Laying the foundation for a digital Nova Scotia

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Abstract. In 2013, the Province of Nova Scotia began an effort to modernize its coordinate referencing infrastructure known as the Nova Scotia Coordinate Referencing System (NSCRS). At that time, 8 active GPS stations were installed in southwest Nova Scotia to evaluate the technology’s ability to address the Province’s coordinate referencing needs. The success of the test phase helped build a business case to implement the technology across the entire Province. It is anticipated that by the end of 2015, 40 active GPS stations will be in place across Nova Scotia. This infrastructure, known as the Nova Scotia Active Control Stations (NSACS) network, will allow for instantaneous, centimetre level positioning across the Province. Originally designed to address the needs of the surveying community, the technology has also proven to have applications in mapping, machine automation, agriculture, navigation, emergency response, earthquake detection and other areas. In the foreseeable future, all spatial data sets captured in Nova Scotia will be either directly or indirectly derived from the NSACS network. The technology will promote high accuracy and homogenous spatial data sets across the Province. The technology behind the NSACS and the development of the system are described. Examples of how the technology is contributing to a digital Nova Scotia are presented. Future applications of the technology are also considered.

1. Introduction
Since 1968, the Province of Nova Scotia has carried out a mandate of providing a coordinate referencing system for its citizens. A coordinate referencing system allows users to locate property and infrastructure in a framework that can be related to other systems around the world. In the late 1970s, over $10 million was invested to develop the Nova Scotia Coordinate Control System (NSCCS) system through the Land Registration and Information Service (LRIS). The NSCCS was the predecessor to the current framework for providing location based information which is known as the Nova Scotia Coordinate Referencing System (NSCRS).

Since the 1990s, the Province’s coordinate referencing mandates have been carried out through the NSCRS. The NSCRS is the foundation for the Province’s geographic data holdings including the land administration system. It also enables various legislation including the Land Registration Act, the Crown Lands Act and the Land Surveyors Act. The system enables surveyors to spatially relate properties, objects and features. The resulting survey plans provide the underlying data set for Property Online, which is the Province’s primary tool for managing property and property rights. The
NSCRS provides transformation tools to allow historic surveys performed in previous coordinate referencing systems to be related to present day surveys.

The NSCRS requires ongoing maintenance of the Nova Scotia Control Monuments (NSCMs) (sometimes referred to as survey monuments) used to realize the coordinate referencing systems. The NSCMs provide a physical manifestation of the mathematical coordinate system used to spatially relate property boundaries and other locations. The infrastructure is spread across the Province so that surveyors can readily connect their work to the system.

At its peak, the NSCCS had over 23,000 NSCMs demarcating the reference frame. The NSCCS was realized using observations made with electronic distance measurement (EDM) technology in the late 1970s and 1980s. As GPS became more commonplace in the 1990s, distortions in the NSCCS became apparent. The newer NSCRS was realized in the late 1990s by observing 153 NSCMs with precise GPS. The reference frame was named the Nova Scotia High Precision Network (NSHPN).

Over the past several decades, NSCMs across the Province have been destroyed by construction work and have been overgrown by vegetation. It is estimated that 75 per cent of the 23,000 NSCCS reference frame is now unusable. This outcome was inevitable, considering insufficient human and financial resources to support the coordinate referencing program. Such issues are not unique to Nova Scotia. Generating support for infrastructure whose functionality is not generally well understood has been an ongoing challenge across Canada.

As NSCMs disappear, risks and inefficiencies associated with decaying infrastructure increase. In recent years, it became clear that action would be required to address risk concerns and accuracy and accessibility challenges raised by Nova Scotia Land Surveyors (NSLSs). In 2012, a strategy to modernize the NSCRS with an emphasis on sustainability began to be developed. The strategy adopted technologies that had emerged in an effort to better address coordinate referencing mandates with fewer resources. At the core of the strategy were Global Navigation Satellite Systems (GNSS) Active Control Stations (ACSs).

