of interest in technical fields by Canadian youth, leading to a deficiency of human resources</li> </ul>



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**Space Robotics**

Recommendation: Canada should expand on its expertise in space-based robotics

Once the maps have been populated, follow-on missions can be sent to gain further detail of interesting bodies. Unlike our dangerous past, however, we need not send human explorers to scout the perilous environments (space is hazardous). Instead we can leverage our country’s robotics industry, currently focused on off-shore oil exploration and military applications, to seek out new resources, or other interesting areas. While Canada can likely find its own way, she should instead seek partnerships with like minded countries/corporations. Many other countries have similar capabilities and interests in this effort, and Canada should partner with them to further all our ambitions

With renewed interest in satellite refuelling and the intent of private businesses creating hotels in space, the case for robotic repair of space assets has never been more promising. To encourage our youth, and to create new business, Canada should invest in capitalizing on its extensive expertise of space-based robotics.

In addition to the obvious pay-back of satellite operators interested in revitalizing otherwise dead assets in space, robotic exploration of space could yield benefits in terms of extra-terrestrial mining efforts. Secondary benefits would be immeasurable because of all the lives not being risked in the dangerous environments of nearby celestial bodies.

Strengths	Weakness
<ul style="list-style-type: none"> <li>- Builds on Canadian knowledge base and success in robotics</li> <li>- Robotic technology applies to many fields</li> <li>- Canada has world leading expertise in Space robotics</li> </ul>	<ul style="list-style-type: none"> <li>- not as ‘sexy’ as human exploration</li> <li>- Requires other industries to succeed in space to provide return on investment.</li> <li>- Skills and knowledge fading fast, as past engineers are retiring.</li> <li>- No defined customer base exists</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- Highly attractive to new generation of Canadian engineers</li> <li>- Robots can/will play a major role in resource extraction missions</li> <li>- Robots could be the most ideal method in building space infrastructure and/or preparing for human space colonies/hotels, etc. (e.g. robots will prepare area prior to human arrival)</li> </ul>	<ul style="list-style-type: none"> <li>- Skills and knowledge fading fast, as past engineers are retiring</li> <li>- Requires other industries to succeed in space to provide return on investment.</li> <li>- Other countries could catch-up and surpass Canada’s expertise</li> </ul>

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- Role of robots in on orbit services to repair and maintain space based assets	
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**Human Space Flight**

Recommendation: Canada must be a part of the international community’s efforts to expand human presence beyond Earth.

Canada has had a manned spaceflight program for more than 30 years. The wealth of knowledge gained in past ventures should not be lost. As the world looks to explore the vast regions of space, Canada should be among them. Partnerships with almost every space faring nation have proved that Canada has much to offer in this arena. Through our partnership with the US and Russia, Canada has enjoyed many excursions to Low Earth Orbit, in multiple space vehicles (shuttle, Soyuz), visiting multiple space stations (ISS, Mir). As our partners venture further into the void, so too should Canadians. As our astronauts venture further out, the remainder of the population should be able to follow close behind. Already our citizens have followed astronauts to low-earth orbit and the International Space Station. As international partnerships bring pride to our astronaut corps, the country should pursue areas that would allow regular citizens to follow in their footsteps. Already partner countries are planning commercial ventures in space, while their governments talk about astronauts visiting nearby celestial bodies.

An additional benefit of the human space flight efforts to date is the expansion of life sciences that goes along with keeping humans alive, and healthy, in the harsh environment of space. The secondary benefits are vast, in terms of what can be learned about the human body and how to better treat illnesses on Earth. With an aging Baby-boomer population in Canada, interest in health and well-being in the retirement age is at an all-time high.

Technologies: Space Shuttle, ISS, Orbital repair, Osteoporosis research, Life science Research/Experiments

Direct financial benefit of this activity would be from the commercialization of any research benefitting humans while in space, for consumption by the regular population on Earth (drugs, physio techniques/procedures, etc.). Secondary benefits would include improved international partnerships within the global community, and continued relevance on the world stage.

Strengths	Weakness
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<ul style="list-style-type: none"> <li>- Canada has a history of firsts and exploration</li> <li>- Canada has a history exploration and settling in succeeding in the settlement of challenging environments</li> <li>- HSF technology is important to human exploration and expansion</li> <li>- Public has largely been supportive of Canadian astronaut efforts</li> <li>- Canada has an Astronaut Corp that is well respected in the international community, e.g. Chris Hadfield will be the first Canadian to command the ISS</li> </ul>	<ul style="list-style-type: none"> <li>- Canada relies on other countries for space transportation</li> <li>- Very expensive</li> <li>- Relies on others' technologies to get there</li> <li>- Competitive with other astronauts/cosmonauts for spots</li> <li>- Lack of marketing plan for applications of space-based research.</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- Role of humans in on orbit services to repair and maintain space based assets</li> <li>- Promote Canadian culture and values in future space colonies</li> <li>- Pride from future Canadians living in space knowing that their ancestors and leaders planned for their future</li> <li>- More humans in space should create greater interest/develop new technologies</li> <li>- Canada recently hired two new astronauts</li> <li>- Commercial flights are becoming proven, as demonstrated by Space X</li> </ul>	<ul style="list-style-type: none"> <li>- More humans in space increase risk of more deaths in space</li> <li>- Without continued investment in the Space program, Canada will not have access to more flight opportunities for its astronauts</li> </ul>

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**Global Partnerships within the space community**

Recommendation: Canada needs to expand its international partnerships with other players in the space area. The benefits, and historical successes, prove this to be a smart way forward.

