Canada's Space Sector: The Essential Enabler of Canada's Northern Strategy

NORSTRAT CONSULTING
BUILDING ON THE NORTHERN STRATEGY

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Contents

It took a railway to connect Canada from East to West.

It will take satellites to connect Canada from South to North.

EXECUTIVE SUMMARY

Though most Canadians have never set foot in our northern territories, they nonetheless view them as an integral part of the country and of our cultural identity.

These vast and unforgiving landscapes of the North are etched into our collective Canadian consciousness as barren and cold lands, but the widely acknowledged warming trend in the Arctic has begun to change this view. Globalization has driven demand for natural resources ever upwards, and thanks to the change in the Arctic climate coupled with technological advances over the last 20 years, the North has been opened up to exploration like never before. This exploration has revealed a richness of resources, from hydrocarbons to minerals, fresh water to fisheries. The North no longer looks so barren.

Yet it would be shortsighted to view the North as only a repository of resources. There is also a strong cultural link to our Canadian heritage. The aboriginal peoples of the North and their contributions to our national heritage are also part of our collective consciousness. Indigenous to the land for over 4,000 years, the Inuit were marginalized for a long time, but the Canadian Government has developed and implemented many devolution, self-government and land claim agreements over the last 20 years. The support of the Inuit is an integral component of any Canadian sovereignty policy regarding the Arctic and as such the human element of the North cannot be ignored.

The Government of Canada has announced a comprehensive Northern Strategy that addresses the opportunities and challenges associated with the development of the North. The strategy is based upon the following four priorities:

1. Exercising our Arctic sovereignty
2. Protecting our environmental heritage
3. Promoting social and economic development
4. Improving and devolving Northern governance

Focusing upon these four priorities will provide the foundation for a healthy, prosperous and secure North within a strong and sovereign Canada.

But I submit to you that there are a number of key issues almost as broad and vast as the North itself that need to be addressed if the Northern Strategy is to prove successful in its mandate. Among the obstacles are the interconnectedness and complexities of multi-departmental involvement in the Northern Strategy; the exorbitant costs associated with traditional infrastructure development in the North; and the question of establishing sovereignty in the face of global interest in the changing North.

This paper will present a four-pronged framework for Northern Strategy Infrastructure Development and six recommended policy options that will address the need for a Lead Northern Strategy Development Department, the establishment of a coherent framework regarding federal infrastructure investments and sovereignty issues, and the role of innovative aerospace and space-based infrastructure as a critical strategic enabler for Canada's Northern Strategy. If implemented correctly, these policy recommendations will help secure the North, aid in its development, and bring greater prosperity to all of Canada.

Summary of Recommendations

1. That Canada establish an infrastructure framework for the Northern Strategy and use that framework to better assess, prioritize, define, and integrate federal infrastructure investments.

2. That Canada appoint a lead Northern Strategy development department and individual to coordinate and integrate the infrastructure projects being undertaken by a long list of Federal departments and agencies.

3. That Canada provide predictable, long-term and sustained funding to allow previously recommended and approved Northern Strategy projects to proceed to completion without gaps.

4. That Canada vigorously pursue public-private-partnership-type funding arrangements with industry when and where appropriate.

5. That Canada consider collaborative space missions with our circumpolar neighbours, including pay-for-use of foreign-built missions, shared development, and pay-for-use of Canadian-built missions by other countries.

6. That Canada develop clear sovereignty guidelines for determining which missions must be Canadian built and which systems may be imported. Those guidelines should consider that Inuit "Sovereignty begins at home" tenet.

KEY FACTORS RELATED TO THE DEVELOPMENT OF CANADA'S NORTH

The global trends of climate change and globalization are bringing dramatic political, socio-economic and developmental change to Canada's North. They are two of the main drivers behind Canada's Northern Strategy, but before we look at them in greater detail, let us explore some constants that are important in any discussion regarding Northern development. The North is remote, severe, vast and populated (RSVP). Understanding the implications of these constants with regards to the key trends is integral to my policy recommendations.

Constants

Remote

The North is typically considered to consist of the Yukon, Northwest Territories and Nunavut, while the Far North refers to the lands located above the Arctic Circle. The remoteness of the North really hits home when one realizes that the three territorial capitals are all located above 60°N latitude, and the 100 or so other communities (most of 500 inhabitants or less) are scattered throughout 3.867,271 square kilometers. The world's northernmost permanently inhabited settlement is Alert in Nunavut, a mere 817 kilometers from the North Pole.

The transportation infrastructure is severely under-developed. As of 2003, a mere 1% of Canada's total road network was located within the three territories, and there are no roads to Nunavut.[1] Ice roads over frozen rivers and lakes are still used as a seasonal means of transporting goods across the vast distances. Of the three territories, only the Northwest Territory has any operating rail lines, and these account for a paltry 0.2% of the total Canadian rail network.[2]

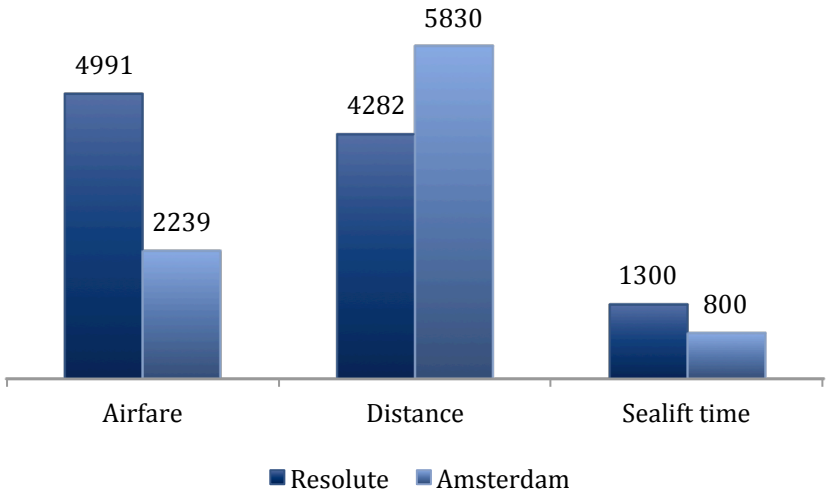

Figure 1: Access from Montreal to Resolute Bay and Amsterdam

[1]Statistics Canada, Length of Canada's Public Road Network 2003. (http://www.statcan.gc.ca/pub/16-002-x/2009001/tbl/transpo/tbl001-eng.htm)
[2]Statistics Canada. Percentage Distribution of Canada's Rail Network by Province and Territory. 2007. (http://www.statcan.gc.ca/pub/16-002-x/2009001/tbl/transpo/tbl002-eng.htm)

Air and sea routes provide for the majority inter-territorial transit and are also the primary supply chain infrastructure for goods from the south. These methods are both time consuming and costly. It takes a ship 13 days to travel from Montreal to Resolute, yet only eight days to make the transatlantic journey to Rotterdam in the Netherlands. Airfares from Montreal to Resolute cost over twice as much as airfares from Montreal to Europe or Asia.

Severe

The Northern climate can be considered challenging at best and severe at worst. Winters tend to be long and cold, while summers are relatively short and mild. Average January mean daily maximum temperatures range from -15°C across vast stretches along the 60th parallel, to -40° or so in the extreme northern reaches. Average January daily mean minimum temperatures are often an additional 10° to 15°C colder.[3]

Conditions throughout the North can become even more hazardous when there is a combination of low temperature and strong Arctic winds as the wind chill can drop to extreme or very extreme levels, reaching temperatures where exposed skin will freeze in minutes. Additionally, these strong winds can whip up falling or fallen snow into whiteout conditions.

Figure 2: C-130 aircraft weathers through an Arctic blizzard in Churchill, Manitoba, Canada

Vast

The North is quite simply, vast. In this instance, some numbers illustrate the sheer size of the North more effectively than words. Approximately 40% (3,593,589 km2) of Canada's land mass is located north of the 60th parallel.[4]Approximately 37% (328,150 km2) of Canada's freshwater surface area is found in the North. [5]The Canadian Arctic Archipelago consists of 36,563 islands, among them the world's fifth largest, Baffin Island. Almost 66% of Canada's territorial waters lie in the North.

Figure 3: The Canadian North is a vast territory of land and territorial water

[3]Natural Resources Canada.*Daily Minimum and Maximum Temperatures.*The Atlas of Canada. (http://atlas.nrcan.gc.ca/site/english/maps/environment/climate/temperature/temp_winter)
[4]Natural Resources Canada.*Land and Freshwater Areas.*The Atlas of Canada. (http://atlas.nrcan.gc.ca/site/english/learningresources/facts/surfareas.html)
[5]Natural Resources Canada.*Distribution of Fresh Water.*The Atlas of Canada. (http://atlas.nrcan.gc.ca/site/english/maps/freshwater/distribution/1)

Populated

Remote, severe and vast as the North may be, it is not devoid of human settlement. The Arctic has been inhabited by indigenous peoples for over 4,000 years. The Inuit were the first to arrive and came from the west, across the land bridge that spanned the Bearing Sea from Siberia to Alaska. The Inuit followed a nomadic lifestyle for millennia, but recently began to establish small, scattered communities throughout the North.