2. Leveraging Technology
Since the NSCRS was first implemented though the NSHPN in the late 1990s, several key technologies have emerged which collectively presented a significant opportunity to modernize the system as subsequently discussed.

2.1. Active Control Stations
Permanent Global Navigation Satellite System (GNSS) stations, known as Active Control Stations (ACSs) or Continuously Operating Reference Stations (CORS), allow for real-time kinematic (RTK) GNSS positioning to be performed. RTK surveys are a method of Differential GNSS positioning that utilize a reference (or “base”) station to generate high accuracy coordinates up to about 25 km from the reference station. Horizontal positioning accuracy is typically ± 2 cm + 1 ppm (1 mm/km) and vertical positioning accuracy is typically ± 3 cm + 1 ppm in real-time. Higher accuracy can be achieved by using longer observation periods for the point of interest. When longer observation periods are used to improve accuracy, the observation technique is known as a static survey.

In essence, the ACS eliminates the need to have a dedicated surveyor operate a reference station in the field using traditional reference and rover receiver setups. By locating the GNSS equipment in secure locations, it can run continuously so that the Differential GNSS requirement for simultaneous measurements can easily be achieved. ACS technology makes observing NSCMs to maintain the NSHPN more achievable with fewer human resources.

2.2. Network, Real-time Kinematics GNSS Surveys and Cellular Communications
GNSS software has also evolved so that by locating ACSs across a large region corrections can be modelled and used for Network RTK (NRTK) positioning. By forming a polygon with ACSs, GNSS corrections can be interpolated, and the distance dependent positioning error can be reduced from 1 ppm to 0.5 ppm (0.5 mm/km). These corrections can be broadcast over the internet to users in the
field. Users require a cell modem or can tether to another internet connected device. Approximately 85 per cent of Nova Scotia has cellular coverage, providing a unique opportunity to offer RTK positioning services throughout the Province. By utilizing NRTK, NSCM observations can be made in minutes to update coordinates to NAD83 (CSRS) values, which allows the NSHPN to expand and become more accessible.

2.3. Crowd Sourcing
The widespread development of communications networks has also enabled users of various technologies to generate and submit data to accomplish certain tasks. This crowd sourcing technique can also be used to allow NSCRS users to contribute to the maintenance of the NSCRS infrastructure. By implementing appropriate quality control, the technology provides an efficient way to keep data current.

3. Modernization of the NSCRS using Active Control Stations
In the winter of 2013, the Province issued a request for proposals to provide an ACS based solution that would help address the coordinate referencing needs previously described. Recognizing that the ACS data would become the primary access point to the NSCRS, it was specifically requested in the tender that any devised solution would allow the archived data from each station to be made freely available to the public. This open data effort would allow Differential GNSS surveys to be conducted within the Province with a direct connection to the NSCRS at no cost to the user.

In the spring and summer of 2013, eight ACSs were installed in the southwest region of Nova Scotia to test the technology. This infrastructure was named the Nova Scotia Active Control Stations (NSACS) network. The NSACS network provides additional NSCMs in the NSCRS reference frame to help address the accessibility and accuracy needs. Figure 1 shows the NSACS station in Digby.

Figure 1: Nova Scotia Active Control System (NSACS) station in Digby. (Photo credit: Province of Nova Scotia)
A proposal to expand the NSACS network across the Province was put forward in 2013. The proposal was supported by a comprehensive business case based upon results obtained during the test phase. The test phase demonstrated that the NSACS network offered several advantages: a) greater access to a NAD83 based, coordinate referencing system than traditional passive control approaches; b) opportunities to maintain passive control with low cost; and c) opportunities to create a sustainable maintenance plan by licensing the real-time data streams and implementing a cost recovery model.

