Canadian Space Agency Agence spatiale canadienne

Canadian Space Agency

CSA Submission to the Review of Canada's Transportation Act

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Canada

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EXECUTIVE SUMMARY

"Space-based assets are strategic infrastructure essential to the functioning of modern economies and societies. They have made possible a global communication revolution, new ways of monitoring the Earth's surface and atmosphere, the command and control of transportation systems and military hardware, and a more profound understanding of our place in the universe." (Source: Aerospace Review Report, 2012)

Throughout Canadian history, transport has played a critical role in the development of our nation, forging a strong economy and establishing strong trade connections around the world. Moreover, the exploration of space has changed the manner in which we see and understand the universe and our origins. We live in a world of technology where technology innovation will continue to accelerate with greater relevance to our lives and our environment. Space has had a formidable and pervasive impact on all modes of transportation. As space technology evolves, it will continue to revolutionize the transportation industry.

Canada's Space Policy Framework (SPF) reflects the intention of the government to align the deployment of Canada's future space systems with our national priorities. In this context, the review of *Canada's Transportation Act* provides a unique opportunity to signal space requirements that are specific to transportation when planning for future space capability in Canada. Based on today's usage of space across the economy and in transportation more specifically, it could be envisaged that its impact will increase, and that space will further become deeply rooted into all transportation modes especially in the North. In 2011, the Canadian satellite Anik F2 malfunctioned and disrupted long-distance calls, cell phone service, data communications, internet, television services and banking machines causing a total black-out in the North. This interruption of satellite communications provides an illustrative example of how critical space-based services have become integral to our day-to-day activities.

Tomorrow's autonomous, intelligent transportation systems will rely on two-way satellite communications, remote sensing, and accurate positioning and timing available from global navigation satellite systems. The deployment and integration of next-generation wireless communication technologies into surface transportation will create an information-based ecosystem of connected vehicles and transportation infrastructures whose applications, in turn, will increasingly rely on space-based assets. As a result, future space resources and capacities could be used to modulate the energy budget of future transportation with the view of saving costs and limiting the footprint on the planet while boosting industrial efficiency.

Upcoming communication satellite capacities will provide availability with the same quality of service throughout Canada, including in the North which is a key priority in the context of the transportation sector in support of Northern development.

Aside from transportation in the air and on Earth, an emerging trend of space transportation will have a positive benefit to the global space economy. Space transportation is seen to have the potential to become an important sector in its own right, first with suborbital and orbital launches and later, with improved, accessible and affordable access to space for cargo and humans.

As space transportation evolves over the coming decades, Canada has an opportunity to support new business models allowing for a new era of transportation to space and in space. Investments in transportation and space infrastructure will be required if we are to support this evolution.

1 INTRODUCTION

The Canadian Space Agency (CSA) is pleased to provide this submission to the *Canada Transportation Act Review* Chair, Advisors, and supporting Secretariat. This submission provides information regarding how the rapidly evolving space sector influences and is influenced by transportation in Canada.

The CSA is an Agency of the Government of Canada within the Industry Canada Portfolio, created under the *Canadian Space Agency Act* of 1990. The objectives of the CSA are “to promote the peaceful use and development of space, to advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits for Canadians.".

The CSA is delivering on its mandate in collaboration with Canadian industry, academia, government departments, and other international space agencies and organizations. The CSA’s founding legislation conferred four (4) main functions to the CSA:

1. Assisting the Minister in coordinating space policies and programs of the Government of Canada (GoC);
2. Planning and implementing programs and projects related to scientific or industrial space research and development, and the application of space technology;
3. Promoting the transfer and diffusion of space technology to and throughout Canadian industry; and
4. Encouraging commercial exploitation of space capabilities, technology, facilities and systems.

This document will highlight how space can be used as an enabler to support critical transportation infrastructure, increasing efficiency and sustainability of the sector. As space continues to increase its role in the daily lives of Canadians, the intent of this submission is threefold:

1. To emphasize the applicability of space technology and services and influences on transportation in Canada;
2. To underscore the importance of the role of space in supporting safety and security of transport in the North; and
3. To outline emerging modes of space transportation, including commercial space transportation, leading to new opportunities such as space tourism.

This multifaceted intersection of space and transport in a rapidly evolving world is illustrated by the current extensive use of space capacities, including:

- Earth Observation (EO)
- Global Navigation Satellite System (GNSS)
- Satellite Communications (SatCom)

These capacities support transportation by both the government and the private sector. The future direction of space and transportation will likely augment closer interdependencies between the two sectors.

1.1 THE SPACE POLICY CONTEXT

This submission has been developed in the context of Canada’s 2014 SPF, a key element of the Government’s response to the Aerospace Review Report published in 2012.

The SPF recognizes that protecting our national sovereignty, security and safety is paramount. Space systems have become crucial to daily essential services, from banking to the internet to telephony. Weather forecasting and environmental monitoring, natural disaster warning and response, air traffic control and seagoing navigation, border security, military surveillance, and crop management – all of these depend on sophisticated space technologies. Space allows government agencies to monitor and protect our extensive coastlines and deliver services that Canadians rely on in remote regions, including in the North.

The SPF is underpinned by five (5) key principles:

1. Canadian Interests First:
   National sovereignty, security and prosperity will be the key drivers of Canada's activities in space. Canada's first priority must be to use space effectively in support of these interests;
2. Positioning Canada’s Private Sector at the Forefront of Space Activities:
   Supporting the domestic space industry in innovation and utilizing industry when it can be more efficient and cost-effective;
3. Progress through Partnerships:
   Continue partnerships to share the expenses and rewards of major space initiatives. This will include collaboration with international partners to pool data for mutual benefit and obtain services and technologies that would otherwise be unavailable;
4. Excellence in Key Capabilities:
   Continue to support and advance proven Canadian competencies while keeping a close watch on new niches of technological accomplishment; and
5. Inspiring Canadians:
   Working with industry, universities and colleges, the Government will communicate the importance of space in the effort to recruit, support and retain highly qualified personnel.

2 SPACE IN SUPPORT OF TRANSPORTATION

This section addresses space technologies in support of transportation, and describes certain application areas to illustrate the extent to which space technologies and capabilities are already embedded into transportation.

All transportation depends on technology, whether it's a wheel, jet engine or computer chip. Technology plays a key role in shaping transportation systems, which in turn shape our lives, landscapes and cultures.

In this context, safety and efficiency continue to be two important drivers of transportation. As transportation capabilities expand, so will the need for improved safety. In light of their broad application, space capacities and resources will become essential to transportation.

Efficiency of the transportation system as a whole could result in a major decrease in transportation energy demand and related emissions. Smart and integrated transportation systems will offer rational operational patterns to commuters and shippers, helping to reduce urban congestion, and improve transfers between modes of transportation. As well, improved real-time information will reduce energy requirements, i.e., costs, and improve efficiency, i.e., time, accuracy and reliability, for shipping by train and truck.