Exploration by the early European settlers and the discovery of rich resources and developing trade practices in the North led to the establishment of early outposts. Over time these outposts have waxed and waned, but eventually they led to the development of larger towns and cities. According to the 2006 census, the population of the North stood at 101,310 with a population density of just 0.03 people per square kilometer. [6]

But it is largely thanks to the presence of the Inuit in the east and north and First Nations peoples in the west, whose unique culture and strong ties to these Northern lands have proven to be the foundation of Canadian claims of sovereignty in the Arctic that Canada is able to sing of the "True North, Strong and Free."

Figure 4: Inuit mother and daughter on Baffin Island

[6]Statistics Canada.Population and dwelling counts, for Canada, provinces and territories, 2006 and 2001 censuses. (http://www12.statcan.ca/english/census06/data/popdwell/Table.cfm?T=101)

Key Trends

Climate Change

Current scientific opinion on climate change is that the world's climate system is unequivocally in the midst of a cycle of global warming. The Intergovernmental Panel on Climate Change (IPCC) position of January 2001 states:

An increasing body of observations gives a collective picture of a warming world and the changes in the climate system.

Two of the main conclusions of the IPCC were the following:

1. *The global average surface temperature has risen 0.6 +/- 0.2 C since the late 19th century, and 0.17 C per decade in the last 30 years.*
2. *If greenhouse gas emissions continue, the warming will also continue, with temperature projected to increase by 1.4 C to 5.8 C between 1990 and 2100. Accompanying the temperature increase will be increases in some types of extreme weather and a projected sea level rise.*[7]

There are currently no scientific bodies of national or international standing that hold a dissenting opinion, though some have adopted a more neutral "non-committal" position on the topic.

Figure 5: Pond Inlet Beach, Latitude 72° North, August 2008

This trend of global warming and climate change is even more pronounced in the North. Scientific evidence indicates that the Arctic climate is changing at a rate twice as fast as the rest of the planet.[8] The geo-physical implications of this accelerated rate of climate change in the North are worth noting.

First and foremost, the Arctic sea ice cover is in the midst of an extraordinary transformation. The Arctic Climate Impact Assessment, released by the Arctic Council at the Iceland Ministerial meeting in November 2004, documented that Arctic sea ice extent has been declining for the past five decades. Research has also indicated that sea ice thickness has been decreasing during the same period, and the area of multi-year ice has also been declining in the central Arctic Ocean.[9]

In 2007, record low levels of sea ice were observed and for the first time in history the Northwest Passage became fully navigable.[10] In 2007, the IPCC released its Fourth Assessment Report and the Global Climate Models presented simulated a continuous decline in sea ice coverage through the 21st century.

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[7] Intergovernmental Panel on Climate Change. Climate Change 2001. IPPC Third Assessment Report. 2001.
[8] U.S Navy. Energy, Environment and Climate Change. (http://greenfleet.dodlive.mil/climate-change/arctic-and-maritime-security/)
[9] "Arctic Marine Shipping Assessment 2009 Report." Arctic Council, 2009.
[10] Arctic Climate Impact Science. World Wildlife Fund. 2008. (http://assets.panda.org/downloads/final_climateimpact_22apr08.pdf)

The current consensus amongst researchers is that the Arctic will be "ice-free" for at least four weeks every summer by the 2030's. But these predictions are just that -- predictions.

Declining sea ice coverage can accelerate the effects of climate change in the North due to the ice-albedo positive feedback loop. White sea ice reflects sunlight back into space and helps keep the Polar Regions cool. As sea ice levels diminish more seawater is exposed, and since it is darker and less reflective it absorbs more heat, thereby accelerating the ice-melt process.

Reaching the tipping point at which the sea ice begins to melt at an exponential rate will result in a new climatic equation.[11]

Furthermore there is speculation that as the Arctic warms up there will be a corresponding increase in severe weather events and the North will become stormier.[12]

Yet even with the uncertainties that are inherent in trying to predict change in a system as complex as the Arctic climate, it is only prudent to acknowledge some of the implications that the consensus opinion on Arctic warming will have on the Canadian North.

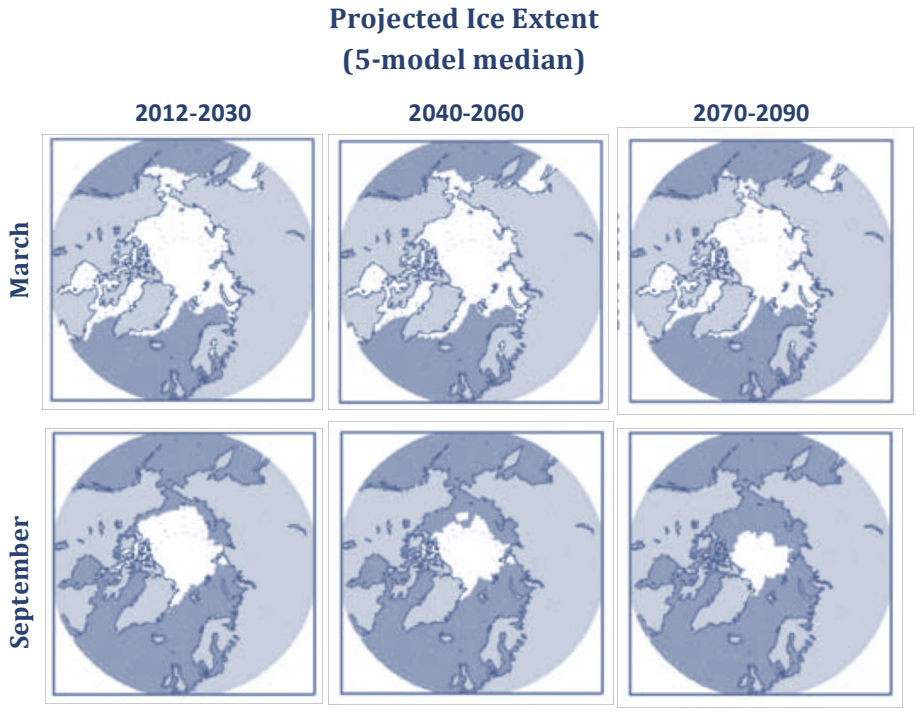


Figure 6: Projected Ice Extent

[11] Report of the Standing Committee on Fisheries and Oceans. Controlling Canada's Arctic Waters: Role of the Canadian Coastguard. Senate of Canada. December 2009. (http://www.parl.gc.ca/Content/SEN/Committee/402/fish/rep/rep07dec09-e.pdf)
[12] Sirpa Hakkinen et al., *Rising Arctic Storm Activity Sways Sea Ice, Climate*. American Geophysical Union's Geophysical Research Letters. Goddard Space Centre. 2008.

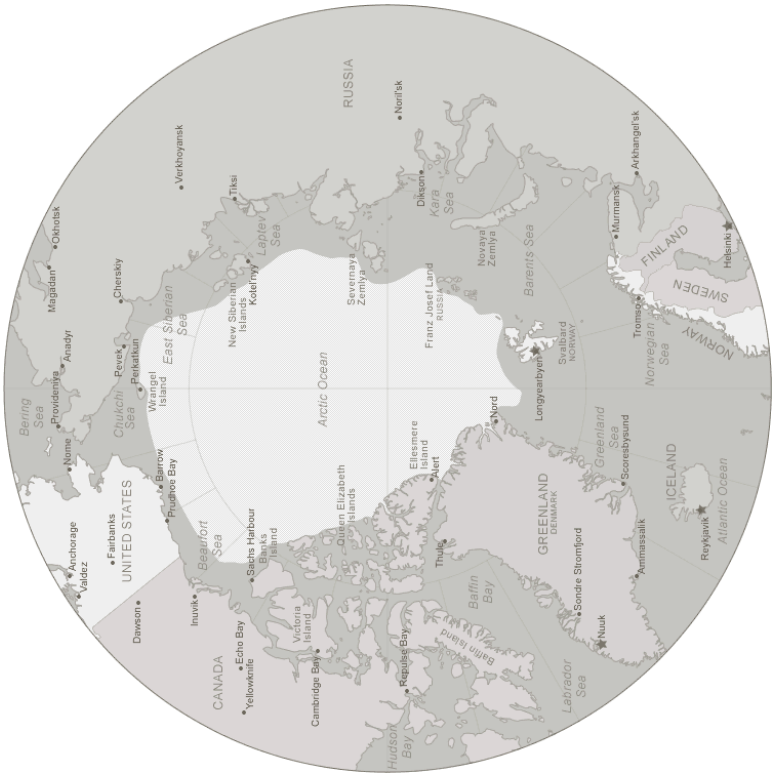


Figure 7: Arctic Ocean Summer 2012

Figure 8: Arctic Ocean Summer 2040?

Implications

The consensus opinion on climate change in the Arctic is that sea ice levels will recede and at some point in the not too distant future the Arctic Ocean and our territorial waters in the Canadian Arctic Archipelago will open to conventional shipping. The implications of this change are clear.

