CDGPS – Canada-wide DGPS Service: Quality Real Time GPS Positioning

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Abstract:

The Canada-wide DGPS service (CDGPS) project is a Canadian Federal/Provincial/Nunavut Government partnership to deliver GPS corrections to all Canadians via the MSAT communication satellite. These corrections will be freely accessible and are based on Geodetic Survey Division, Natural Resources Canada's GPS•C real-time wide-area GPS correction information. By applying these quality GPS corrections, users will improve their real-time GPS positions and allow for direct access to the Canadian Spatial Reference System (CSRS).

On behalf of the Federal/Provincial/Nunavut partners, the Base Mapping & Geomatics Services Branch (BMGS) of the B.C. Ministry of Sustainable Resource Management are acting as project managers. A contract is in progress to develop a user receiver and the MSAT "hub" system to allow for the broadcast of GPS•C corrections. The service is expected to be on-line in Spring 2002.

Over the last several years the delivery and use of the GPS•C technology has been demonstrated in various parts of Canada utilizing the BMGS's Global Surveyor™ MSAT receivers and a prototype MSAT satellite communication hub. Clients include the Canadian Hydrographic Service, who has utilized this prototype system since 1998 in the Canadian Arctic.

As well, since 1998, the Canadian Hydrographic Service has been utilizing the operational Global Surveyor ™ service available in British Columbia, for its operations on the West Coast. This has helped prove the MSAT technology in an

operational setting. In addition, and in preparation for the national CDGPS service, this local DGPS service has been utilizing the GPS•C technology since late 2000.

This paper provides a description of the CDGPS project, prototype testing, pre-cursor operational utilization on the West Coast using the Global Surveyor service™, service availability to clients, and plans for the future.

Introduction

The delivery and use of local DGPS (LDGPS) corrections over MSAT, have been demonstrated through the BMGS's Global Surveyor™ service in British Columbia and Alberta [Kassam, et al; 1999]. Since 1998, the Canadian Hydrographic Service has been utilizing this operational service for its operations on the West Coast. This has helped prove the MSAT technology in an operational setting.

As well, the MSAT receivers from the Global Surveyor™ service have been utilized, on a project-specific basis and with GPS•C as the LDGPS source, to demonstrate the viability of MSAT and GPS•C to serve across Canada. Clients for the cross-Canada trials have also included the Canadian Hydrographic Service in the Canadian Arctic.

Through these experiences, it had become clear that MSAT technology and wide-area based DGPS offered a unique opportunity to provide a viable public DGPS service across Canada, complementing and filling-in from the Coast Guard and emerging U.S. WAAS services.

At a September 1999 meeting of the Canadian Council of Geomatics (CCOG) an investment opportunity was discussed to provide a Canadian differential GPS correction service based on Natural Resources Canada's real-time GPS·C infrastructure and the MSAT communications satellite based DGPS technology developed under the Global Surveyor™ program in B.C. The proposal outlined a high level view of the project that would allow access to GPS·C correction information and broadcast it to all Canadians via the MSAT-1 communication satellite. The project would also fund the design and manufacture of 1000 user radio receivers. Representatives from the Provinces, Federal Government and Territories were asked to consider the proposal as a means to provide Canadians easy and direct access to the Canadian Spatial Reference System. CCOG passed a resolution (99-03) supporting the proposal. A formal Memorandum of Agreement was subsequently signed by 10 provinces, the Territory of Nunavut and the federal government in May 2000. The service to be developed was named the Canada wide Differential GPS (CDGPS) service.

On behalf of the Federal/Provincial/Nunavut partners, the Base Mapping and Geomatics Services Branch (BMGS) of the B.C. Ministry of Sustainable Resource Management are acting as project managers. A contract is in progress to develop a user receiver and the MSAT "hub" system to allow for the broadcast of GPS•C corrections. The service is expected to be on-line by summer 2002.