Tomorrow's autonomous, intelligent transportation systems will rely on two-way satellite communications, remote sensing, and accurate positioning and timing available from global navigation satellite systems. The deployment and integration of next-generation wireless communication technologies into surface transportation will create an information-based ecosystem of connected vehicles and transportation infrastructures increasingly reliant on space-based assets. As a result, future space resources and capacities could be used to modulate the energy budget of future transportation with the view of saving costs and limiting the footprint on the planet while boosting industrial efficiency.

Examples provided in the following sub-sections are non-exhaustive, and are meant to reflect key uses by Government and industry of space technologies for the transportation sector.

2.1 SPACE TECHNOLOGIES IN SUPPORT OF TRANSPORTATION

"Technological advances, primarily in the capabilities of satellites, have made space indispensable to the functioning of contemporary societies. Space-based assets make life on Earth more productive, prosperous, safe, and interesting. The value of space activity – both in commercial terms and in its contribution to the public good – will multiply in the future".
Source: Aerospace Review Report, 2012).

2.1.1 Infrastructure

Protection and surveillance of infrastructure is crucial to air and road transportation, such as the detection of terrain disturbances that affect roads, rail and airports. Space capabilities such as EO and GNSS make the long-term monitoring of terrain deformation, movement of bridges, and landslides possible. While much information is provided through in-situ monitoring, only space can provide systematic "contextual" monitoring of surrounding areas and, to a large extent, of infrastructures themselves.

Monitoring the environment surrounding pipelines, highways and Arctic roads will increase safety and security. Monitoring the progression of permafrost melt will allow timely planning for alternatives for roads, railways or airport landing sites. Overall, more accurate and recurrent information will prompt alerts that can trigger maintenance, improvements or rapid decision-making that can influence transportation planning and forecasting.

Remote Sensing Satellites introduce an innovative technique called "interferometry" to monitor terrain and structure deformations for bridges, roads and rail infrastructure. It uses a series of space-based images to generate maps of surface deformation or digital elevation that is then used by the Government for security and safety. In Canada, the RADARSAT series of satellites developed by MacDonald Dettwiler and Associates Corporation (MDA) use Synthetic Aperture Radar (SAR) for its uniqueness in imaging capability. SAR can provide high-resolution images of the Earth's surface independent from daylight, cloud cover and weather conditions.

Improved space-based EO monitoring combined with Canada's future access to additional space-based GNSS constellations, will provide timely high precision information enabling rapid reaction time for organizations responsible for safety, quality and transportation effectiveness.

2.1.2 Global Navigation Satellite Systems

GNSS is a system of satellites that provide autonomous geo-spatial positioning with global coverage. It allows small electronic receivers to determine their location (longitude, latitude, and altitude) to high precision (within a few metres) using time signals transmitted along a line of sight by radio from satellites. In Canada, positioning, navigation and timing information uses are supported by the United States (US) space-based Global Positioning System (GPS). Universal Time Coordinated (UTC) is distributed through the GPS and has become the time standard for the control of virtually everything, including in transportation (civil, military, and commercial).

The following are key applications:

- Rail Transportation:
  - to track the location of locomotives and rail cars, maintenance vehicles and wayside equipment; and,
  - to know the precise location of rail equipment to reduce accidents, delays, and operating costs, enhancing safety, track capacity, and customer service.
- Air Transportation:
  - to facilitate aircraft navigation in remote areas that are not well served by ground-based navigation aids;
  - to support collision-avoidance systems;
  - to improve approaches to airport runways; and,
  - to operate unmanned aerial vehicles for reconnaissance, logistics, target and decoy.
- Marine Transportation:
  - to accurately determine the position of vessels when they are in the open sea and manoeuvring in congested ports.
- Road Transportation:
  - to provide location and navigation in vehicles equipped with navigation displays using maps;
  - to track and forecast the movement of freight and to monitor road networks, improving efficiency and enhancing driver safety; and,
  - to more quickly locate distress signals for Search and Rescue (S&R) operations and disaster relief.

Presently, only the US GPS and the Russian Global Satellite Navigation System (GLONASS) are global operational GNSSs. China is in the process of expanding its regional Beidou Navigation Satellite System into a global navigation system called Compass. The European Union's (EU) Galileo (satellite navigation) is a GNSS in initial deployment phase, scheduled to be fully operational by 2020 at the earliest. France, India, and Japan are in the process of developing their own regional navigation systems. This diversity of sources will increase access and reliability to systems information.

However, in light of cybersecurity, alternative sources of positioning, navigation and timing information may be required either in space (e.g., different satellites in different orbits) or on the ground, to support certain strategic and critical services. The US Government is currently developing such capacities and is eager to see collaboration from Canada for Northern deployment.

A government coordinating body was created to look at the future of GNSS in Canada. The Federal Government Coordination Board on GNSS is the venue to stimulate “whole-of-government” action to respond to future threats to GPS systems utilization in Canada. Canada is presently well served by the GPS system, but there could be future security risks requiring Canada to review its strategic position.

2.1.3 Satellite Communications

SatCom is defined as the use of satellites as a relay for communications between two distant points on the Earth. Communication satellites are at the core of Canada's communication infrastructure at the regional, national and international levels, and complement ground-based networks. Satellites are the most economical way to connect fixed and mobile users to advanced communication services in remote areas (without fiber optics) and eliminate the need for an extensive and cumbersome ground-based infrastructure. They are critical to Canada with its large landmass and sparse population. They support many applications, from providing schoolchildren in rural areas access to virtual classrooms, enabling real-time medical care, especially for Northern communities, and providing encrypted communications services for the Canadian Forces.

In the transportation sector, satellite communications is also making key contributions:

- Air transportation:
    - Providing critical communications between ground control centers and airplanes, and between drones and other flying objects, which are essential from a safety perspective.
- Marine transportation:
    - Satellite communications remain an essential part of how ships communicate to the terrestrial world when they are in high seas.
- Road transportation:
    - Transport companies are using satellites to relay real-time positions of all their fleets. Using SatCom as part of their communications infrastructure provide the transportation sector with the ubiquitous coverage needed to conduct business worldwide.

A key trend in the next decade will be a large increase of broadband capacity available worldwide via satellite communications. This will enable cruise ships to provide broadband internet to passengers. It will also enable broadband and television access to airline passengers. Projections are that within five (5) years, there will be near real-time tracking and global coverage of all large marine vessels and all airplanes via satellite. Satellite communications will continue to provide support for road transportation and machine-to-machine communications in remote areas.

2.1.4 Weather Satellites

Scientists and forecasters work closely with government and university partners to develop prediction models and other tools to improve services to Canada's space weather community. Weather satellites are key components of the infrastructure supporting the forecasting of weather throughout the globe. Needless to say, weather predictions supported by these satellites have a significant impact on transportation. Environment Canada's Numerical Weather Prediction analyzes millions of observations from meteorological satellites to provide information on sea state, ice conditions, and weather on a 24/7 basis.