1. Increased Maritime Traffic

As sea ice recedes, the Arctic will become a much busier place. Should the Northwest Passage open up, commercial shipping (through traffic) would increase dramatically as it would offer international shipping companies significant savings in time and cost. It would shave 1,000s of kilometers and days off of the voyage from ports on the eastern coast of North America to ports in East Asia versus a similar trip through the Panama Canal.[13]

Vessel traffic would also be increased due to increased natural resource development in the North. The untapped potential of hydrocarbon and mineral deposits will create significant increases in destination traffic as energy and mining companies seek to explore and extract the previously inaccessible reserves that are generally considered to lie in abundance north of the 60th parallel.

Further vessel traffic will come via tourism. As the North opens up, Arctic cruises are expected to become more popular as more people become interested in the Arctic and wish to see it for themselves' before it is too severely affected by global warming.

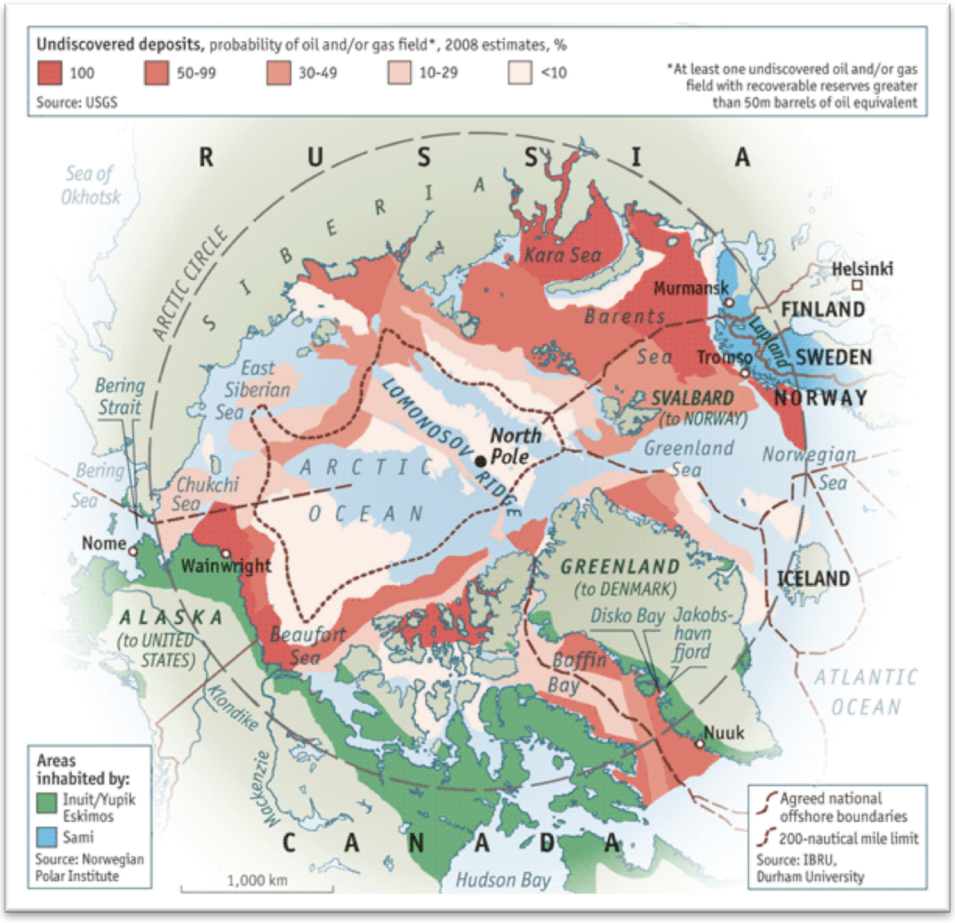


Figure 9: Our New Resource Frontier (Ref: The Economist)

[13] Report of the Standing Committee on Fisheries and Oceans. Controlling Canada's Arctic Waters: Role of the Canadian Coastguard. Senate of Canada. December 2009. (http://www.parl.gc.ca/Content/SEN/Committee/402/fish/rep/rep07dec09-e.pdf)

2. The Need for Improved Arctic Monitoring

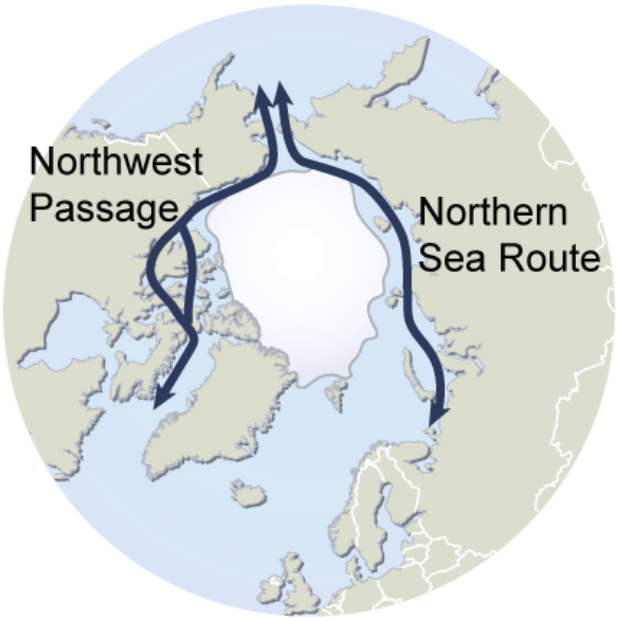


Figure 10: Better forecasting and monitoring will be required for NWP Traffic

With the predicted change in climate and sea ice coverage, and the expected associated change in maritime traffic, there also comes a need for ever greater and improved Arctic monitoring.

With the increased maritime traffic also comes increased risk of adverse maritime events. Collisions (vessel to vessel, vessel to ice, vessel to shore) become a much more real threat in a heavily traversed Arctic. The risk of pollution also increases as maritime traffic increases, with the potential of chemical pollutants, introduction of invasive species via discharge of ballast tanks, and noise pollution at the top of the list. Improved monitoring of vessels moving through Arctic waters is imperative.

While there is a general consensus on what will happen in the North with regards to the aforementioned climate change and sea ice levels, it is important to note that these are predictions and models, not absolutes. The climate is a complex system and as such extremely hard to predict with absolute accuracy. It is also worth noting that the Arctic Climate Impact Assessment and Global Climate Models were pushed to their limits in their determinations. [14]

Sea ice conditions will remain challenging, particularly throughout the winter, and as such would benefit from substantially improved regional monitoring and observations. Additionally, these observations can be used to help adequately assess future changes in sea ice extent and thickness via improved Global Climate Models.

[14] *Impacts of a Warming Arctic: Arctic Climate Impact Assessment*, Arctic Council, Cambridge University Press, 2004

Globalization

As another primary driver of development, globalization is likely to heavily impact the resource rich north. Global population growth, the unequal distribution of wealth, resource scarcity and political instability all look to play as the world increasingly looks to the North as a yet untapped repository of resources.

Figure 11: Climate Change Hits Heavily Populated Areas Hardest

Figure 12: Today's Piracy Plagued Maritime Trade Routes

The Ministry of Defence in its Strategic Trends Programme Global Strategic Trends – Out to 2040, 4th Edition noted that globalization is likely to continue:

> *Globalization is likely to continue…..Politically, globalization is likely to raise the level of interdependence between states and individuals within the globalized economy…..Economically, globalization is likely to generate winners and losers…..The physical manifestations of globalization are likely to be most apparent in the globalized core, which comprises the most interdependent and economically successful regions of the world. Instability within the globalized core is likely to adversely affect the national interests of major powers…..Resources, trade…..are likely to flow through this core and rely on complex networks of infrastructure that are likely to be vulnerable to physical disruption…..This infrastructure includes air and sea lanes and their associated ports, rail and road infrastructure, communications links, gas, oil, electricity pipelines…..energy production facilities.*[15]

[15]"Global Strategic Trends out to 2040." Development, Concepts and Doctrine Centre (DCDC), UK Ministry of Defence, February 2010

Implications

1. The growth of the global economy will not occur evenly and the improvements in and expanded use of Information Communications Technology will heighten the sense of grievance and marginalization between the 'haves" and the "have-nots". This disparity is likely to create new sources of insecurity, instability and tension.

2. The growth of the both the global population and the global economy will increase demand and competition for essential resources. Demand for energy is likely to grow by more than half again and fossil fuels will have to meet more than 80% of this increased demand.[16] The majority of the world's bulk energy trade will continue to transit primarily by sea and should the annual reduction in Arctic sea ice continue, Arctic sea routes will become strategically significant, offering shorter, more secure and more direct trade links between North America, Europe and Asia.