In December of 2014, Government announced that funding would be granted in April of 2015 to complete the NSACS network in Nova Scotia. The project would be completed in two phases over two fiscal years. During the first phase in 2015-2016, the remaining ACS stations would be installed across the Province. Forty ACSs would be installed in total. Figure 2 illustrates the final design of the network. In the second phase over 2016-2017, the focus would be on densifying the NSHPN network so that a better grid shift model can be generated between ATS77 and NAD83 (CSRS) 2010.0. It is desired to update between 500 and 1000 NSCMs with NAD83 (CSRS) coordinates to expand the NSHPN.

The NSACS was originally intended to address the coordinate referencing needs of the surveying profession, but the technology has widespread applications. Moving forward, the NSACS will serve as the backbone for all of the Province’s spatial data. The following sections outline ways in which the technology has recently been applied.

4. Current Applications
Since the first NSACS installations in 2013, the technology has been integrated for various applications. Examples of the work currently under way are summarized in the following subsections.

Figure 2: Map of the Nova Scotia Active Control System (NSACS) network.
(Map credit: Province of Nova Scotia)
4.1. Geo-referencing Aircraft and Aerial Photography
The Nova Scotia Topographic Database (NSTDB) is the Province’s source for topographic information that includes natural and cultural features. For over 40 years, the NSTDB program has been mapping the Province’s topography using aerial photography. A different portion of the Province is mapped each year. The NSACS network allows the position of the aircraft to be accurately located so that the imagery can be referenced to the NSCRS. Additionally, the NSACS allows ground control points to be positioned at strategic locations so that quality control can be performed on the final image products. In 2014, aerial photography was captured for Sable Island and georeferenced using the Sable Island NSACS. Figure 3 illustrates an aerial target positioned using GPS and a small section of the imagery that was captured at the West Spit.

![Figure 3: Aerial target being positioned on the ground, at left, and aerial view of the West Spit of Sable Island, at right. (Photo credit: Province of Nova Scotia)](image)

4.2. Highway Construction
The majority of highway construction work performed in Nova Scotia is currently completed using automated machine guidance technologies. Digital elevation models are developed and input into the control unit of heavy machinery, such as graders, bulldozers and excavators. Software applications running on the control unit allow finished grade to be achieved more quickly through machine guidance than through manual methods, which creates operational efficiencies and cost savings.

4.3. Property Surveys
In Nova Scotia, land surveyors are regulated to connect their property surveys to the Province’s coordinate referencing system. This allows all properties to be related in a common boundary fabric in the land administration system. Traditionally, this has been achieved by occupying NSCMs and commencing the survey from these points with known coordinates. The NSACS are NSCMs with permanently installed GPS hardware that are constantly logging and archiving data. Land surveyors in Nova Scotia are inherently connected to the NSCRS when they utilize NSACS data. Efficiencies are created by allowing the surveyor to immediately begin a survey at the job site and by accessing the NSACS data either in real-time through a service provider or free of charge from Canadian Geodetic Survey’s (CGS) Canadian Active Control System (CACS) data download portal.

4.4. Asset Management Surveys
Towns and municipalities in Nova Scotia are leveraging the NSACS network to build databases of their assets with accurate location information. Location information for public infrastructure, such as catch basins, waterlines, gas lines and signs, is being collected so that more informed decisions can be
made regarding maintenance and overall management. The data accurately overlays other municipal or provincial data sets collected using the NSACS.

4.5. Tectonic Modelling
Each NSACS site can have its position monitored with millimetre level accuracy on a daily basis. The position information for each site can be analyzed over the long term to determine any trends that may exist. Velocities, typically in the order of a few millimetres per year, can be determined to model tectonic movement for the Nova Scotia portion of the North America Plate. This information is utilized by the Geological Survey of Canada to better understand how the absolute position of Canada is changing over time.

4.6. NSCRS Maintenance
The NSACS network has made maintenance and expansion of the Province’s passive NSHPN network possible in a sustainable manner. The high accuracy, real-time updates allow NAD83 (CSRS) coordinates to be generated for new and existing NSCMs in a fraction of the time that traditional methods required. The new approach only requires one resource to perform an update, whereas traditional methods required several. Surveyors can also contribute to ongoing maintenance of the system through a new web portal that allows observation data to be submitted to the NSCRS database. In this case, a selected crowd with known credentials is used to source the data.

5. Future Applications
In addition to the afore-mentioned applications, the NSACS creates opportunities to acquire further high-accuracy spatial data sets in a coordinate referencing system tightly integrated with other systems around the world. These opportunities are explored below.

5.1. Automated Vehicle Guidance
When combined with an extensive cellular network the NSACS network offers a unique opportunity to provide access to high accuracy GNSS corrections across the majority of the Province in real-time. This infrastructure has significant potential for automated vehicle guidance applications. Theoretically, a map-and-match approach could be used to navigate a vehicle from one end of the Province to the other without human intervention. Having the route mapped once with GNSS, the vehicle could be programmed to follow the same route with the assistance of other onboard sensors.

5.2. High-resolution, Laser scanning
New 3D laser scanning technology has made the rapid capture of highly accurate, digital models of the world around us a reality. Depending on the manufacturer, different techniques for measuring position are being utilized. At a very basic level, the scanning instrument emits laser pulses at angular increments which, upon reflection from an object, allows the distance from the scanner to the object to be determined. By knowing the angular orientation of the scanner at the time of transmission as well as the scanner’s location, the 3D position of the reflective object can be determined. Commercially available scanners can acquire 1,000,000 points per second with millimetre level accuracy [1]. Fröhlich and Mettenleiter [2] provide a more detailed discussion of the technology. Figure 4 illustrates a laser scan captured in the Burnside Industrial Park area in Dartmouth, Nova Scotia.

The price of terrestrial laser scanners has reached a level where it is not unrealistic to expect in the foreseeable future that a standard survey will be delivered as a 3D point cloud with draped imagery. In Nova Scotia, these surveys can be positioned using GNSS and the NSACS network. As these data sets are being submitted to the land registry system, a coherent 3D model of the Province will evolve.

Laser scanning technology has also been applied to different mobile platforms to facilitate widespread 3D data capture. The technology has been integrated into aircraft, hydrographic vessels and terrestrial vehicles. The NSACS enables the real-time positions of these platforms to be calculated so that laser scanning results can be accurately referenced to the NSCRS.
**Figure 4:** Laser scan, at top, and photographic image, at bottom. (Credit: Cansel Surveys Limited)

**Figure 5:** High resolution imagery, acquired using a drone, covering an area of approximately 150 m by 80 m. (Credit: Cansel Surveys Limited)
5.3. **High Resolution, Drone Imagery**

The emergence of drones to capture aerial imagery creates new opportunities for acquiring more accurate, more detailed and more current spatial data for Nova Scotia. Using basic principles of photogrammetry, position information can be derived from the high resolution (up to 20 cm pixel resolution) imagery captured by the drone. Both the drone and the targets placed on the ground to georeference the imagery can be positioned using the NSACS network. Figure 5 shows a high-resolution image acquired by a drone in the Bayers Lake area of Halifax, Nova Scotia.

5.4. **Earthquake Detection**

During the past five years a total of 16 earthquakes have been recorded in Nova Scotia. The most recent one occurred approximately 42 km northwest of Yarmouth on July 1, 2015, reaching a magnitude of 3.8 [4]. Although earthquakes of this relatively low magnitude are of little concern, the NSACS can be utilized to detect them. Spectral analysis can be performed on the GNSS observations at each site to determine if frequencies caused by earthquake activity exist. Additionally, the position information at each site can be monitored for abnormal movements.

6. **Summary**

The NSACS network was implemented starting in 2013 to help address the coordinate referencing needs of the Province. Originally designed to address the needs of the surveying community, the NSACS network has also proven to have applications in mapping, machine automation, agriculture, navigation, emergency response, earthquake detection and other areas. In the foreseeable future, all spatial data sets captured in Nova Scotia will be either directly or indirectly derived from the NSACS network. The technology will promote high accuracy and homogenous spatial data sets across the Province, leading to a more detailed digital model of Nova Scotia.

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