Air, marine and surface transportation rely heavily on the use of applications from weather satellites, ranging from real-time weather maps to severe weather avoidance and prediction applications.

One of the major challenges concerning weather prediction is to obtain regular observation data from remote regions. Future planned space systems could provide enhanced observations, especially in the Arctic.

2.1.5 Satellite-Based Automatic Identification System

Satellite--based Automatic Identification System (S-AIS) is the use of Automatic Identification System (AIS) receivers on-board satellites for identifying and monitoring vessels from space. Satellite-based systems provide global coverage in the following Marine applications:

- Global Vessel Monitoring:
  - Optimising logistics planning;
  - Port-to-port tracking;
  - Vessel dynamic information;
  - Marine planning and analysis operations; and,
  - Increasing vessel traffic management systems beyond the horizon for a complete picture of global shipping even in remote regions such as the Arctic.
- Defense and Security:
  - Optimising the investigation of suspicious ship movements at sea; and,
  - Reducing the need for routine patrol missions.
- Environmental Protection:
  - Providing the means to analyse historical ship traffic patterns; and,
  - Helping to increase violator prosecutions and to prevent environmental incidents.
- Illegal Fishing:
  - Immediate identification of non-cooperative illegal, unreported and unregulated vessels in the vicinity of legitimate fishing vessels or in areas where vessels are not intended to be fishing.

- S&R:
  - Confirming and identifying other vessels in the S&R area, reducing response time and ultimately saving lives; and,
  - Proactive notice of any ships entering remote coverage zones preventing potential S&R incidents.

The Canadian Department of National Defense (DND) has initiated the Polar Epsilon project to monitor marine traffic along Canada's coasts and surrounding oceans, including in the Arctic. The information generated by DND is shared with the Department of Fisheries and Oceans (DFO), Transport Canada and the Canada Border Services Agency (CBSA) to improve safety of navigation, awareness of hazardous cargo and other marine security concerns.

Eventually using a complete set of satellites working together in concert (i.e., a constellation of satellites), the S-AIS system will be ubiquitous, providing near-real time vessel observation and monitoring capacity for added improvement of the applications. This should allow for improving future deployment and use of Canadian resources in the field, such as with the Canadian Coast Guard. Furthermore, this will lead to increased efficiencies for commercial users through the monitoring and routing of cargo and other shipments worldwide.

The evolution of S-AIS will likely be adopted by all classes of ships with the information provided in real-time to organizations responsible for safety and security. The system may further expand to smaller private vessels, e.g. pleasure, and adapt to surface transportation means to complement the location-tracking capacities derived from existing GPS signals and other monitoring means on the ground.

2.1.6 Satellite-Based Search and Rescue System

A satellite-based S&R system detects and locates emergency beacons from space activated by aircraft, ships and backcountry hikers in distress. The S&R instruments are flown on satellites in either Low Earth Orbits (LEO) or Geosynchronous Earth Orbits (GEO). They are known as Low-Earth Orbit Search-and-Rescue (LEOSAR) and Geosynchronous Search-and-Rescue (GEOSAR).

The Cospas-Sarsat Programme is an international, humanitarian satellite-based S&R distress alert detection and information distribution system. The system consists of a network of satellites, ground stations, mission control centers, and rescue coordination centers. Cospas-Sarsat was introduced by Canada, France, the US and the former Union of Soviet Socialist Republics (USSR) thirty-five (35) years ago to respond to distress and disasters world-wide. The Cospas-Sarsat System is used by the National Search and Rescue Secretariat (NSS).

The Cospas-Sarsat system provides a tremendous resource for protecting the lives of aviators and mariners that was unthinkable prior to the Space Age. With a beacon, a distress message can be sent to the appropriate authorities from anywhere on Earth 24 hours a day, 365 days a year. This allows authorities to plan the quickest and most efficient route for rescue operations. Cospas-Sarsat has proven to be an essential system for transportation safety and continued access is crucial. In 2013 alone, the system contributed to the rescue of 2,700 persons world-wide.

Its capacities are and will continue to be complemented and enhanced through satellite remote-sensing systems and improved communications providing for rapid intervention. The system utilization will likely increase with the proliferation of light hand-held terminals and on-board equipment for vehicles.

2.1.7 Space-based Earth Observation Satellites

Space-based EO can be defined as the gathering of information about Earth's natural phenomena via space-based remote-sensing technologies (usually satellites). EO remote sensing satellites can use a variety of sensors to acquire data for imagery such as SAR, optical instruments and Light Detection and Ranging (LIDAR).

Here are some examples where the transportation sector is currently benefitting from space-based EO information:

- Marine:
  - Ice monitoring;
  - Optimisation of marine routes; and
  - Illegal marine activities.
- Road:
  - Integrity of transportation infrastructure;
  - Optimisation of shipping routes; and
  - Maps for car navigation.
- Rail:
  - Rail corridor planning; and
  - Rail maintenance.
- Air:
  - Optimisation of air traffic; volcanic ashes tracking and avoidance.

The Canadian Coast Guard makes use of information from RADARSAT about location, extent and nature of ice. This contributes to reducing transit time, ice-related delays, accidents, fuel consumption and the use of icebreakers. The number of space-based EO systems that could support the transportation sector will increase in the future and most of the data will be more openly accessible to the public domain. As space systems evolve with more frequent revisits and higher resolution imaging, real-time data acquisition and processing with faster data transmission will provide highly accurate information.

2.1.8 Space Weather Satellites

Space weather could be defined as the time-varying-conditions within the Solar System, including the solar wind, and especially for the space surrounding the Earth. Space weather is increasingly monitored as certain space phenomena can have impacts on terrestrial and space infrastructure. For example, the effect of the Sun's flare ejections on electrical grids, computers, space systems, and on sensitive electronic devices could impact all modes of transportation.

Space weather events can impact transportation systems. For example, magnetic storm activity can induce electric fields in the Earth's atmosphere, which then can affect electric power grids through ground connections, driving uncontrolled electric currents that interfere with grid operations. This can damage transformers, trip protective relays, and cause blackouts.

The reality of this complicated chain of cause and effect was demonstrated during the great magnetic storm of March 1989, which caused the complete collapse of the Hydro-Québec electric-power grid, temporarily leaving six million people without electricity. This event also affected transportation systems such as traffic lights, electric trains, and subway systems.

Striving for increased transport safety requires improved predictions and forecasting of space weather events. Electrical and electronic equipment used in transportation, while becoming more sophisticated, must also become more resilient to disturbances from space weather. Hence, additional satellites are being put in place on a regular basis to continue to enhance the monitoring of space weather events.

2.2 USE OF SPACE BY DIFFERENT MODES OF TRANSPORTATION

The transportation sector is considered to be Canada's top business users of space-based solutions. Benefits derived from space-based services are directly related to business operations in all modes of transport including:

- Monitoring of remote or inaccessible regions in real-time in order to improve their business efficiencies or acquire key information for their decision-making;
- Providing communications for business operations and other services over satellite links to vast, broad, and remote geographical areas.