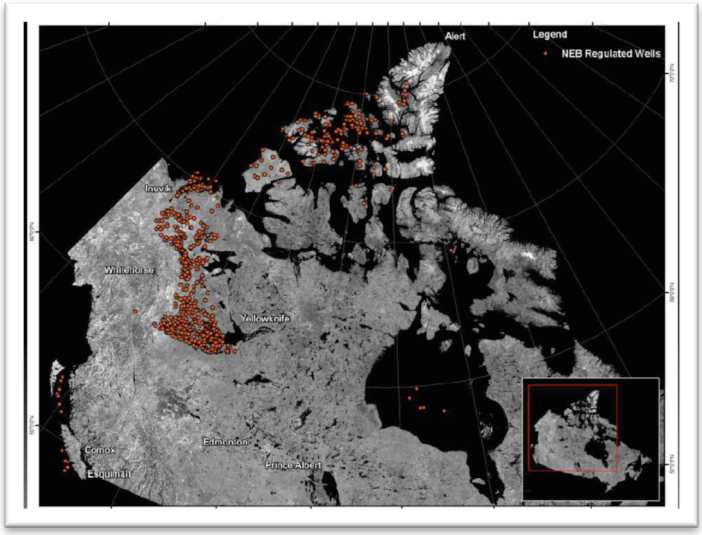


Figure 13: Oil and Gas Exploration in Canada's North

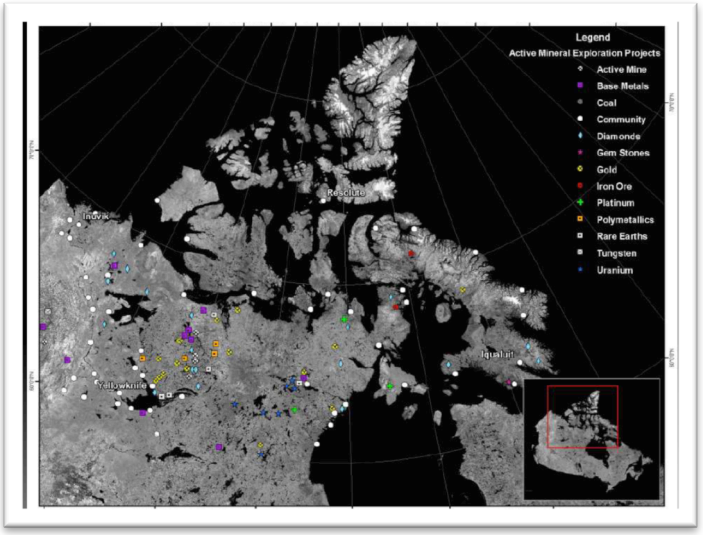


Figure 14: Mining Activity in Canada's North

Commercial air routes are already growing for the some of the same reasons. The number of polar flights has grown from 884 flights in 2003 to more than 10,000 per year anticipated by the end of 2011.[17] With this increase the need for improved infrastructure (air traffic control systems, radar, terrestrial and space weather monitoring) will also need to be addressed.

[16] British Petroleum. *Energy Outlook 2030*. January 18, 2012.
[17] NAVCanada. Strength in Numbers: 2011 Annual Report.

The Human Face of the Arctic

At first glance the Arctic and Antarctica would appear to have much in common. Remote, vast and severe can well be applied to both Polar Regions. Where the difference lies is in the human element. Antarctica is home to research stations manned by rotating crews of scientists and support workers. While many of the stations are permanently manned, they are occupied by, in effect, seasonal workers.

Not so the Arctic. The Arctic has been inhabited by numerous aboriginal peoples for the last 4,000 years. The Inuit arrived in Alaska from Siberia via a land bridge across the Bearing Sea. They proceeded to spread out throughout the North, following a mostly nomadic lifestyle, preferring to remain in the Northern latitudes primarily above the tree line. They followed this way of life for millennia, and many continue to do so. Marginalized for a long time, it has only over the last 20 years that the Canadian Government has developed and implemented many devolution, self-government and land claim agreements with the Inuit.

As of 2008, all of the Inuit claims in Canada have been settled and the new Canadian territory of Nunavut created. Self-government regimes are being established in the 3 other Arctic regions in Canada: the Inuvialuit Settlement Region in the Northwest Territory, Nunavik in northern Quebec, and the Nunatsiavut Government was established for the Inuit in northern Labrador in 2008. The signing of these land claims is very significant as it makes the Inuit a true partner in the development issues and sovereignty of Canada's North.

It is vital that the Inuit take their rightful place in the economic development opportunities emerging in the North. Lloyds of London, in its Arctic Opening: Opportunity and Risk in the High North study states:

> *The businesses which will succeed will be those which take their responsibility to the region's communities and environment seriously, working with other stakeholders to manage the wide range of Arctic risks and ensuring that future development is sustainable.*[18]

The notion of sustainable development quite clearly extends beyond the environmental impact – it must also recognize the socio-economic and cultural impacts upon Inuit communities.

[18]Arctic Opening: Opportunity and Risk in the High North, Lloyd's of London & Chatham House, April 2012 .

Sovereignty and Security Issues

Sovereignty and security concerns in the North revolve predominately around resource exploration and development and commercial shipping routes.

Under the United Nations Convention on the Law of the Sea (the LOS Convention), states are granted sovereign rights for exclusive exploitation of natural resources within a 200 nautical mile limit, their Exclusive Economic Zone (EEZ). Under the United Nations Convention on the Law of the Sea, a coastal state can claim control over mineral, oil and gas development to a maximum of 350 nautical miles if it can prove that the seabed is an extension of its continental shelf. Currently, Canada, Denmark, Norway, the Russia Federation and the United States are all mapping the ocean floor so as to stake a claim to the maximum allowable area for resource development. With so much at stake there are almost certainly to be disputes amongst circumpolar neighbours and other states who have cast an eye the riches of the North. For example, there is a long-standing dispute between Canada and the United States regarding the maritime border between Yukon and Alaska. There is also a dispute over Hans Island between Canada and Denmark in the eastern Arctic.

The second sovereignty issue surrounds the Northwest Passage. There is significant international dispute as to the status of the Northwest Passage. Canada considers it to be part of Canadian internal waters, and as such subject to our laws, regulation of usage and oversight. Under the Law of the Sea Convention, foreign vessels are not granted the right of innocent passage through internal waters. Canada has not tried to prevent innocent passage of international vessels, but if the Northwest passage were to be deemed an international strait (as the United States views it) Canada would lose the right to enforce our own laws and regulatory framework regarding shipping standards on international vessels seeking passage. Without the ability to apply these standards to foreign vessels the Northern environment and its citizens are at risk from vessels operating in Canadian internal waters that fail to meet the marine standards enacted by Transport Canada.

Summary

They say the world is getting smaller, yet thanks to climate change and globalization Canada (and the North in particular) is well positioned to play a much bigger part on the global stage. We have the opportunity to become a true resource superpower. But with that opportunity comes risks – to the environment, our citizens, our security, our sovereignty. We have a responsibility to see that the environment is respected and protected, that development is pursued in sustainable ways, and that all Canadians benefit from the development of our Northern frontier. To achieve these goals we must also recognize the challenges that the North presents due to it's scale and lack of infrastructure, and seek out technologies that could enable the realization of the aforementioned opportunities while meeting our responsibilities.

Vancouver Pre-Last Spike

Vancouver Post-Last Spike

Nunavut Pre-Northern Strategy Implementation

Nunavut Post-Northern Strategy Implementation

CANADA'S AEORPSPACE AND SPACE SECTORS AS POTENTIAL ENABLERS

"To develop the North, we must know the North. And to protect the North, we must control the North."

-Right Honorable Steven Harper, 2008

This simple yet astute summary of the Northern Strategy offered by the Prime Minister captures the essence of what is required of Canada in order to develop and protect our interests in the North. It is of course a summary, but it does provide a foundation from which a more thorough framework can be extrapolated.

The development opportunities and potential benefits to Canadians from coast to coast are immense, but they require an understanding of the North and the necessary investments that will be needed to be made in infrastructure along with a management and regulatory framework that will ensure sustainable development while our sovereignty is recognized and respected.

Northern Strategy Cornerstones

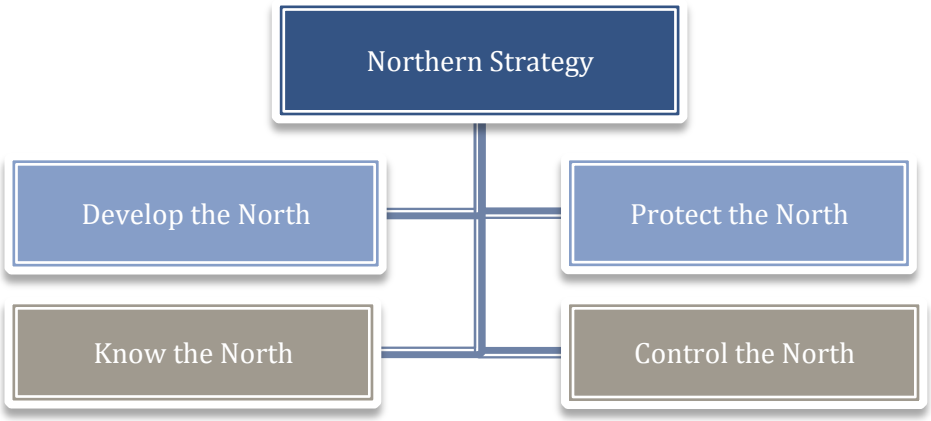


Figure: A Framework for Northern Strategy Infrastructure Development

The foundation contains two fundamental goals with regards to the sustainable development of the North (Develop the North, Protect the North), as well as two essential requirements (Know the North, Control the North). Let's look at these four cornerstones of the Northern Strategy independently.