Space is an expensive endeavour. While other countries may be able to fund their space interests independently, the sustainable means to space usage is with carefully selected partnerships. While not always easy, space ventures allow different nations to show their technological prowess, on an international stage. Despite all the criticisms of the international space station, considered the largest international development in history, Canada’s robotic contribution to the endeavour is acknowledged as a monumental success, both technologically, and for its significant contribution to a much larger program.

Small successes in larger projects, keep the international community coming back to seek Canada’s assistance. When the shuttle program was in difficulty, following the loss of the Shuttle Columbia, NASA turned to Canada to extend the existing Canada Arm capabilities and provide a means of scanning the entire surface of the shuttle for microscopic signs of damage. Were it not for Canada’s prior success and reliability in the area of space robotics, NASA would not have been so keen on engaging our services.

Strengths	Weakness
<ul style="list-style-type: none"> <li>- Inspires innovation.</li> <li>- Provides specialized resources</li> <li>- Increased coordination of space programs and efforts result in more efficient spending (e.g. less duplication of efforts)</li> <li>- In line with Canadian foreign policy</li> <li>- Canada is seen as a reliable international partner</li> </ul>	<ul style="list-style-type: none"> <li>- Integration is more challenging</li> <li>- Uncertain long-term commitment.</li> <li>- Vulnerable to political pressures</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- Enables execution of large programs</li> <li>- Enhances diplomatic relations</li> <li>- May encourage international standards</li> </ul>	<ul style="list-style-type: none"> <li>- Risk of transfer of intellectual property.</li> <li>- Differing motivations for participation</li> </ul>

# Aerospace Industry Review Paper

## Canadian Space Society

### Education, and workforce development

Recommendation: Canada should invest in space as a high-tech sector of opportunity to keep highly educated, highly paid employees in the country. Current trends in the space market sees too many Canadians leave for the United States or Europe. In order to accomplish all the efforts mentioned above, Canada will require a large, highly educated, technical pool from which to draw. More and more, those qualified to work in the field of space are moving elsewhere to do that work. Investing in an indigenous space capability will prevent this brain-drain.

Investing in the space industry in Canada will also reduce the drastic decline in the numbers of students interested in the sciences that has been taking place in North America over the past 10 years. It has been shown in many instances that the driving motivator for technical folks of the past was, in large part, the successes of the space race during the Cold War. With investment in the space sector in Canada, more jobs will be created, thus motivating students to maintain an interest in science and technology.

Strengths	Weakness
- Competent sector exists today, and can be built upon	- Space sector knowledge diminishing rapidly. Need to move fast.
Opportunities	Threats
- Create interesting new science and tech jobs for Canadian youth - Stop the “Brain Drain” to US and Europe	- Loss of current knowledge base - Inability to re-gain experience in a new generation of workers

### Mining and Materials processing in Space

Recommendation: Canada invest in technologies that support terrestrial based interests and space relate interests such as mining and materials’ processing in space

Dating back to the Chapman report, sound suggestions for Canadian industry include the investment in accessing materials from celestial bodies. With the recent venture by American investors to mine nearby asteroids, and China’s announcement to access resources on the moon and elsewhere, Canada could prove a very useful partner to both of these ventures, and in doing so, advance mining capabilities here at home, in terms of yield and environmental impact.

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Strengths	Weakness
<ul style="list-style-type: none"> <li>- Canada is a global leader in resource and mineral exploration, and extraction technologies especially in sever/harsh environments (far north, coastal, deep ocean drilling, etc.)</li> <li>- Provides opportunity for fiscal return on investment</li> <li>- Builds on Canadian knowledge base and success in space robotics that would be required in resource extraction/processing</li> <li>- Prospecting missions compliments Canada's strength in remote sensing</li> </ul>	<ul style="list-style-type: none"> <li>- Canada has never lead a mission that has rendezvoused/touched down with another celestial body</li> <li>- Technical feasibility may prove impossible.</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- Continuity of space programs</li> <li>- The abundance of minerals and resources on the Moon, asteroids, comets, etc. are mines that have long since been discovered, and yet to be extracted.</li> <li>- Internationally, both private firms and governments are interested in mining asteroids</li> <li>- Interest by terrestrial mining companies in improving "Dry-drilling" techniques, especially reducing the environmental impact</li> </ul>	<ul style="list-style-type: none"> <li>- Extremely risk</li> <li>- Inadequate international policies to protect investment and return of investment (e.g. unclear, unagreed upon ownership, and rights of access policies)</li> <li>- Environmental conservation and protection needs/ethics (e.g. disturbing pristine environments we don't yet understand)</li> </ul>