2.2.1 Air Transportation

The air transportation industry is a heavy user of satellite solutions. Satellite-enabled positioning and timing is tightly integrated in the avionics systems of commercial and high-end business aircraft across Canada and through panel-mounted displays for regional and general aviation users. The precision of GNSS solutions helps to increase safety, reduce congestion, save fuel, protect the environment, reduce infrastructure operating costs, and maintain reliable all-weather operations, even at the most challenging airports.

In addition, the aviation industry has a growing demand for satellite-enabled communications solutions driven by growing passengers' expectations of anytime/anywhere connectivity. In 2014, as part of the race for new consumer technologies, WestJet announced an investment plan to add a satellite connectivity solution for live television streaming and Wireless Fidelity (Wi-Fi) connectivity to its entire fleet, which handled over 18.5 million passengers in 2013. With 75% of these passengers using their own web-enabled devices on-board, this satellite-based internet connectivity service will provide WestJet with a distinct advantage over its competitors, while improving productivity and entertainment options for its passengers.

Tailored weather services also support air transportation logistics, and provide storm warnings, among other uses. The Volcanic Ash Advisory Centre (VAAC) of Meteorology Canada monitored the fall-out of the Iceland Volcano incident in 2010 to advise regulatory authorities and commercial airlines on safe travel corridors.

NAV CANADA, a privately run, not-for-profit Corporation that owns and operates Canada's civil Air Navigation System (ANS), has been responsible for the safe, orderly and expeditious flow of air traffic in Canadian airspace since November 1, 1996. NAV CANADA successfully demonstrated the Automatic Dependent Surveillance – Broadcast (ADS-B), a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked. The information can be received by air traffic control ground stations and by other aircraft to provide situational awareness and allow self-separation. The next step is its deployment through space, which would provide a world-wide service.

2.2.2 Rail Transportation

GNSS figures prominently in Canada's rail transportation network, which handles the fourth largest volume of goods in the world. Driver advisory systems designed to improve comfort and safety and optimize overall performance are being fitted to many trains. Positioning information is routinely fed back to train operators to provide them with input for operations management. VIA Rail has greatly improved its operations through precise and automated GPS-enabled real-time statistics for each train, as opposed to the previous system that relied primarily on manual time entries to record arrival and departure times.

Satellites also form part of VIA Rail Canada's hybrid Wi-Fi solution available on trains running between Windsor, Toronto, Ottawa, Montreal, and Quebec City. Over the most recent Labour Day weekend alone, nearly 62,000 passengers travelled this corridor with VIA Rail. Many of these passengers made use of the satellite-enabled Wi-Fi network, visiting the equivalent of more than 2.4 million websites.

2.2.3 Marine Transportation

With the longest coastline in the world, Canada's marine transportation continues to grow exponentially. Canada is home to one of the world's busiest marine industries with eighteen (18) major international ports handling 310 million tons of cargo annually.

The shipping industry has increasing requirements for satellite communications, regarding reliability and data rates, to support operations and crew welfare. This is especially necessary when considering the increasing marine traffic in the Arctic, where there is limited available connectivity. Recently, one Canadian shipping company reported to have spent $2,500 a month per ship for their satellite communications due to growing needs for real-time connectivity to support their operations.

Canada's marine transportation industry became an early adopter of GPS and continues to be an extensive user. Today, GNSS solutions are employed to report and track vessel position for safety and commercial purposes. As well, there is increased reliance on GNSS for precision navigation and as an input for traffic management and bridge systems.

The sector also benefits from the provision of services from the Canadian Ice Service, including regular updates to sea-ice mapping and iceberg detection, including wider Meteorology Ocean (MetOcean) products such as marine forecasts and wave models. Such services use a combination of geostationary and polar-orbiting weather satellites and SAR data for ice mapping.

2.2.4 Road Transportation

The trucking industry, employing over 400,000 Canadians, is one of the largest beneficiaries of GNSS solutions. These solutions help to overcome some of the challenges on the road such as increased congestion, pollution, and costs of fuel and insurance. Both GNSS and Machine-to-Machine (M2M) satellite technologies are increasingly being integrated with Enterprise Resource Planning (ERP) software solutions designed to improve the operational efficiency and performance of trucking fleets. These satellite enabled "fleet tracking" solutions enable transportation and distribution companies to instantly access and analyze a wealth of operational data such as fuel consumption, time driven, container location, and refrigeration system and engine performance. The ubiquity of satellite coverage offers a key benefit compared to terrestrial solutions.

With more than one million kilometers of roads, as many as 20 million light vehicles and widely dispersed urban centres, road transportation is the most important mode of passenger transportation in Canada. As such, space-based positioning systems, notably GPS, play an important role for Canadians in helping to improve the efficiency, cost, safety and environmental impact of their commutes and travels. Through features such as real-time traffic overlays and eco-routing, GPS devices can help shave valuable time off commutes, resulting in fuel savings (between 5% to 15% per year) and lower carbon dioxide (CO2) emissions. The number of installed road GPS devices in Canada is estimated to be roughly 5 million as of 2014, split equally between Personal Navigation Devices (PNDs) and in-vehicle systems installed directly by car manufacturers.

As of 2013, an estimated 55% to 60% of Canadians owned smartphones, including mapping/navigation tools, which rely on space-based GPS satellite constellation services. These are amongst the most frequently used and downloaded applications (apps), trailing only weather apps, Facebook and games. GPS-enabled tablets and cameras as well as fitness and tracking devices are also multiplying and, when combined with smartphones, it is estimated that there are up to 40 million "location-based service" GPS devices in Canada alone. This must be taken into consideration when planning transportation of the future.

Tracking applications such as pay-per-use insurance have been burgeoning in Canada while encouraging safer driving and reducing car insurance premiums. For example, Desjardins Insurance has managed to add nearly 50,000 users in little over a year to its "Ajusto" program, which relies on a credit card sized GPS receiver to track driving metrics such as time, distance, speed, acceleration and braking. The program accounts for nearly 40% of all new policies, and has led to an average annual premium savings of 12% per client. This space-based system effectively rewards and encourages safer driving habits as reports are sent to clients with information that can be used to further adjust premiums.

Examples of Satellite Enabled Activities are listed in Table 2-1.