Fundamental Goals

Develop the North

Looking at the first fundamental goal, we can see that it can be broken down into three constituent parts:

1. The exploration and extraction of the renewable and non-renewable resources (mineral, energy and fisheries most notably)
2. The socio-economic development of the North and its communities,
3. The creation of a legacy of core infrastructure improvements throughout the North.

Figure B: Northern development includes both resource and community development

It is important to consider that the success of the first constituent part will likely be dependent upon the level of success achieved in respect to the second two constituent parts.

Protect the North

Inter-twined with the development of the North is the protection of the North. Not only must the natural environment of the Arctic (land and sea, flora and fauna) be protected, but the people and communities of the North must also be provided with positive outcomes. Resource development often leads to untold riches, and at times unanticipated accidents and adverse impacts. As it is such necessary to ensure that there is an established regulatory framework that will help prevent out and out exploitation of the North and its people.

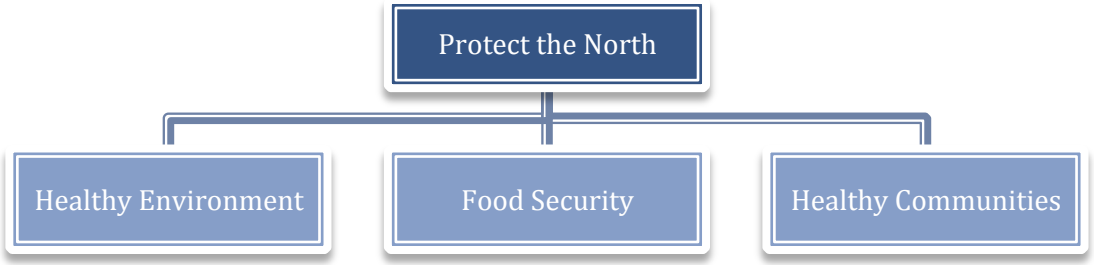


Figure C: The Northern environment, communities, and valued wildlife must be sustained

Essential Requirements

Know the North

To know an area as vast as the North will require essential investment in knowledge based infrastructure. The onset of Arctic climate change and its impact upon sea ice levels, coastlines, resource exploration and vessel traffic dictates that newer, more accurate and reliable information systems will be needed if we are to have a more complete understanding of the geo-physical, climatological and meteorological changes and the impact they will have on development and sovereignty.

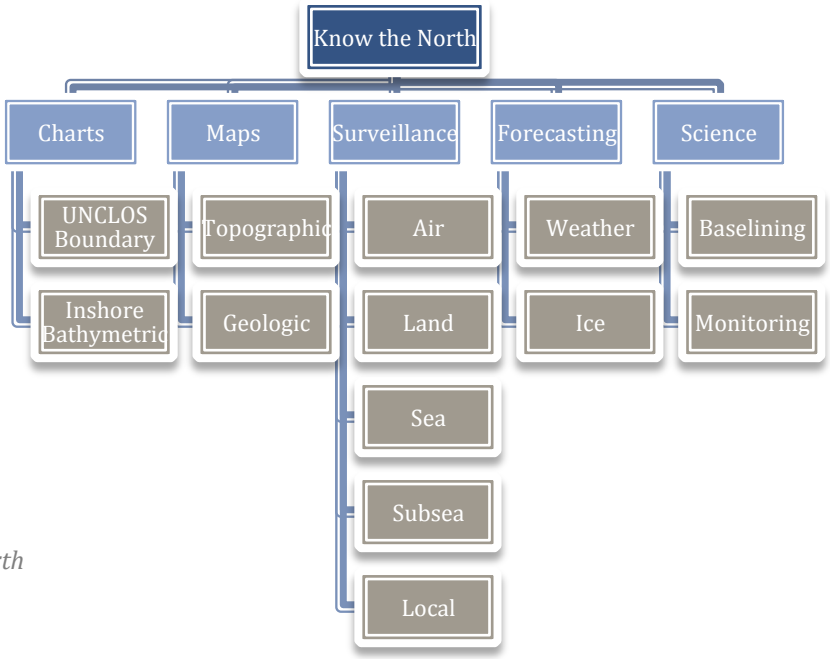


Figure D: Essential elements of knowing the North

Areas identified as requiring investment in knowledge-based infrastructure are:

- **Charts** of the Canadian coastal waterways, including hydrographic surveys. Accurate nautical charts help enable safe navigation of our territorial waters while hydrographic surveys and their emphasis on shorelines, tides, currents, soundings, and sea floor mapping (in particular identifying the extent of Canada's continental shelf) are especially important with regards to marine resource exploration under UNCLOS.
- **Maps** of the land including modern and up-to-date topographic and geological maps that will help facilitate land based resource exploration and development.
- **Surveillance** of land, sea, sub-sea, air, and space activities both on a macro scale but also as need dictates on a smaller regional or even localized levels.
- **Forecasting** and modeling of climatological change and its potential impact upon development as well as meteorological forecasting so as to be better informed of basic weather and sea ice conditions that may have a more immediate impact upon the development and security of the North.
- **Scientific** funding because science and knowledge are synonymous, and in order for Canada to make informed decisions regarding the North it is imperative that we not only understand the environment we are working in, but also how we affect it as we develop it.

Control the North

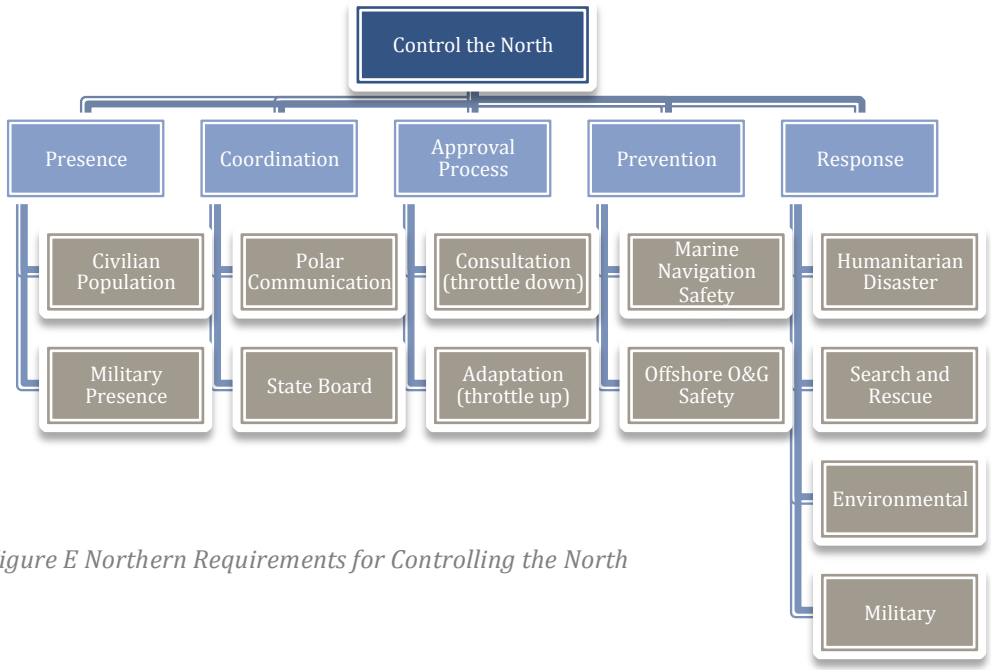


Figure E Northern Requirements for Controlling the North

Knowledge based infrastructure alone is not enough to assure the success of the Northern Strategy. We must also address the need for investment in means and methods that will ensure that Canada is able to control the North, among them:

- **Presence** is required, both military and civilian. The military presence requires investment in both personnel (a.k.a. "boots on the ground,") but also in vehicle platforms such all-terrain vehicles, air support and ice-breaking ships, as well as the supporting infrastructure such as airstrips and ports. Civilian presence needs to be garnered through active engagement of the people of the North.
- **Co-ordination** of elements as required to effect command and control, including communication links that provide the needed bandwidth across the whole of Canada's Arctic as well as decision support tools to fuse important date together into actionable intelligence. This includes high bandwidth connectivity to both fixed sites and mobile platforms, most importantly along the Northwest Passage, but also at latitudes above those served by geostationary satellites.
- **An Approval Process** that provides the appropriate level of review and scrutiny of development proposals in order to ensure they are sustainable and will create positive results for the North, while also providing support for changes to existing developments that have already been approved. The review process must be clearly laid out and follow clear timetables. Consultation and partnership with landowners is essential.
- **Prevention** measures and infrastructure that will help minimize the likelihood of accidents and damage to people and/or the environment. Key focus areas include the prevention of shipping incidents (groundings, collisions, discharge of pollutants, etc.) and offshore oil incidents.
- **Response** measures should the preventative measures fail. The North is set to become busier than ever with many groups taking an interest in it. We need the ability to respond to incidents of all kinds, including but not limited to humanitarian efforts, search and rescue operations, environmental threats and threats to our sovereignty.