CDGPS Description

The Canada wide DGPS service will deliver freely accessible, high quality GPS correction information across Canada to allow for improved GPS positioning directly referenced to the Canadian Spatial Reference System (CSRS).

The correction information is derived utilizing Geodetic Survey Division of Natural Resources Canada's real-time component of the Canadian Active Control System referred to as GPS·C. This GPS·C infrastructure includes high quality GPS tracking stations located across Canada (Figure 1). Each tracking station (Active Control Point) includes a state of the art dual frequency GPS receiver, a high precision frequency standard, a networked workstation with real-time application software and a high-speed communication link. [Caissy et al, 1996] A real-time master active control station (RTMACS) controls the network of ACP's, manages the data and computes the GPS·C correction information.

Figure 1. Current Real-Time GPS-C Automated GPS Tracking Stations

A CDGPS project office was established within the British Colombia Provincial Base Mapping and Geomatics Services (BMGS) branch to manage all aspects of the project. Based on the CACS infrastructure and RTMACS, NRCan's Geodetic Survey Division is making available its GPS·C in a high-quality and robust 7 x 24 manner to CDGPS. At BMGS, a key piece of the work entailed the selection of a contractor to develop the CDGPS network. The network specifications, including those for the MSAT communications hub and the user MSAT receiver, were carefully developed [BMGS, 2000]. Through a Request for Proposals process, SiGEM Inc. of Kanata Ontario was subsequently selected to develop and deliver the user network. TMI Communications (now Mobile Satellite Ventures) was engaged as a sub-contractor to assist in the development and implementation of the communications hub.

The CDGPS design is illustrated in Figure 2. GPS·C correction information is made available to the CDGPS hub at the TMI communications facility. The hub system assembles and prepares the correction data for MSAT-1 upload. The format for the data is in a documented format similar to the RTCA-159 wide area GPS correction standard referred to as the GPS·C Modified RTCA Data Format (GPS·C MRTCA). The correction data is broadcast on L-band frequencies over the MSAT-1 communications satellite on four beams allowing for Canadian coverage. The CDGPS receiver collects the correction data from the MSAT-1 satellite and also tracks the GPS satellites utilizing the same L-band antenna. The CDGPS receiver function allows for three user-selected outputs;

1/ GPS·C MRTCA

- This allows the CDGPS receiver to be interfaced to a dual frequency GPS receiver capable of receiving the MRTCA format, thereby achieving up to few decimetres (95% confidence) positioning. Until dual frequency GPS receivers interface directly to this output, these highest accuracy results are possible through the use of an intermediate processing system such as a PC interfaced to a dual frequency GPS receiver.

2/ CSRS position (corrections applied) in the NMEA format or ,

- Secondly, users may attach a Personal Digital Assistant (PDA) or other device to receive corrected CSRS positions at an expected 5 m (95% confidence) level.

3/ Local differential RTCM-104 correction stream based on the CDGPS receiver position.

- Last but not least, users may select the RTCM option and pass on pseudo-range corrections to any "DGPS-ready" or "RTCM-ready" GPS receiver in order to achieve an expected 1-5 m postioning (95% confidence)

As with any GPS based solution, accuracy performance depends on the user GPS receiver and field conditions.

CDGPS is designed to offer 7 x 24 service with minimal off-hours maintenance. However, it is not designed to meet public safety availability requirements, such as those required for emergency services. It is a quality and monitored service intended to complement other public DGPS services.

The SiGEM contract will deliver on the items outlined by the dashed lines in Figure 2.

The CDGPS broadcast protocol is an open specification and is made available describing the details of the MSAT-1 broadcast signal and data formats. This specification will allow other receiver manufacturers to build CDGPS capability into their hardware.