TABLE 2-1 - EXAMPLES OF SATELLITE ENABLED ACTIVITIES

Sector	Sector GDP (2013)	Examples of Satellite-Enabled Activities
AIR TRANSPORTATION	$6.1 B	• Airport flight simulation • Safety regulatory compliance • Flight tracking/remote surveillance • Navigation • Air traffic management • In-flight entertainment
RAIL	$6.1 B	• Passenger broadband connectivity • Navigation
ROAD	(unavailable)	• Congestion monitoring and reporting • Optimizing routes for fuel and time efficiency, fleet tracking, safety
MARITIME	$1.5 B	• Vessel tracking/identification • Safety/regulatory compliance • Crew welfare • Navigation • Provision of MetOcean products (sea conditions) • Sea-ice mapping • Iceberg detection

2.3 KEY CONSIDERATIONS FOR SPACE TECHNOLOGY SUPPORT OF TRANSPORTATION

Space resources and capacities have already transformed the world of transportation. As space systems further evolve their impact will be increasingly pervasive on the safety, efficiency and cost of transportation. In that context, measures could be envisaged for Canada's transportation to remain leading edge and competitive, serving both the economy and society. Below are some specific considerations to take into account for how space can support transportation.

- Implementing tomorrow's autonomous, intelligent transportation will increase safety, security and efficiency through two-way satellite communications, remote sensing, and accurate positioning and timing available from global navigation satellite systems;
- Using Canadian space technologies, capacities and services as competitive levers for the transportation industry;
- Promoting early adoption of new space capacities by government departments concerned with transportation-related operations; and
- Planning for vulnerabilities and possible disruption of space systems that can impact transportation.

3 TRANSPORTATION IN THE NORTH OF CANADA

The enormous resource potential, linked to minerals, oil and gas reserves, and improved access to marine shipping routes due to reduction in ice cover, are becoming drivers for economic development in Canada's North. Due to the confluence of environmental, political and socio-economic factors, these new opportunities could spark an increase in transportation activities over land, water and in the air.

Space is also an essential "life-line" infrastructure in the North, as demonstrated by the October 6 2011 Anik F2 satellite malfunction that disrupted long-distance calls, cell phone service, data communications, internet, television services and banking machines causing a total black-out in the North. Communications outage also meant limited or no weather reporting and forecasting, and no communications with NAV CANADA Area Control Centres. As a result, 48 scheduled flights were cancelled stranding about 1,000 passengers just before the Thanksgiving long weekend.

3.1 ARCTIC SOVEREIGNTY

"Through a vigorous presence in the North, using satellites as a key instrument of policy, Canada will be able to accelerate wealth creation, protect the environment, and assert its sovereignty. Given the intensification of multiple, conflicting national claims in the arctic, both international law and pragmatic geopolitics demand that Canada be active in the region if it wants to secure its interests there." (Source: Aerospace Review Report, 2012)

Ensuring sovereignty in the Arctic is a challenging task, especially in a context where Arctic countries dispute territorial sovereignty and marine rights in the region. Canada has a growing number of defense personnel, navy ships (Canadian Patrol Frigate and submarine patrols) and aircraft operating within regional bases for military exercises.

Increasing surveillance activities in the Arctic require more infrastructure that can be supported by various methods. Providing robust communications services in the Arctic is imperative for successful command and control of Canadian Armed Forces' operations, both for fixed stations and mobile units (road, marine, and air including Unmanned Aerial Vehicles (UAVs)). Satellite constellations in a polar orbit may be the preferred means of communication given the reliability and transparency of transmission and the projected significant augmentation of DND needs.

Space-based EO has enabled protection of the site of the discovery of the Franklin expedition ship *HMS Erebus* in the Arctic from damages and pillages. RADARSAT imagery supports the Government enforcement efforts of the Canadian Coast Guard by monitoring ships coming in the vicinity of the designated area.

3.2 OPPORTUNITIES

As we further exploit the Artic, there are some valuable opportunities that can be realized.

- Reduction in sea ice thickness and cover, and an increase in the length of the summer shipping season, will provide more direct shipping points for resource development in northern regions, support future oil and gas development, attract new industry, and expand international trade opportunities;
- New or longer access to marine transportation routes will result in the increase in international traffic circulating through Canadian waters;
- The Arctic offers tremendous potential for the mining and resource development sector;
- The Arctic is becoming a new destination for tourism resulting in increased traffic, ranging from flights to Arctic destinations, cruise lines, and eco-tourism; and
- Flying through the Arctic will result in shorter flights for opposite locations in the northern hemisphere.

3.3 CHALLENGES

Space can play an important role in supporting safety and security of travel in the North by providing services such as communications, weather forecasting, navigation aid, and EO and surveillance. Transportation infrastructure is needed to enable the economic development and the increase in air, marine and road traffic in the North. However, due to several factors, there remain some key challenges to be addressed.

- Thawing permafrost affects the integrity of buildings, roads and other critical infrastructure;
- Extreme or unexpected weather events such as severe storms can threaten transportation and infrastructure as well as human safety;
- Reliability and availability of winter roads is dependent on freeze-up and break-up of Northern water bodies ;
- Coastal areas and its infrastructure are being impacted by reduced ice due to later freeze up, rising sea levels, and storm surges;
- Current surveillance systems are not developed to meet the foreseen increased traffic in the Arctic to support activities such as policing, emergency response, and disaster management;
- The safety of policing in the Arctic is impacted by the isolation, extreme weather conditions, and dependency on reliable transportation and communications; and
- S&R response times are protracted because of the severe climate, great distances involved, remoteness, and the relative shortage of personnel and equipment.

3.4 HOW SPACE SUPPORTS TRANSPORTATION IN THE NORTH

The following is a description of the various types of satellites systems that support transportation in the North, as well as how they can improve services.

- Communications Satellites:

  Space-based systems are among the best methods for providing communications across the vast, but sparsely populated, Arctic. Current demand below 75 degree North parallel is being met mostly by existing GEO systems. Above 75°N, there is a gap in coverage, due to the GEO orbit location with existing systems providing unreliable, limited capacity and at low data rates. Most of the demand above 75°N will be from vessels and aircraft, although exploration expedition teams also require support.

- Weather Satellites

  Systems currently in use are mostly GEO in near-equatorial orbits and are unable to provide weather information on high-latitude atmospheric conditions. Some weather satellite systems look to the Polar Regions employing LEO that provide high-quality spatial resolution information over high latitudes but on a narrow flight path – sometimes taking six (6) hours before the same area is imaged again.

- Navigation Satellites

  GNSS are used in the Arctic as the preferred method of navigation for transportation and a variety of other positioning and timing applications. The lack of navigation infrastructure (radio beacons) and the high magnetic deviation make satellite-based solutions particularly attractive to users in the North. GNSS have some limitations in higher latitudes. New systems are being implemented that could improve higher latitude coverage.

- Earth Observation Satellites

  Given the Arctic region's vast geography, remoteness and isolation, EO is frequently the only cost effective and technically feasible means of obtaining reliable information in a timely fashion for applications such as:

  - the systematic monitoring of shipping routes to detect vessels and icebergs;
  - S&R and disaster response; and
  - the assessment of land stability within permafrost regimes.

  Limitations of current EO systems are largely due to restricted spatial coverage and revisit frequency. Future EO sensors of most importance for Arctic applications are the European Union's Sentinel 1 and Canadian Radarsat Constellation radar satellites. These satellites will offer increased frequency of coverage.

  In addition, the North is in darkness for a significant part of the year. The SAR technology used in RADARSAT allows for imaging to be acquired night or day.

- Surveillance Satellites

  Space-based surveillance systems are useful sources of information for sovereignty and safety applications in the Arctic. The expansion of movement through the Arctic, enabled by climate change, is increasing the need for effective S&R capabilities and the protection of borders from movement of illegal goods.

3.5 KEY CONSIDERATIONS FOR TRANSPORTATION IN THE NORTH

The vast, remote and harsh environment of Canada's North has long meant the region was underserved by traditional infrastructure means. The opening of the North, with the potential for tremendous economic development, will require greater monitoring for safety and security both of humans and the environment.

Space can offer cost effective solutions to support the safe and efficient deployment of transportation means, in support of sound Northern development, if available early.

- Adequate space systems are needed to support commercial and government operations in the North.
- A better understanding and prediction of weather in the North, possibly through satellites capable of providing continued information over the North, will be required for safety and for the economy of the Arctic.

4 COMMERCIAL SPACE TRANSPORTATION

4.1 INTRODUCTION

In addition to the traditional transportation sectors of road, maritime, and air, described previously, the emerging sector of Commercial Space Transportation should now be considered in its own right, especially in the context of a review of the *Canadian Transportation Act*.

There is at present no international consensus on the status and international regulatory environment needed for sub-orbital or orbital spaceflights. This issue is just starting to be addressed at the international level, and will likely remain open for debate due to the complex and challenging environment in which these will occur, and because existing regulations – and regulatory agencies –concentrate mostly on air traffic.

Currently, only Russia and China have the capability to launch humans in space. Only Russia can send a crew to the International Space Station (ISS).

In 2012, the National Aeronautics and Space Administration (NASA) started the commercial crew and cargo program to help commercial companies develop new capabilities for transporting crew and cargo to the ISS. These services are intended to replace some of the ISS resupply services performed by the retired Space Shuttle. The first of these vehicles, SpaceX's Dragon, became operational in 2012, restoring NASA's ability to deliver and retrieve cargo in LEO.

Space-based transportation systems can be automated, remotely piloted, or piloted by humans on-board. They can carry payloads for technology demonstration or science; they can carry cargo of all kinds, or even human passengers (either government-funded or privately-funded). With the exception of the SpaceX Dragon, all other orbital vehicles in the world are expendable rockets, that is, most of the spacecraft is not reusable for future launches.

Orbital spaceflight refers to spacecraft traveling in orbit around the Earth or beyond (requiring very high speeds and associated propulsion systems to reach orbital velocity), and suborbital spaceflight refers to spacecraft traveling high enough in altitude to reach or nearly-reach the vacuum of space, without attaining sufficient velocity to enter into orbit.

4.1.1 What is "Space"?

Although the United Nations has debated the issue for 40 years, there is no agreed legal definition of the term 'Outer Space'; however, for all practical purposes it is an accepted convention that "space" begins at approximately 100 km (Karman Line) of altitude from the Earth sea level. At this altitude, the atmosphere is so rare that there is very little friction due to the atmosphere, allowing for much faster flight as well as "coasting" almost indefinitely. The higher the altitude, the less atmospheric drag is a factor.

4.1.2 How do we Access Space?

As mentioned above, “space” is only 100 km away from the surface of the Earth. Rockets are generally used to access space because most aircraft engines require atmospheric air to be pushed through a chamber or by propellers and over a certain altitude these engines are just no longer efficient. Rockets allow for propulsion whether or not there is an atmosphere around the vehicle.

In suborbital spaceflight, high altitudes are achieved, where atmospheric draft is no longer present, the curve of the Earth can be observed, as well as the blackness of space. However, orbital velocities are not achieved and the arc flown by the spacecraft intersects the Earth at some distant point. This is the typical trajectory used by intercontinental ballistic missiles, but also of spacecraft envisioned for very fast travel in the future, and for space tourism applications.

Globally, the nature of both crew and cargo launch capabilities is undergoing a major shift with the emergence of commercial entities, as well as by more government players. Canadian access to launch services benefits from the increasingly robust launch capacities emerging in the US. Currently, Canada depends on NASA to fly its astronauts (via Russia) to the ISS and has relied mainly on the US, Russia and India for government and commercial launches of communication, Earth Orbit and Space Situational Awareness satellites.

Bristol Spaceplanes, based in the United Kingdom (UK), have received government funding, as well as contracts from the European Space Agency (ESA) to support feasibility studies into its spaceplane designs. Bristol Spaceplanes has developed plans for Spacecab (Figure 4-1), which is aimed at being the first orbital spaceplane. Spacecab is designed to carry six (6) astronauts to a space station or to launch a 750 kilogram satellite. As a lead-in to Spacecab, the company has plans for the Ascender sub-orbital spaceplane, which would carry one paying participant and one crew member. Other European commercial spaceplane manufacturers include Swiss Space Systems (S3) and Reaction Engines.

FIGURE 4-1 - SPACECAB

It is anticipated that increased commercial launcher availability will reduce the cost of sending payloads, e.g., satellites, science instruments, cargo, into orbit and increase traffic. The US Defense Advanced Projects Research Agency (DARPA) is actively working on an Experimental Spaceplane (XS-1) that will provide economical access to space by reusing the first stage in a short turnaround time. SpaceX Dragon (Figure 4-2) is carrying out similar experimentation. This could contribute to enhancing transportation here on Earth (in terms of technology development for space being used for terrestrial transportation systems) while also impacting air transportation.

FIGURE 4-2 - SPACEX DRAGON

4.2 SPACEPLANES TODAY AND TOMORROW

A spaceplane is a vehicle that is designed as two vehicles in one - it acts as an aircraft while it operates in Earth's atmosphere but also acts as a spacecraft while it operates in space. Typically, they use powerful engines while in launch mode and glide back to Earth during landing mode. Space planes can be used for orbital applications, i.e., the US Space Shuttle, but there has recently been an increase in activity in the development of commercial suborbital spaceplanes such as Virgin Galactic's SpaceShipTwo (SS2) (Figure 4-3) and XCOR Lynx (Figure 4-4).

Sub-orbital spaceplanes and sub-orbital human spaceflight have the potential to re-define the economics of the entire space sector and of the transportation sector. Much of the activity in this area is led by private and commercial interests, with new technologies being developed on a fast timeline compared to previous space development led mostly by governmental organizations around the world. Savings can be achieved by carrying the spaceplane to an initial launch altitude by a more conventional aircraft, requiring much less fuel to be carried on the spaceplane itself. The spaceplane is released from the carrier at as high an altitude as possible and rocket engines are only ignited at that point.

The business model assumes the cost of launches will be reduced significantly due to a commercial market for space tourism and very frequent flights and re-use of flight hardware.

The sub-orbital space tourism market was catalyzed by the Ansari XPRIZE that was won by Scaled Composites in 2004 when they were the first privately-funded group to launch a reusable human-piloted spacecraft into space twice within two weeks. This group is behind the design of SS2 (Figure 4-3), being marketed for space tourism by Virgin Galactic. Other major players include Blue Origin, Masten Space Systems and XCOR Aerospace.

FIGURE 4-3 - SPACESHIPTWO (SS2)

in a captive flight configuration underneath White Knight Two

FIGURE 4-4 - XCOR LYNX SUB-ORBITAL VEHICLE

4.3 COMMERCIAL MARKETS FOR SPACE LAUNCHES

4.3.1 Orbital Launches

Since the late 1950's, when the first satellites were launched, the commercial satellite sector has become a worldwide, multi-billion dollar industry. As the need for orbital assets increases, so does the need for launch vehicles to bring them to space. Communication satellites and EO satellites dominate the market, with navigation and scientific satellites also being major players. Governments, universities, and commercial entities purchase on a regular basis, launches to orbit from private companies, making the commercial launch sector a real and viable industry.

As commercially-based human-rated launch systems become available, more opportunities will emerge for private citizens to access these flights. The first high-volume commercial spaceplane operations will likely be suborbital and will provide point-to-point transportation. Future commercial flights will take passengers to the edge of space. By entering sub-orbital flight paths, vehicles will be subjected to lower atmospheric drag and would allow the Earth to rotate under them. This will permit substantially faster journey times for intercontinental flights. For example, it is claimed that a flight from New York to Tokyo could be cut from thirteen (13) hours to less than two (2) hours.

4.3.2 Spaceports

Spaceports that will support future suborbital flights will look partly like a traditional airport, partly like a rocket launch site. If the prevailing technologies adopted by the commercial sector involve mostly horizontal take-off vehicles, spaceports will look like current airports, only probably with longer runways, larger hangars, and special facilities for flight preparation for passengers and crews. Training facilities for passengers may also be incorporated into spaceports.

As spaceplanes begin to replace other methods of travel for intercontinental flights and as costs come down (one should think of spaceplanes like the "Train à Grande Vitesse (TGV)" for intercontinental flights), air traffic control will be required, with special provisions for the special aircraft launching and landing.

Landing operations may most likely be carried out unpowered – as a glider – which is basically a forced landing. Holding traffic patterns will not be an option. Much planning must occur for this scenario in air traffic control, especially if these operations are to occur near or at large airports.

In the US, many spaceports, both government and commercial, have been or are being developed, and are vying to attract new space companies to set up shop there. More than just being a facility, a spaceport can act as the focal point for an entire industrial cluster, including not only space companies, but all the manufacturing, construction and logistics industry required to support it. In this way they can become powerful catalysts for economic development of an area in a similar way that an airport can. Figure 4-5 shows Spaceport America in New Mexico.

FIGURE 4-5 - SPACEPORT AMERICA IN NEW MEXICO

4.3.3 Spaceports in Canada

Canada will be no exception to the proliferation of suborbital launch activities. At the moment, for example, S#, an European company, will conduct its inaugural test from North Bay in the week of October 4-10 of 2015. North Bay has the potential to become Canada's first Spaceport. Canada is particularly well positioned to attract more spaceports in view of its vast uninhabited territory, parts of which are increasingly easier to access.

4.4 KEY CONSIDERATIONS FOR TRANSPORTATION TO SPACE

In terms of transportation to space, much can be learned from the approach adopted by the US and the UK. The development in Canada of an industrial context that is conducive to the emergence of new space-related transportation activities can be seen as a natural evolution to road, marine and air transportation.

- Sub-orbital launchers can be used for transportation (rapid delivery of cargo, displacement of humans and science instruments) and for "space tourism". Sub-orbital launchers will likely evolve to provide affordable and fast access to space. As the private sector gets more involved with orbital and suborbital systems, new markets will emerge for space-based transportation, such as information delivery, cargo delivery, fast travel, entertainment, or tourism.
- Commercial providers such as Boeing, SpaceX, Orbital ATK, and Bristol Spaceplanes are playing a growing role in the provision of both crew and cargo launch systems and vehicles; the launch marketplace is becoming more competitive and access to launches more widespread and hopefully, more economical.

5 CONCLUSIONS

Space is increasingly gaining recognition as an important and necessary component of the Canadian transportation infrastructure. The review of *Canada's Transportation Act* provides an excellent opportunity to ensure that current and rapidly evolving space capacities are suitably considered in the future management of transportation in Canada. We live in a world of technology, and technology development will continue to accelerate with ever-greater impacts to our lives and our environment. So far, space has had a formidable and pervasive impact on transportation, from airlines to marine vessels to road transportation. Space technology will evolve, and in combination with other technologies, will continue to change all forms of transportation.

A few key points to take-away from the three themes presented in this submission include:

Space in Support of Transportation

Satellite-based navigation is part of our daily lives. The Canadian public and the Canadian government are already dependent on the continued functioning of these systems, especially the US-led GPS system. In the planning of future transportation, vulnerabilities of GNSS systems should be accounted for and mitigated for example, through partnerships with the US and other GNSS providers to improve the availability of Positioning, Navigation, and Timing (PNT) information so as to avoid major impacts on transport. Using Canadian space technologies, capacities and services can be competitive levers for the transportation industry.

Space weather can have major effects on electrical grids, computers and increasingly sensitive electronic devices. Space weather events have the potential to disrupt all modes of transportation. Canada should continue to be active in monitoring space weather and, for the transportation sector more specifically, consider adopting and enforcing industrial standards that will increase safety in this area. Planning for vulnerabilities and possible disruption of space systems will decrease impacts to the "bottom line".

The use of future space resources (tracking, surveillance, navigation, communications, internet access) and capabilities to modulate the energy budget of future transportation requires close examination with the view of saving costs and limiting footprint on the planet, and for contributing to vehicular autonomy – in the aim of increasing safety and decreasing the environmental impact.

Real-time detection using space resources of sea ice, weather, and vessel traffic should be further developed and exploited and made available to commercial operators. This should allow for better deployment and use of Canadian resources in the future, within the Canadian Coast Guard, for example. Canadian sovereignty also requires detailed and real-time knowledge of the territory, as well as robust support for deployed assets.

While space offers many interesting solutions and has become embedded into a number of civil and government transportation related applications, continuity of data and robustness of the systems require continued investment.

Transportation in the North

Climate change will prompt increased activities in the North, ranging from the exploitation of natural resources to marine shipping, tourism, air flights and human mobility overall. Transportation is key to ensure this future development. Space resources and capabilities can offer cost effective solutions to enhance safety, security and the economy of transportation in the North. Access to future space systems, whether indigenous or foreign, that are attuned to serving Canada’s Northern transportation requirements, will be key to the competitiveness of transportation operations in the region and, therefore, to Canada’s economy globally.

Space capacities of relevance may include; data communications satellites; payload instruments or satellites to detect and monitor solar weather events; additional EO radar satellites for increased resolution, revisit and coverage for land monitoring and safety and security; and improved meteorological forecasting and understanding.

The private sector is rapidly embracing new technologies derived from space namely communications, acquisition and dissemination of information, positioning, navigation, and timing (i.e., GPS), weather monitoring and prediction and safety, as soon as these become commercially available. This will create an increasing demand for space resources in Canada overall but especially in the North.

Investments in future space and transportation infrastructure and new technologies that are not available today will support the North in achieving its economic potential.

Commercial Space Transportation

Aside from transportation in the air and on Earth, an emerging trend of space transportation will have a positive benefit to the global space economy. Space transportation is seen to have the potential to become an important sector in its own right, first with sub-orbital and orbital launches and later, with improved, accessible and affordable access to space for cargo and humans (i.e., space tourism).

As space transportation evolves over the coming decades, Canada has an opportunity to support new business models allowing for a new era of transportation to space and in space.

“Though the role of government must have clear limits, there has been historical recognition in Canada that space-related public investments are essential for the achievement of fundamental imperatives of nationhood, including guarding the country’s borders and coastlines, raising its global standing, linking together and serving a small population spread across a huge land mass, spurring economic growth, protecting the environment, advancing the development of new technologies, and pushing the boundaries of knowledge”
(Source: Aerospace Review Report, 2012).

6 ACRONYMS

ADS-B	Automatic Dependent Surveillance – Broadcast
AIS	Automatic Identification System
ANS	Air Navigation System
app	application
CBSA	Canada Border Security Agency
CO2	carbon dioxide
CSA	Canadian Space Agency
DARPA	Defense Advanced Projects Research Agency
DFO	Department of Fisheries and Oceans
DND	Department of National Defense
EO	Earth Observation
ERP	Enterprise Resource Planning
ESA	European Space Agency
EU	European Union
GDP	Gross Domestic Product
GEO	Geosynchronous Earth Orbit
GEOSAR	Geosynchronous Search-and-Rescue
GLONASS	Russian Global Satellite Navigation System
GNSS	Global Navigation Satellite System
GoC	Government of Canada
GPS	Global Positioning System
ISS	International Space Station
LEO	Low Earth Orbit
LEOSAR	Low-Earth Orbit Search-and-Rescue
LIDAR	Light Detection and Ranging
M2M	Machine-to-Machine
MDA	MacDonald Dettwiler and Associates
MetOcean	Meteorology Ocean
NASA	National Aeronautics and Space Administration
NSS	National Search and Rescue Secretariat
PND	Personal Navigation Device
PNT	Space-based Positioning, Navigation, and Timing
S3	Swiss Space Systems
S-AIS	Satellite-based Automatic Identification Systems
S&R	Search and Rescue

SAR	Synthetic Aperture Radar
SatCom	Satellite Communications
SPF	Space Policy Framework
SS2	SpaceShipTwo
TGV	Train à Grande Vitesse, "high-speed train"
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
US	United States
USSR	Union of Soviet Socialist Republics
UTC	Universal Time Coordinated
VAAC	Volcanic Ash Advisory Centre
Wi-Fi	Wireless Fidelity
XS	Experimental Spaceplane

7 REFERENCES

The content of these documents and websites have been used as reference and quoted throughout this submission.

1) Federal Aviation Administration "The Annual Compendium of Commercial Space Transportation: 2014".

2) Civil Aviation Authority "UK Government Review of commercial spaceplane certification and operations" Technical Report July 2014.

3) SPACE REF Canada, "will North Bay Become a Canadian Spaceport?", April 27, 2015 http://spaceref.ca/commercial-space/will-north-bay-become-a-canadian-spaceport.html (accessed 20.05.15.).

4) National Aeronautics and Space Administration (NASA), http://www.nasa.gov/, 2015 (accessed 20.05.15.).

5) SPACEPORTAMERICA, http://spaceportamerica.com/, 2015 (accessed 4.06.15.).

6) "Soyuz-TMA," Wikipedia, http://en.wikipedia.org/wiki/Soyuz-TMA, last modified on 31 May 2014. (accessed 3.06.15.).

7) SpaceX, NASA selects SpaceX to be part of America's Human Spacecraft Program, SpaceX news, NASA-selects-spacex-be-part- americas-human-spaceflight-program, 16 September http://www.spacex.com/news/2014/09/16/nasa-selects-spacex-be-part-americas-human-spaceflight-program, 2014 (accessed15.05.15.).

8) XCOR, About Lynx XCOR Aerospace, http://xcor.com/lynx/ , 2014 (accessed 20.05.15.).

9) Erik Seedhouse "SUBORBITAL Industry at the Edge of Space", Praxis Publishing, ISBN 978-3-319-03484-3, 2014. 2009.

10) Joseph N. Pelton and Peter Marshal" LICENSE TO ORBIT - The Future of Commercial Space Travel, published by Apogee Books, ISBN 978-1-894959-98-8.

11) Polar View, "Contribution of Space Technologies to Arctic Policy Priorities", June 2012.

12) Governments of Yukon, Northwest Territories and Nunavut, "Developing a New Framework for Sovereignty and Security in the North", discussion paper, April 2005.

13) Governments of Yukon, Northwest Territories and Nunavut, "Pan-Territorial Adaptation Strategy" presentation, part of "A NORTHERN VISION: A Stronger North and a Better Canada".

14) Governments of Yukon, Northwest Territories and Nunavut, "A NORTHERN VISION: A Stronger North and a Better Canada", August 2014.

15) Hothern, L.D., "Multi GNSS Current Status and Future", presentation at the IAG/FIG Commission 5/ICG Technical Seminar: Reference Frame in Practice, U.S. Geological Survey, May 2012.

16) Martínez Morán, G., "Future GNSS: Improved Signals and Constellations", technical paper at European Telemetry and Test Conference, Airbus Defense & Space, 2014.

17) Euroconsult – "Socio-Economic Impact Assessment of the Canadian Space Sector", study report for the CSA, 2015.

18) Canada's Space Map V 2.0, 2014.

19) Intermediate experimental vehicle Launchers "ESA EXPERIMENTAL SPACEPLANE COMPLETES RESEARCH FLIGHT", http://www.esa.int/Our_Activities/Launchers/IXV/ESA_experimental_spaceplane_completes_research_flight (accessed 3.06.15.).

20) Industry backs government's spaceport plans" A spaceport consultation outcome has been published, paving the way to make UK commercial spaceflight operations a reality." https://www.gov.uk/government/news/industry-backs-governments-spaceport-plans (accessed 3.06.15).

21) Canada's Space Policy Framework http://www.asc-csa.gc.ca/eng/publications/space-policy/ (accessed 5.06.15.).

22) exactEarth, http://www.exactearth.com/applications/global-vessel-monitoring, (accessed 09.07.15).

23) Novatel, http://www.novatel.com/an-introduction-to-gnss/chapter-5-gnss-applications-and-equipment/applications, (accessed 09.07.15).