NORTHERN INFRASTRUCTURE PROBLEMS AND SOLUTIONS

In order for the Northern Strategy to be implemented successfully, it will require immense investment in the systems and solutions outlined in the aforementioned framework. These required systems could best be described as an Arctic infrastructure. The problem? Currently there is very little in the way of an Arctic infrastructure, and in an environment as vast, remote and severe as the North, it becomes prohibitively expensive to build the traditional and familiar types of infrastructure (road, rail, power transmission lines, etc.) that are taken for granted in the rest of Canada.

Figure 15 The Canadian Arctic is lacking in basic infrastructure

Figure 16: The Arctic "Big Picture" from Space

Therefore, we need to look to alternative solutions to the Northern Strategy infrastructure requirements that are more cost-effective than the traditional types. The answer? Innovative, affordable aerospace and space-based solutions. These sectors have the potential to become the "silver bullet" solution to the problems associated with infrastructure requirements for areas as remote and severe as the North.

Space-based infrastructure is ideally suited to the North, as no place on earth is remote to a suitably orbited and tasked satellite. Satellites orbit above the weather, are able to image the earth in complete darkness and can view the big picture or the finer details.

To test the hypothesis that space-based infrastructure can meet the Northern Strategy's infrastructure requirements in a cost-effective way let's look at the requirements individually.

Figure 17: Northern Strategy Infrastructure Requirements and Space Solutions

Goal	Category	Requirement	Space-based Infrastructure Solution	Announced Project
Know	Charts	UNCLOS Boundary mapping		UNCLOS
		Inshore Bathymetric Charting	LIDAR satellite	
	Maps	Topographic mapping	Radar satellite constellation	RCM
		Geological mapping	EO or hyperspectral satellite	GEM
	Surveillance	Surveillance of air	ADS-B constellation	NWS
		Land	Radar satellite	Radarsat 2, RCM
		Sea	Radar satellite, AIS constellation	RCM
		Subsea		
		Local		Northern Watch
	Forecasting	Weather	Polar Orbiting Met satellite constellation	Polarsat
		Ice	Radar satellite constellation	Polarsat 2, RCM
	Science	Baselining	Atmospheric science satellites	BREA, CHARS, PCSP
		Monitoring	Climate change monitoring satellites	CHARS
Control	Presence	Civilian	ADS-B constellation	Polar Icebreaker, Polar Hawk, Hybrid Airship
		Military	Polar orbiting communications satellite, Cyber security	Rangers
	Coordination	Polar Communication over 75	Polar orbiting communications satellite, Cyber security	
		Response Management	Satellite ground segment and fusion centre	Polar Epsilon
	Approval Process	Consultation	Telepresence	
		Adaptation	E-Learning, Telepresence	
	Prevention	Marine Navigation Safety	AIS Constellation	
		Offshore O&G Safety	Radar satellite constellation, Communications satellite	RCM, Polarsat
	Response	Humanitarian Disaster	Radar satellite constellation	RCM
		Search and Rescue	COSPAS-Sarsat satellite constellation	MEOSAR
		Environmental	Radar satellite constellation	RCM
		Military	Polar orbiting communications satellite, Cyber security	AOPS
Develop	Resources	Energy	Radar satellite constellation	RCM
		Mineral	EO or hyperpersonal satellite	
		Fisheries	AIS Constellation	
	Communities	Living Standards	Telecommunications satellite, Elearning	
		Employment	Telecommunications satellite, Elearning	
		Social Conditions	Telecommunications satellite, E-Health	
	Core Infrastructure	Housing		
		Energy		
		Water		
		Waste management		
		Education	Telecommunications satellite, Elearning	
		Health care	Telecommunications satellite, E-Health	
		Social service delivery	Telecommunications satellite, E-Health	
		Transportation	AIS Satellite constellation, ADS-B Satellite constellation	
		Communications Network	Telecommunications satellite	
Protect	Healthy Environment			
	Food Security			
	Healthy Communities			

Analysis of the categories and their respective requirements and the space-based infrastructure solutions that address them indicate that most needs can be met via satellite solutions. There are already a plethora of satellite solutions either at conceptual, pre-announcement or announcement stages, most notably:

- **Radarsat Constellation Mission (RCM)**, which will provide end of life replacement to Radarsat 2 in support of land surveillance and sea ice forecasting, but which will also provide more frequent coverage and tandem satellite operation with applicability to maritime traffic surveillance, topographic mapping, humanitarian efforts, oil spill detection and response and directly support the oil and gas industry.
- **Polarsat**, which will provide accurate weather forecasting above the latitudes supported by geo-stationary meteorological satellites, but also high bandwidth satellite communication for fixed and mobile platforms north of 70 latitude.
- **Polar Epsilon**, which provides a needed ground segment to support military response in the Arctic.
- **MEOSAR**, which will provide timely transmission of search and rescue beacon distress signals for incidents around the world, including the Arctic.
- **AIS-S Constellations** of the type being developed and operated by industry on a pay for use basis. This constellation supports Arctic maritime traffic surveillance and maritime accident prevention.
- **ADS-B Constellations** of the type recently announced by NAVCAN that will provide civilian air space surveillance over the increasingly busy polar routes.

Needs that are not able to be met via satellite can still be addressed by non-traditional infrastructure solutions that are aerospace based. Some of these alternative solutions include:

- **Hybrid Air Vehicles**, such as the Discovery Air hybrid airship, which offer the potential to provide affordable, all-season logistical support to land based operations virtually anywhere in the North.
- **Multi-sensor (Satellite and Aircraft) Ground Segment** allowing for near real-time analysis and response from polar orbiting satellites and aircraft as well enabling command of manned or unmanned aircraft operating in the North.

Figure 18: Innovative northern presence infrastructure proposed by Discovery Air

As yet unannounced infrastructure requirements identified within the Know the North framework that could be implemented in a relatively cost-effective manner with space-based infrastructure include:

- Wide area space based bathymetric charting using LIDAR.
- Wide area geological mapping in support of mineral exploration using hyper-spectral EO sensors.
- Scientific research to baseline the Arctic environment and to monitor and predict the effects and impacts of climate change.
- Higher capacity satellite telecommunications coverage with increased and improved applications (including E-learning, E-health, high speed internet and television) for Northern communities.

INVESTMENT SURVEY AND ANALYSIS

In order to better understand the investments required to provide these Northern Strategy infrastructure needs, NORSTRAT Consulting interviewed a number of experts within Canada's space sector as well as experts on the Northern Strategy. These are listed in Table 1 below.

Expert	Affiliation	Title	Note
Terry Audla	Inuit Tapiriit Kanatami	President	1
Doug Bancroft	Natural Resources Canada	Director General, Canada Centre for Remote Sensing	
Paul Bush	Telesat	Vice President, North American Sales	
Lee Carson	NORSTRAT Consulting	President	
Andre Dupuis	Department of National Defence	Director, Space Requirements	
Ron Holdway	COM DEV Canada	VP, Government Relations	2
John Hornsby	MDA Surveillance & Intelligence	V.P. Geospatial Strategy, MDA Surveillance & Intelligence	3
Steve Maclean	Canadian Space Agency	President	
Mike Manore	Environment Canada	Director, Monitoring Strategies and Data Management	4
Jean-Francois Petit	EADS Astrium	Regional Director, Europe and Canada	
Nick Xenos	Aboriginal Affairs and Northern Development Canada	Director, Arctic Science Policy	5

Notes:

1. ITK was unfortunately not available for an interview.
2. As delegated by David Lizius, President of COM DEV Canada.
3. As delegated by Mag Iskander, President of MDA Information Systems.
4. As delegated by David Grimes, ADM (Meteorological Systems)
5. As delegated by Janet King, ADM, Aboriginal Affairs and Northern Development Canada

These experts were asked a range of questions, including:

1. In your view, where can Canada's space sector best contribute to Canada's Northern Strategy with existing technologies?
2. What solution gaps exist, and what research and development would you propose to close those gaps?
3. What investments are needed to implement these space-based infrastructure solutions, and by whom (space industry, resource industry, government)?
4. What are the major obstacles to investment and what needs to be done to remove, reduce or overcome them?
5. What should be the government's policy in facilitating cost-effective implementation of the Northern Strategy?

Summary of Responses

The experts interviewed for this survey represented government and industry, and it was interesting to note that their views and assessments were very similar. Both private and public sector experts made the observation that in order to implement Canada's Northern Strategy, Canada's strategic space industry and government need to work together in partnership.

High Value Space Infrastructure Contributions

Many of the experts made the compelling case that space-based infrastructure is ideally suited to the 'RSVP' North. Remoteness is not an issue for polar-orbiting satellites as they can provide frequent, or if arrayed in a constellation, continuous coverage of the North. Satellites fly above the weather and, with active sensors, can perform their missions even through cloud and 24-hour polar nights.