Real time positioning accuracy performance numbers for the CDGPS service have been initially stated as better than 5 metres 2drms. Note that GPS positioning with no corrections applied is stated in the GPS Standard Positioning Service Performance Standard as less than or equal to 13 metres 95% horizontal error based on a 24 hour period and less than or equal to 36 metres 95% for "worst site" positioning over a 24 hour period. [U.S. DOD, 2001]

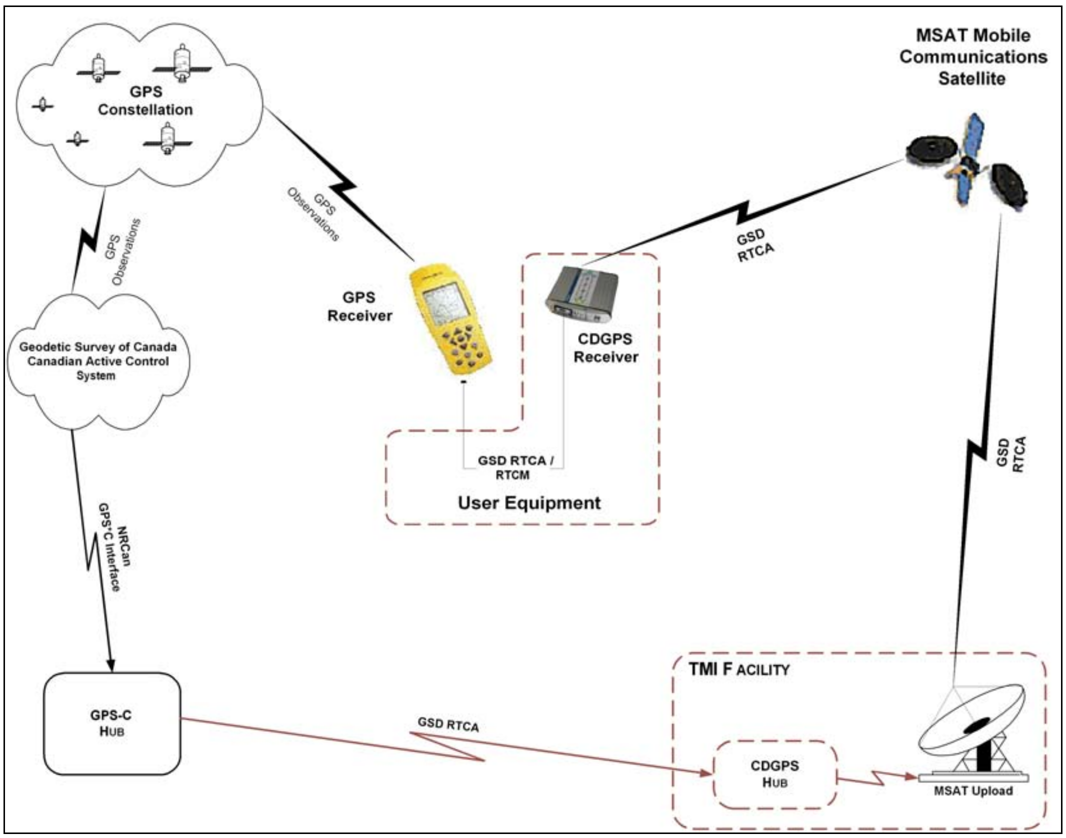

Figure 2. CDGPS Network Architecture

Operational experience with Global Surveyor™ service in B.C.

BMGS have had experience in providing West Coast users the GDBC Global Surveyor™ service via the MSAT satellite. This LDGPS program originally provided corrections based on two BC located reference stations to clients in BC, but since November 2000 the Global Surveyor™ service has been based on

NRCan's GPS·C signal, serving as a test bed for the national service. The Global Surveyor™ service has been utilized in many applications. This is a list of possible applications, with examples, in which CDGPS will have significant impact with its increased coverage, accuracy and reliability:

- **Aerial Mapping**: e.g. navigating and resource mapping from a helicopter
- **Airborne Guidance**: e.g. guiding the application of fertilizer/ herbicide
- **Bathymetric Surveying**: e.g. dynamic positioning of survey launches on lake and fjords
- **Engineering**: e.g. creating a plan view of a golf course to design a drainage system and locations for fairway reconstruction
- **Environmental**: e.g. mapping occurrences of Douglas Fir Tussock Moth and Gypsy Moth
- **Forest Inventory and Silviculture**: e.g. relocating start and end points of line transect plots which had been spaced and pruned since previous mapping was completed
- **Forestry Pre and Post Harvest Mapping**: .e.g. maintaining maps locating pre harvest boundaries and mapping post harvest blocks
- **Fisheries Inventory**: e.g. mapping streams and creeks
- **GIS Data Capture and Mapping**
- **Precision Agriculture**: e.g. regulating the quantity and location of the application of fertilizer and herbicides or pesticides
- **Surveying**: e.g. locating lot corners to identify forest license boundaries, or georeferencing remote parcels for inclusion in reference maps
- **Road Inventory Mapping**: e.g. mapping main haul roads
- **Wildlife**: e.g. sampling wildlife habitat sites

The Canadian Hydrographic Service (CHS), Pacific Region began using the BMGS Global Surveyor™ service in the fall of 1997. The receiver unit was borrowed for testing and analysis purposes. It was mainly used to position the survey launch during a reconnaissance survey of Adams Lake. CHS uses NovAtel 3151R receivers, frequently with multipath resistant antennas. A report was written [Czotter, 1997] which documented the ease of use, costs and benefits and estimated horizontal accuracy of 2 metres, 2-d rms.

The main advantages come in the logistics, since there is no requirement to establish a local reference station, carry an extra GPS receiver, batteries, solar panels, radio link, etc. In addition to that, there is no worry about vandalism or theft of unguarded expensive GPS equipment at the reference station.

The CCG Marine Radio Beacon (MRB) DGPS service does not cover the interior of BC well, so this service is ideal for application in navigable lakes and rivers. The MRB DGPS receivers have been somewhat problematic due to their low frequency (300 kHz) and the requirement for good grounding and electrical noise suppression – sometimes difficult on small fibreglass vessels. DynaPlates were installed on these vessels in order to improve grounding and had to deal with noisy alternators on several occasions. Global Surveyor™ does not suffer from these limitations. In addition, due to the very low data rate (100 bps at the time) of the MRB service, data latency was adding to the position error budget. This is less of a problem since May 2000 as documented in testing carried out by Parallel Geo-Services Inc. [Keel, 2000]

Since 1998, CHS have been using the Global Surveyor™ service for the majority of its field survey applications. It has proved to be invaluable for Revisory Survey operations and small "brushfire"/emergency type surveys that require rapid movement from place to place and survey only for short periods of time. At present, the only time the service is not considered for use would be for surveys requiring vertical measurements with a precision better than 5 cm (95%). For these surveys dual-frequency RTK GPS is used by installing a nearby reference station and high rate data link. For the most part, Global Surveyor™ meets all of the horizontal positioning needs.

CDGPS Prototype Testing and Operational Uses across Canada

Prototype testing/demonstration of the performance of GPS·C has been carried out in conjunction with the Department of Fisheries and Oceans, Canadian Hydrographic Service, other Government Departments and private industry partners over the past 4 years. Some of the demonstration projects include;

- Canadian Coast Guard and Canadian Hydrographic Service Summer 1998 St. Lawrence River to Hudson Bay. [Lochhead et al, 1998, 1999]
- Canadian Hydrographic Service 1999 Mackenzie River and Western Arctic [Leyzack et al, 2000]
- Canadian Hydrographic Service 2000 Beaufort Sea and Western Arctic
- Canadian Hydrographic Service 2001 Beaufort Sea and Western Arctic
- Seavisual Inc Prudhoe Bay to Mackenzie River delta. 2001
- UNB GPS·C internet tests 2001
- Legal Surveys Pelly Bay 1999
- Ministry of Natural Resources Ontario testing 1999
- Forest Engineering Research Institute of Canada (FERIC) testing in Quebec and Newfoundland 1999.

These prototype demonstrations/operations have been carried out using Global Surveyor™ radios receiving correction information via MSAT-1 for specific work areas.

