Demonstration Project Results of GPS•C Wide-Area GPS Corrections for Remote Areas including the Arctic

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BIOGRAPHY

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ABSTRACT

Wide-area differential GPS offers significant advantages for special needs users, such as Canadian Coast Guard (CCG), and the Canadian Hydrographic Service (CHS) for their Canada-wide operations, particularly in remote areas of the country. The Geodetic Survey Division of Natural Resources Canada (NRCan) has developed a system of nation-wide GPS corrections or GPS•C. GPS•C provides real-time GPS corrections for distribution and broadcast throughout Canada. The corrections are made available in standard RTCA-159 or RTCM-104 formats for direct input to GPS receivers.

The CCG provides a Differential GPS "Initial" operating service (CCG DGPS) for general navigation in identified high traffic areas of the Canadian Waterways System. GPS•C's RTCM-104 format is compatible with the CCG Differential GPS Navigation Service.

A joint Canadian Coast Guard, Canadian Hydrographic Service, Geographic Data B.C., TMI Communications, Cygnus Satellite Systems Corp. and NRCan GPS•C demonstration project was conducted from mid-July to mid-October 1998. The data collection phase of the project took place on board the CCG vessel "CCGS GRIFFON" on a voyage from Prescott, Ontario to Churchill, Manitoba via the St. Lawrence River, Gulf of St. Lawrence, Labrador Coast, Davis Strait, Hudson Strait and Hudson Bay. The first half of this 4700 km route was within coverage of the CCG DGPS Navigation Service. GPS•C corrections were delivered to the vessel, for the entire voyage, using the MSAT mobile satellite service. An onboard computer system processed RTCM-104 corrections from both GPS•C and CCG DGPS providing continuous real-time comparisons of position differences between both systems. Stored raw data and GPS•C positions were analyzed, in post processing, to determine the performance of the system outside the CCG DGPS coverage area.

The paper presents the initial evaluation of positional accuracy resulting from the use of GPS•C outside of the CCG DGPS Navigation Service. The results show that GPS•C corrections, via the MSAT link, were available and reliable for the entire voyage to Churchill, Manitoba which reached as far north as 64 degrees latitude. Further testing and operational use by CHS during the 1998 navigation season demonstrated GPS•C reliability and coverage at 69 degrees north latitude.

1. Introduction

The Geodetic Survey Division operates the Canadian Active Control System (CACS). A Master Active Control Station (MACS) and a network of continuously operating GPS data acquisition stations (Active Control Points – ACPs) are the major components. The ACPs are distributed across Canada and track all GPS satellites in view. Nine of the CACS tracking stations (Figure 1) have been enhanced to deliver real-time data to a Real Time MACS in less than 2 seconds for the computation of wide area GPS Corrections or GPS•C. Details of the system architecture and system performance are outlined in [1,2,3]. A project was conducted on board the CCG vessel "CCGS GRIFFON" during the period of July 15 –

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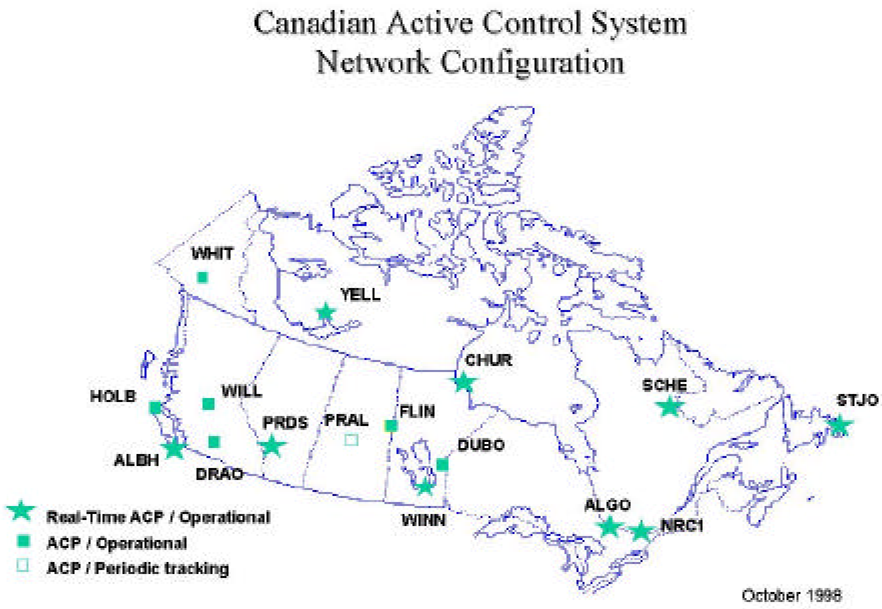

Figure 1: The CACS Network

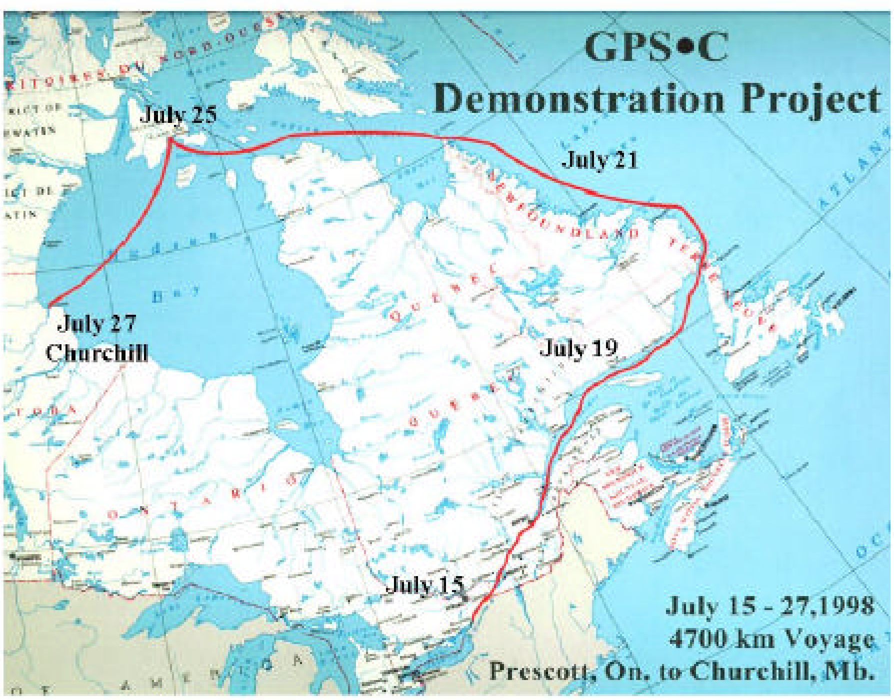

Figure 2: Demonstration Project Route

27, 1998 enroute from Prescott Ontario to Churchill Manitoba (Figure 2). The purpose of the project was to demonstrate the compatibility, accuracy and availability of GPS•C in relation to the CCG DGPS Navigation Service Service [4] in the St. Lawrence River and east coast regions of eastern Canada. Results for the portion of the voyage within the CCG's service, July 15-21, are presented in [5]. The strategy for receiving GPS•C corrections, availability of the GPS•C signal and initial position accuracy comparisons will be discussed.

2. Demonstration Project Data Communication

Wide-area GPS corrections computed by the GPS•C system are normally delivered in a form that is applicable for use in any region of Canada. The corrections are delivered in a standard wide-area GPS format such as RTCA-159. For this project, since RTCM-104 corrections were required, a strategy involving periodic updates for the ship's position was necessary in order to "localize" the wide-area correction information. GPS•C information was sent from the GSD MACS to the TMI up-link site. RTCM-104 corrections were computed and transmitted from TMI to the Griffon via the MSAT geo-stationary satellite. The RTCM-104 corrections were received at the ship and applied to the GPS observations for point positioning. Figure 3 illustrates the data collection configuration onboard the ship.

In keeping with CHS's current mode of operations, an additional radio link was used to re-transmit the MSAT RTCM-104 corrections from the ship to CHS's survey launches.

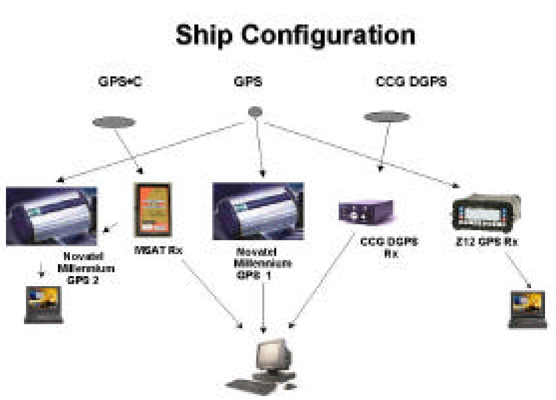

Figure 3: Data Collection Configuration

3. GPS•C Availability

Two separate Cygnus MSAT antenna/radio units were installed on board the ship. Both antennas were located mid-ship above the wheelhouse, one on the port side and the other one slightly starboard. GPS•C-derived RTCM-104 Type 1 corrections were transmitted, from the TMI up-link site, at a rate of .5 Hz or 1800 corrections per hour. Figures 4 and 5 illustrate statistics accumulated in order to assess the availability of the GPS•C signal. Each solid dot represents the percentage of corrections received for each hour of the voyage July 15-27. Differences in these statistics can be seen when comparing the availability of corrections on the port versus starboard antennas. The starboard antenna was particularly susceptible to masking by the ships smoke stack structure when the elevation angle to MSAT was low and the ship's heading was approximately due north. This condition presented itself during the period July 21-22 off the Labrador coast. The port antenna demonstrated better performance due to an unobstructed view to the southwest, the direction to MSAT, and an overall quieter operating environment. The Cygnus quadrafilar antenna has a peak gain at 30 degrees above the horizon and performed well receiving MSAT signals down to 12 degrees on the horizon. CHS conducted surveys in Hudson Bay, Bathurst Inlet (68ºN 108ºW) and Simpson Strait (69ºN 96ºW) from August to early October. They reported good availability and performance of GPS•C. In fact, CHS decided to use GPS•C for their positioning requirements early on, after performing their own evaluation of the system's accuracy and reliability. In doing so, they eliminated the need for shore stations in support of their positioning requirements, reducing the costs of their surveys.

The MSAT signal is delivered on a number of beams and dynamic users will periodically move from one beam to another. During the voyage to Churchill, the ship crossed two beam boundaries. For this project the RTCM-104 corrections were broadcast on a single beam. Once the ship arrived at a beam boundary, the signal was switched to the appropriate adjacent beam. In the regions of the beam boundaries, there were periods of degraded communication performance until the switch over occurred. The beam crossings occurred on July 21 at 20:30 UTC and on July 26 at 13:20 UTC. Figure 4 illustrates the impact of these switchovers. The July 26 crossover was not detected as well as the crossover which occurred on July 21.

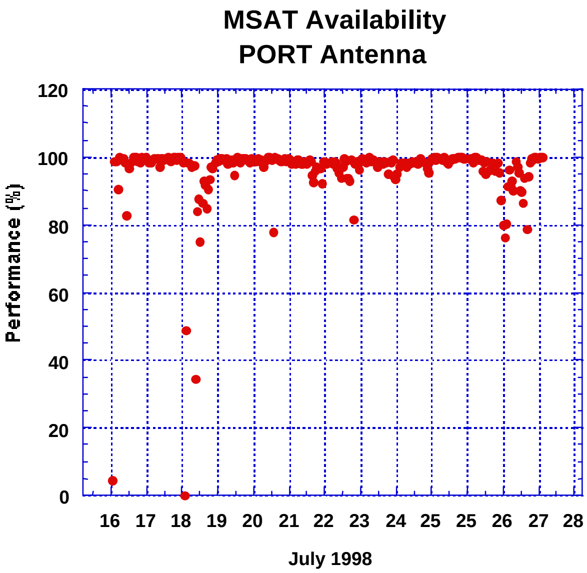

Figure 4: MSAT Availability Port Antenna

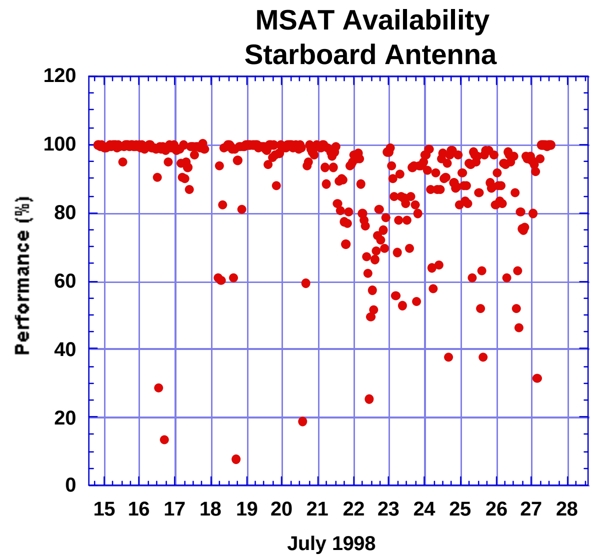

Figure 5: MSAT Availability Starboard Antenna

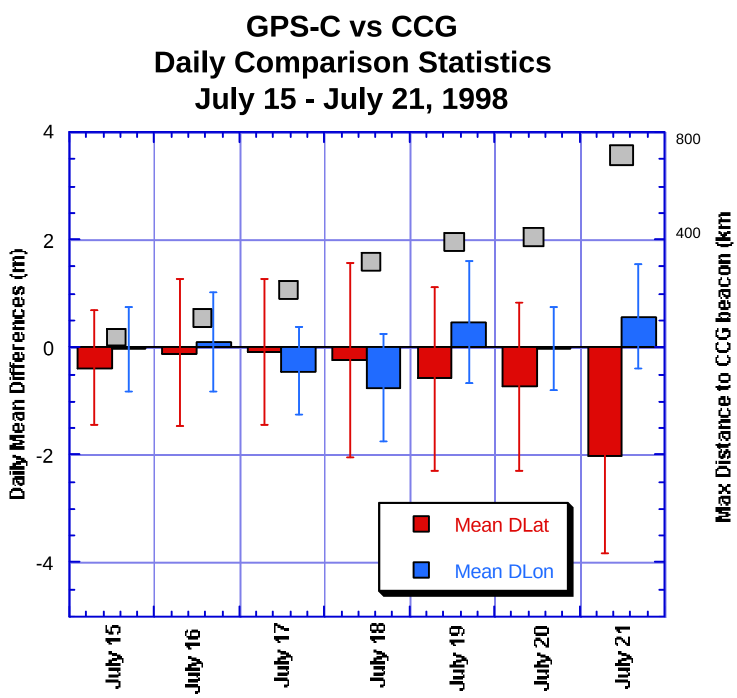

Figure 6: Daily Summary of Position Differences (GPS•C vs CCG DGPS) and Maximum Distance to CCG DGPS Beacon Station

4. GPS•C Accuracy Evaluations

Position difference comparisons between the GPS•C and the CCG DGPS Navigation System derived positions were computed and presented in [5]. Latitude and longitude position difference comparisons show the compatibility of the two independent systems at better than 2-5 metres. These comparisons were possible within the CCG DGPS system coverage. Figure 6 summarizes the daily mean differences and standard deviations for each day of the trip within Coast Guard beacon coverage.

Note the right hand Y-axis shows the daily maximum distance from a Coast Guard reference station. The overall comparison results illustrate the compatibility at the 2-5 meter range of each of these independent systems.

Beyond CCG DGPS Navigation System coverage, GPS•C derived positions were compared to positions computed from post processing with GPSPace precise point positioning software. GPSPace combines precise GPS satellite orbits and clocks with data from a single GPS receiver to provide enhanced static or dynamic positioning [7]. Previous experience with GPS•C and GPSPace techniques yield comparable metre level horizontal positioning results. Comparisons were conducted for the period July 22 to July 27. Generally, horizontal position comparisons show daily mean differences within 1 to 2 metres. [6]

Precise kinematic dual-frequency phase (OTF) post-processing was possible as the vessel approached Churchill, Manitoba from 70 kilometers out. Using 30 second tracking data from the Churchill ACP combined with the ship's GPS receiver data, positions were computed with an estimated precision of 5-10 cm. Horizontal position comparisons between GPS•C derived positions agree at the 1-2 metre level. Standard deviations (1σ) for latitude and longitude were 1.2 m and 1.7 m respectively over a representative 4 hr period. (Figure 7).

A 4 hour static data set was collected when the ship was docked at Churchill. Comparisons of the OTF results and the real-time GPS•C positions show mean horizontal position differences to be better than 1 metre with standard deviations (1σ) for latitude and longitude differences of 0.8 m and 0.4 m respectively. (Figure 8)

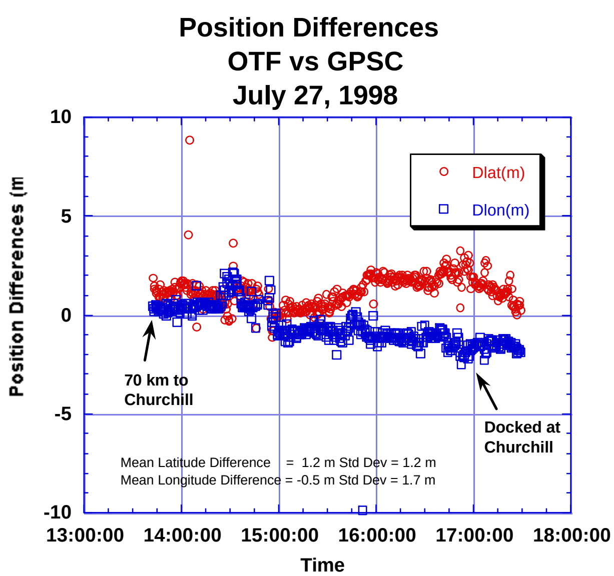

Figure 7: OTF vs GPS•C Dynamic Position Differences

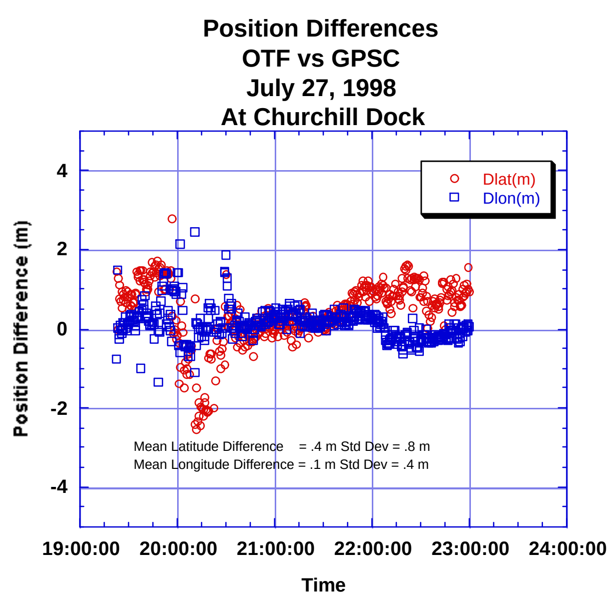

Figure 8: OTF vs GPS•C Static Position Differences

5. Conclusions

The results of this project have shown that GPS•C can be used to augment GPS beyond the CCG DGPS Navigation Service coverage. The GPS•C correction information transmitted by MSAT was available and reliable for the entire period of the project, mid-July to mid-October. The location for the MSAT antenna on-board the ship must be selected to provide an unobstructed view to the satellite. This is especially important when the satellite is low on the horizon. The GPS•C accuracy analysis has shown compatible CCG DGPS Navigation System accuracy in remote areas such as the Arctic.

Acknowledgements

The success of this project was due to the collaboration and important contributions of the following personnel and organizations; Canadian Coast Guard Electronic Engineering (Pieter Leenhouts), Canadian Hydrographic Service, Geographic Data British Columbia (MSAT radios), Cygnus Satellite Systems Corporation (MSAT antennas), and TMI Communications (GPS•C broadcast). Thanks to Waypoint Consulting Inc. for providing GRAFNAV GPS post-processing software.

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