Only satellites can cost-effectively cover vast expanses of the earth, and all of our Northern civilian communities are within range of existing geostationary communications satellites. Satellites provide the means to connect Northern communities to each other, to the South, and to the rest of the world. In short, **space infrastructure is a key strategic enabler of Canada's Northern Strategy**.

Experts from both government and industry also made the case that space infrastructure can make other direct and important contributions to the North. From base lining and monitoring the Arctic environment, to supporting safe and responsible development of our natural resources, to helping establish and enforce our Arctic sovereignty, space infrastructure has the capability to help significantly address Canada's Northern priorities. And improvements are not limited to environmental or resource-based development, but also extend to creating positive outcomes for Northern communities by enabling non-resource, information based sectors of the Northern economy.

The people interviewed made reference to a large number of space missions in operation that are already making important contributions to Canada's Northern Strategy. These include space missions funded by the Federal government, by industry and in partnership. Examples include:

- Radarsat I and Radarsat II, which monitor the environment, help support our sovereignty claims, and increase safety of navigation.
- Existing geostationary communications satellites, which have both the range and the capacity to serve Canada's Northern communities.
- Space-based Automatic Identification System, which significantly reduces the cost of maritime surveillance.
- Atmospheric science missions including MOPITT and SCISAT, which help Canada monitor the global effects of climate change and help to better predict and adapt to the changes.

Value of Future Missions

As for future missions, respondents generally confirmed the value of future space missions already in the pipeline, including:

- Radarsat Constellation Mission, which will succeed Radarsat II and provide more frequent coverage, which will in turn enable new applications for marine safety, and sovereignty.
- Polarsat Weather Mission, which is expected to decrease the cost of travel in the North as well as improve the quality of life and safety of Northerners.
- Polarsat Communications Mission, which will allow real-time broadband communications with moving military platforms (planes, unmanned air vehicles and ships) in the far North.
- ADS-B, which will reduce cost and increase safety of commercial air traffic flying polar routes.

Aside from these large space missions, experts also identified high value investments in Canada's associated ground infrastructure, including:

- Upgrades to our Northern satellite telecommunications ground infrastructure in order to replace aging equipment, and to improve reliability and service to Northern communities.[19]
- Building Northern satellite downlinks, capable of receiving data from not just Canadian earth observation satellites, but also from the dozens of foreign polar orbiting satellites with whom we have or could obtain data sharing rights.
- Connecting those high latitude ground stations with the South via high capacity fiber optic links, so that data can be streamed from the satellite to the users in near real-time.

Finally, respondents identified a number of additional areas where existing and proven space technology can make a large and cost-effective contribution. These include:

- Hydrographic charting of shorelines and shallow water using LIDAR optical remote sensing technology (already proven via a pilot project by the Department of Fisheries and Oceans).
- Geological and topographic mapping using existing optical and future planned radar satellites
- Continuous surveillance of the Arctic using a constellation of radar satellites.

Export Opportunities

It was also noted by some of the experts that significant export spin-off opportunities might arise as a result of Canadian space-based infrastructure investments. The global trends of climate change and globalization are impacting all of our circumpolar neighbours and their concerns and needs are for the most part very similar to ours. Since polar satellites do not "park" themselves over Canada but instead cover all longitudes, it is likely that any Canadian polar space-based infrastructure would have applicability to other circumpolar nations and as such could be developed into an export revenue stream.

[19] "A Matter of Survival: Arctic Communications Infrastructure Assessment Report." Imaituk Inc., The Northern Communications & Information Systems Working Group, April 30, 2011

Solution Gaps and Research and Development Needs

The general consensus among the experts interviewed is that currently there is not much of a capability gap with regards to the development needs of future space missions. Generally, the technologies required to build the needed solutions currently exist, many of them available right here in Canada.

This is especially true in areas where Canada enjoys a leadership niche, including C-band radar satellites and satellite communications. For areas outside of those niches, Canada should negotiate data sharing agreements and build the infrastructure (i.e. high altitude ground stations) needed to access those existing foreign missions.

There was also a broad consensus that there needs to be a continued focus on reducing the cost and cost-related barriers to entry of space missions. This includes:

- Increasing the lifetime and reliability of small satellites.
- Further miniaturization of satellites.
- Better data processing software.

Where there is an identified gap is between the satellite missions and the user community, in particular the development companies that could leverage this space infrastructure to explore, develop and monitor their operations. More work is required to bridge this gap between the space community and the development market, i.e. to make space less elitist and more developer friendly. The good news is that this market is large, the potential benefits of space technology are real, and that the Canadian space industry is working hard to understand and address them.

Case Study: Satellite Technology and Alberta Oil Sands Development

The Athabasca oil sands lie under roughly 141,000 square kilometers of sparsely populated territory in Northern Alberta. The deposits of bitumen represent a significant natural resource that could theoretically rival the proven world reserves of petroleum.

The economic benefits of the oil sands are clear, but part of the cost of extraction is the associated environmental impact. In order to ensure the development of the oil sands is performed responsibly with respect to the environment, satellite remote sensing technology has been implemented for base-lining and regulatory compliance monitoring. Capabilities of remote sensing have expanded from land and vegetation monitoring to also include water quality monitoring.

Remote sensing technology was selected as the data collected is neutral and consistent and allows for detailed (less than 1 metre resolution), multi spectrum (optical, infra-red, radar) analysis that is more frequent and cost-effective.

And it should be noted that Natural Resources Canada observed, *"This space asset is growing but under-utilized!"*

Investment Needed

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. Examples here include the investment in hybrid airships by Discovery Air, in space-based Automatic Identification System (AIS) infrastructure by exactEarth, and in ADS-B space-based air traffic control by NAVCAN.

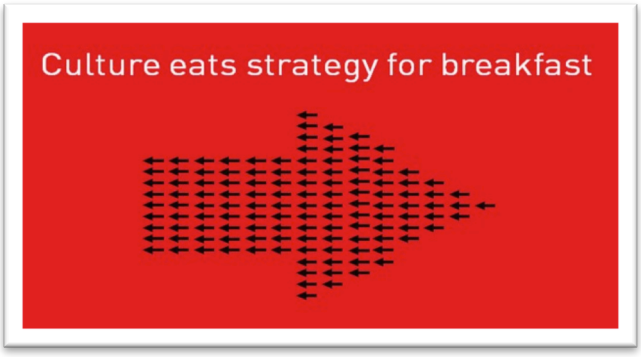
However, in other cases, the sparse population of the North or current public policy makes pure commercial investment in space infrastructure uneconomical. Examples include large private investments in telecommunications infrastructure in the North instead of more lucrative, populous regions; or in building weather forecasting infrastructure when weather forecasts are provided for free to the general public.

In those cases, it is up to the Federal government to make the strategic decision to invest in northern infrastructure, just as it invested in the Trans-Canada Railway. That business model can take on different forms, including traditional up front investments, or public-private-partnership arrangements that amortize the cost over a longer period. Both models are acceptable to industry.

Cost sharing arrangements are also possible and can make sense where the Federal government makes the initial investment in building the infrastructure, but industry and/or academia invests in its operation and in the development of value-added applications that make use of the core infrastructure.

Obstacles to Investment

The responsible development and protection of Canada's North is not just a short-term development need, but rather a long-term, highly strategic and vitally important program. This mandate is, and will continue to be, the most important economic development program in Canada in the 21st century - which makes the Northern Strategy the most important economic stimulus program in the country. All respondents from government and industry agreed on this point.



The Northern Strategy and the investments required to implement it must be managed accordingly. As an all of government strategy, it requires more than the championship of the Prime Minister, as valuable as that is. It requires a strategic plan that includes a framework that guides decision-making, encourages innovative problem solving, and provides support via long-term funding. It also requires top-down leadership, management and coordination.

Until this occurs, the needs and pressures of individual departments and individuals will trump strategic imperatives, decisions will be stalled, recommendations will be vetoed, and costs of projects partially approved will escalate unnecessarily.

Several of the experts I spoke to drew a parallel between the current situation in the space sector with that of the boom and bust cycle of the Canadian shipbuilding industry. In the past, the chronic and thorny issue of Federal Major Crown Project definition and approval has created obstacles to procurement of large, complex projects. This multi-faceted obstacle has several root causes including:

- Capacity issues related to available experience and expertise needed to properly define, specify, estimate and procure complex engineering systems.
- The complex relationships between individuals, boards, departments and agencies for project review and approval.

The recent innovative approach to the National Shipbuilding Procurement Program could perhaps be applied to large space-based projects.

These issues are further complicated in the Northern Strategy because:

- The Northern Strategy is a whole of government strategy involving no fewer than 20 different Federal Government departments in a significant way (AANDC, ANDC, CEAA, CNEDA, CPC, CSA,DRDC, EC,DFO, DFAIT, HC, IC, PCO, DND, NRC, NSRS, NRCAN,NPA, PMO, PWGSC, TC).
- The projects are inextricably linked—in other words, it makes little sense to build patrol ships for the North if there are no charts for navigation or means of communication with the ships.
- As yet, there is no clear lead department or agency, no identified Northern Strategy budget, and no coordinating program integrator.