Typical positioning performance of applying GPS·C corrections is shown in Figure 3. Horizontal position differences are shown with respect to a point with known coordinates at the University of New Brunswick. These results are based on single frequency, code-based GPS observations. Standalone GPS positions are shown in blue and GPS-C corrected positions are shown in green. Over a 24 hour period in August 2001, standard deviations of the GPS-C corrected positions improved by 65% and showed 3-d rms position accuracies at the 2 metre level. [Horvath et al, 2002]. Further analysis will be required for CDGPS accuracy performance.

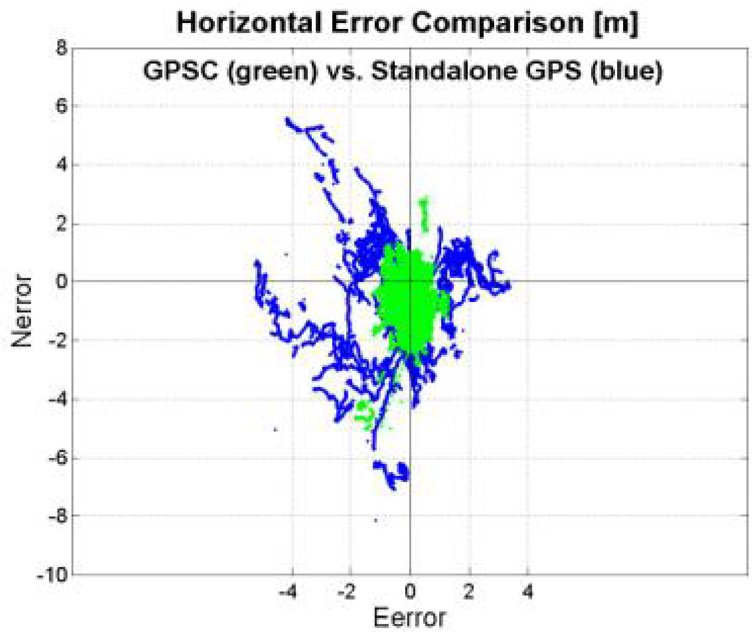

Figure 3. Position Differences of Standalone GPS and GPS·C Corrected positions at UNB
August 13-14, 2001

CDGPS Service Availability

The SiGEM contract is progressing in the development of the hub at TMI Communications and the CDGPS receiver. The GPS·C operational infrastructure is nearing completion. Testing is progressing and alpha and beta trials are scheduled for spring 2002. Through the Beta Trials, real users will test and try out the service. Their results will be posted on the CDGPS web site at cdgps.com. Their experiences will initiate the broader service adoption process. The service is expected to be publicly available by summer 2002. 1000 radios will be manufactured with 500 available to the general marketplace. A marketing strategy has been under development and private distributors are expected to be in place by service launch. Users will be able to purchase CDGPS receivers for an estimated cost of $1500 and with no subscription fee.

Future Plans

Summer 2002 will mark the start of broadcast for the CDGPS service across Canada. Over time, the CDGPS partners and the private distributors of the CDGPS receivers hope to expose the utility of this service to Canadians. Hydrographic users should benefit from this service, particularly in places where the Coast Guard service is not available and in many cases supplement the Coast Guard service.

The potential exists for the CDGPS to allow users equipped with dual frequency GPS receivers to apply the MRTCA format correction stream to their observations. By utilizing the dual frequency observations, improvements in user positioning accuracy can be obtained by directly computing the ionospheric correction.

Many users from areas where the existing Global Surveyor™ service is not accessible have been approached for help and support in the Beta testing phase of CDGPS and have shown a significant interest. These users see benefit in obtaining reliable, consistent and a common base to the existing provincial and territorial geo-referencing infrastructure.

Research continues at Geodetic Survey Division toward performance improvements of GPS•C. This includes the use of GPS carrier phase correction information for dual frequency GPS users thereby enhancing user position accuracy. [Collins et al, 2001].

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