Government Policy on Investment

While the technical and strategic reasons for investing in space-based infrastructure solutions to Canada's Northern Strategy problems are clear, nobody is suggesting that Canada write the proverbial "blank cheque" for their development. Some of the things Canada can do to minimize the cost of these investments are as follows:

1. Using the architectural framework described in Section 3 or an equivalent one, define a top-down statement of requirements and problems that must be solved. Invite departments and industry at large to propose solutions to those problems. The benefits of this approach are as follows:
    a. Avoids the problem of considering and funding "solutions in search of a problem".
    b. Identifies the cost advantages or disadvantages of space solutions as compared to other non-space alternatives.
    c. Identifies gaps, overlaps and interdependencies between related systems and solutions early in the process.
2. Allocate budgets and foster competition. Encourage design-to-cost "good enough" solutions and leverage competition between companies and approaches to get the best possible price. Structure contracts (e.g. public-private-partnerships versus traditional procurement) to minimize cost given the management structure, capacity, costs and capabilities of different organizations.
3. Encourage Northern solutions to Northern problems. Northern facilities and ground stations do not need to be built to Ottawa Class A real estate standards. Ensure applications are written for, and accepted by, Northern residents and developers.
4. Clarify policy definitions relating to "public good" versus "private gain" investments to guide the industry in proposing cost-sharing arrangements. Encourage arrangements whereby Canada pays for initial infrastructure development and possibly "first user" rights, but industry and/or academia invests in operations and value-added applications development for resale to Northern residents and developers.

RECOMMENDED POLICIES FOR AEROSPACE AND SPACE SECTOR SUPPORT

Canada's North is in the midst of a remarkable transformation thanks to climate change and globalization. With these developments comes great opportunity for Canada. The untold wealth of resources that have lain hidden beneath the ice and snow are now slowly being revealed, while the Northwest Passage has the potential to become one of the world's great maritime transit-ways. With these opportunities for development comes responsibility, to the environment and the people. But the North is still as vast and remote as ever, with limited traditional infrastructure. It is in this environment that aerospace and space-based infrastructure solutions can help address the opportunities and responsibilities. What follows are six policy recommendations with regards to aerospace and space sector support of the Northern Strategy.

1. That Canada establish an infrastructure framework for the Northern Strategy and use that framework to better assess, define, prioritize and integrate federal infrastructure investments.
    - Because without such a framework the Government has no basis to judge the merit of development and funding proposals.
    - Because the framework allows the Government to identify critical gaps in its response to Arctic infrastructure and sovereignty.
    - Because the framework allows the Government to identify overlaps or potential overlaps between development proposals and projects being implemented by different departments.

2. That Canada appoint a lead Northern Strategy development department and individual, with a direct link to the Canadian Space Agency, to coordinate and integrate the infrastructure projects being undertaken by a long list of Federal department and agencies.
    - Because the projects *ARE* inter-related and are being done by many different and unrelated Government departments.
    - Because the current lack of coordination and integration is a recipe for waste and project failure.
    - And because space is a critical and strategic enabler of cost-effective Northern infrastructure.

3. That Canada provide predictable, long-term and sustained funding to allow previously recommended and approved Northern Strategy projects to proceed to completion without gaps.
    - Because the opportunities and risks behind the Northern Strategy are far too important and urgent to ignore or defer.
    - Because funding gaps significantly increase the cost and risk of projects that need to be built.

4. That Canada vigorously pursue public-private-partnership type funding arrangements with industry when and where appropriate.
    - Because such arrangements can be an efficient and effective work around to some of the capacity and procedural issues and constraints that plague the Federal Major Crown Project definition and approval process.
    - Because the Canadian space industry has proven its willingness and ability to take on the public-private-partnership responsibility.

5. That Canada consider collaborative space missions with our circumpolar neighbours including shared development, pay-for-use of Canadian built missions by other nations, pay-for-use of foreign built missions by Canada.
    - Because the root cause factors behind Canada's Northern Strategy are largely common to all circumpolar nations.
    - Because the orbits of polar satellites travel across all longitudes.
    - Because Canadian leadership in polar space-based infrastructure development creates the opportunity for significant export opportunities for the Canadian space sector.

6. That Canada develop clear sovereignty guidelines for determining which missions must be Canadian built and which systems may be imported.
    - Because much of the space-based infrastructure will be built to collect sensitive data which could compromise our sovereignty.

ABOUT THE AUTHOR

Lee Carson is a long time member of Canada's space and defence industry, where he held a number of management and executive level positions for Canadian companies at MDA and later with COM DEV Canada. He is very familiar with the Federal Government procurement system, with Major Crown projects and with C4ISR systems –whether they be satellite, aircraft, ship or shore based.

While his experience is with federal procurement of C4ISR systems, Mr. Carson's passion is for the Arctic. From and early interest in polar explorers, to mapping sea ice, to exploring the area by kayak, to striving to better understand the Inuit perspective and culture, Lee really does love Canada's North.

Lee Carson is now the President of NORSTRAT Consulting Inc., a company he has created for the sole purpose of helping clients with their goals to help build the elements of Canada's Northern Strategy.

BIBLIOGRAPHY

Books

Byers, Michael. *Who Owns the Arctic?* Douglas & McIntyre. October 24 2009.

Dyer, Gwynne. *Climate Wars: How Peak Oil and the Climate Crisis Will Change Canada (and Our Lives.*http://www.amazon.com/Climate-Wars-Crisis-Change-ebook/dp/B0031TZAXO/ref=sr_1_1?s=digital-text&ie=UTF8&qid=1341490288&sr=1-1&keywords=Gwynne+Dyer%2C+Climate+Wars Vintage Canada. August 18, 2009.

Emmerson, Charles. *The Future History of the Arctic.* Public Affairs. March 2, 2010.

French, Hugh & Olav Slaymaker. *Changing Cold Environments: A Canadian Perspective.* Wiley-Blackwell. October 14, 2011.

Struzik, Ed. *The Big Thaw: Travels in the Melting North.* Wiley. April 23 2009.

Reports

British Petroleum. *Energy Outlook 2030.* January 18, 2012.

Carson, Lee. Northern Light: Arctic Strategy Points to Comprehensive Solution, Northern Lights Conference, February 2012

Carson, Lee. What's Next for Canada's Northern Strategy? Vanguard Magazine, March 2012

Report of the Standing Committee on Fisheries and Oceans. Controlling Canada's Arctic Waters: Role of the Canadian Coastguard. Senate of Canada. December 2009.
(http://www.parl.gc.ca/Content/SEN/Committee/402/fish/rep/rep07dec09-e.pdf)

Conley, Heather and Jamie Kraut. "US Strategic Interests in the Arctic: An Assessment of Current Challenges and New Opportunities for Cooperation." Centre for Strategic and International Studies. April 2010

Sirpa Hakkinen et al., *Rising Arctic Storm Activity Sways Sea Ice, Climate.* American Geophysical Union's Geophysical Research Letters. Goddard Space Centre. 2008.

Arctic Climate Impact Science. World Wildlife Fund. 2008.
(http://assets.panda.org/downloads/final_climateimpact_22apr08.pdf)

Fournier, Stefan. 'Getting it Right: Assessing and Building Resilience in Canada's North". The Conference Board of Canada, May 2012

Huebert, Rob. "The Newly Emerging Arctic Security Environment." Canadian Defence & Foreign Affairs Institute, March, 2010

Jenkins, Tom. et al. "Innovation Canada: A Call to Action, Review of Federal Support to Research and Development, Industry Canada, October 2011

"A Matter of Survival: Arctic Communications Infrastructure Assessment Report." Imaituk Inc., The Northern Communications & Information Systems Working Group, April 30, 2011

"Arctic Marine Shipping Assessment 2009 Report." Arctic Council, 2009

Arctic Opening: Opportunity and Risk in the High North, Lloyd's of London & Chatham House, April 2012

Canada as an Arctic Power: Preparing for the Canadian Chairmanship of the Arctic Council, Munk School of Global Affairs, May 29, 2012

"Circumpolar Declaration on Sovereignty in the Arctic." Inuit Circumpolar Council (ICC), April 2009

"Circumpolar Inuit Declaration on Resource Development Principles in Inuit Nunaat." Inuit Circumpolar Council (ICC), May 2012.

"Global Strategic Trends out to 2040." Development, Concepts and Doctrine Centre (DCDC), UK Ministry of Defence, February 2010

Johansson, Margareta. The Arctic as a messenger for global processes - climate change and pollution, Lund University, Copenhagen, May 3-6, 2011

Global Climate Models used in the Arctic Climate Impact Assessment (ref. Impacts of a Warming Arctic: Arctic Climate Impact Assessment, Arctic Council, Cambridge University Press, 2004

Comiso, Josefino. Large Decadal Decline of the Arctic Multiyear Ice Cover, C., 2012: