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Canadian plans for participation in GSETT-3

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Abstract
The Geological Survey of Canada (GSC) is making preparations for Canadian participation in GSETT-3 but will be unable to make a formal commitment until the necessary resources have been secured. As Canada is expected to provide at least four alpha stations, and a significant number of beta stations, the financial resources that will be needed are substantial, even though in many respects the GSC is, with the recent modernization of the Yellowknife array and the ongoing installation of the Canadian National Seismograph Network (CNSN), well-positioned to make a significant contribution to GSETT-3. The CNSN currently (October 1993) consists of 17 broad band stations and will grow to 23 and 33 such stations by December 1993 and December 1994 respectively. Some 40-50 short period stations will complete the network. Data from all sites are continuously telemetered in real time to network acquisition centres in Ottawa and Sidney, British Columbia, archived to optical disk, and kept on-line in a 72 h ring buffer. Most of the broadband sites could serve as either alpha or beta stations once the necessary software for continuous data transfer, or on-request provision, of data from the selected sites has been completed. This software will be configured so that changes in station selection are easy to implement, and this will provide considerable flexibility to the GSETT-3 planning and operations working groups in selecting the optimum network. Backup stations can be designated in the case of station failures, and the network centre in British Columbia will serve, at least for beta stations, as a backup NDC to that in Ottawa. Data from the Yellowknife array are collected in Yellowknife and forwarded in ten-minute files to Ottawa, where processing is completed and the results archived. This arrangement would not meet the deadlines for receipt of alpha station data at the IDC and new hardware and software will be needed to forward the data more immediately from Yellowknife to Ottawa. Although the procedures and formats for both alpha and beta station data have not yet been agreed upon, or even discussed, by the GSE, it is apparent that new facilities will be required in Ottawa to multiplex and reformat data for transmission to the IDC. We anticipate that a dedicated 56 kbaud link will be needed between Ottawa and Washington.

Key words *Canada – seismograph network – broad band – array*

1. Introduction

The Seismology Program of the Geological Survey of Canada (GSC) will provide the Canadian contribution to GSETT-3. The stations provided will be the Yellowknife medium-aperture array (YKA) and selected (by the GSETT-3 Planning Group) sites of the Canadian National Seismograph Network (CNSN) as «alpha» stations and other CNSN sites as «beta» stations. The CNSN currently (October 1993) comprises 17 broad band stations and will grow to more than 30 such stations by the end of 1994. As far as can be determined, most of the CNSN stations can meet the requirements for either alpha or beta stations and no new stations will have to be installed specifically for GSETT-3; data from the CNSN are transmitted continuously in real-time to the Ottawa and Sidney, British Columbia offices of the GSC. YKA data are also transmitted to Ottawa, but in the present mode of operation they are sent as files containing 10 min of the array output, arriving 12-15 min behind real time. This clearly cannot meet the strict time deadlines of GSETT-3, and hardware and software modifications will be needed.

A new «alpha station server» will have to be developed to send data from YKA and selected CNSN stations to the prototype IDC in Washington via a dedicated high-speed (56 kbaud) link using TCP/IP protocols. Any of the remaining CNSN stations can function as beta stations and much of the software required for this is already in place.

2. The Canadian National Seismograph Network (CNSN)

The CNSN consists of short period, broad band (BB) and very broad band (VBB) seismograph stations, data from which are transmitted to acquisition systems in Ottawa and Sidney, British Columbia. The VBB stations are equipped with Weilandt-Streckeisen STS-1VBB seismometers, whose response is flat to velocity from 0.003 to 10 Hz. These systems have internal noise that exceeds background earth noise (quiet sites) at frequencies above 3-5 Hz, and thus are unlikely to meet the GSETT-3 requirements. The BB stations employ the Guralp CMG3-ESP seismometer, which has poorer low frequency, but better high frequency performance, than the VBB instruments – the response is flat to velocity from 0.05 to 50 Hz. Both BB and VBB instruments produce three-component data, and have dynamic ranges exceeding 140 dB.

A new 24-bit digitizer has been developed by the GSC instrumentation laboratory to acquire these data. Sampling is synchronised by input from Omega or GPS clocks and for both BB and VBB CNSN sites the sample rates are 40 per s. Finite Impulse Response (FIR) anti-alias filtering is employed to maximise the bandwidth and this allows the VBB and BB system response shapes to be identical to that of the seismometers to frequencies exceeding 15 Hz. The digitizer is quite similar in design and performance to others now on the market – in terms of performance it has low (less than 1 bit rms) noise, achieved at some expense in linearity (which is still better than 20 bits). It has internal (RAM) buffering capacity for up to six hours of data – this will accommodate short losses of communications due to solar transits and other factors, as well as brief outages of the network data acquisition systems. A communication protocol has been developed to provide data retransmission, remote calibration, and timing verification. Data compression based on differencing and a bit-level encoding scheme is employed to minimise the communications bandwidth required, and at most CNSN sites one data sample can be compressed to less than 8 bits. During very large events the data will become less compressible and may accumulate in the digitizer buffer if the capacity of the communications link is temporarily exceeded. The data are sent in 6 s packets, each individually time tagged and with a CRC check.

Very Small Aperture Terminal (VSAT) satellite links are used to relay the continuous data from the VBB and BB stations to the network data acquisition systems. Satellite links are cheaper than dedicated telephone links over distances greater than about 200 km and are the only viable means of communications to many of the remoter areas of Canada. All communications links are provided with a capacity sufficient to transfer 2 bytes per data sample (note that these two bytes are for the compressed differences, and thus easily accommodate actual data values exceeding 24 bits). A 2400 baud link suffices for a three-component, 40 samples/s broad band site.

A Network Acquisition System (NAQS) in Ottawa is now acquiring, processing and archiving the data produced by the CNSN, and an identical system will soon be installed in Sidney, British Columbia. Data from the VSAT-linked sites are received at a Master Earth Station in Toronto, where they are concentrated and sent over separate high-speed (128 kbaud) satellite links to both Ottawa and Sidney. The data are processed and archived at both locations, providing enhanced overall CNSN reliability. If a data packet or packets are garbled or missing, the remote site is requested to retransmit the packet(s) in question. The two separate satellite links used produce a delay of just under one second, but in addition to this, packet handling and FIR filtering delays are such that if the initial transmission is successful, the oldest data in a (6 s) packet will be just under 20 s old when it arrives in Ottawa. If retransmission is necessary (typically several packets per day for each station component) the data delay will be increased by at least 10 s, and is sometimes longer.

The NAQSs carry out signal detection and subsequent automatic location processing, and archive the continuous data on optical disk. They also maintain a 3-4 day ring buffer on magnetic disk, in order to satisfy requests for recent data as rapidly as possible. An efficient mechanism for extracting data from this buffer has been developed and will, with some additional front-end software, allow any of the CNSN sites to serve as beta stations.

Figure 1 shows the locations of present and planned CNSN BB and VBB stations, and table I provides the corresponding coordinates. Not all of the stations are at sites of low background noise, but many are, and thus the GSETT-3 Planning Group has a pool of stations from which the best possible elements of alpha and beta station networks may be selected, taking into account the geographical coverage provided by the stations offered by other countries.

3. The Yellowknife Array (YKA)

The medium-aperture short-period (SP, 20 samples/s) array was modernized during the period 1986-89. At the same time a four-element VBB (also 20 samples/s) array and a single three-component high frequency (HF, 100 samples/s) site were added. Data from all sites are sent by UHF radio telemetry to an array control centre in Yellowknife, where they are accumulated into 10 min files which are locally archived on optical disk and also forwarded over a dedicated 56 kbaud link to Ottawa, where the data files are again archived and array processing is carried out. The latter includes beamforming and detection, post-detection processing, and generation of long period data from the VBB data streams. It is assumed that the YKA SP array data is that most likely to prove useful for GSETT-3 and that the VBB and high-frequency data are of less interest, though it would be trivial to add them if desired. One of the Yellowknife VBB sites also functions as a CNSN station and is processed, archived and made available in the same manner as all the other CNSN sites.

In its current mode of operation, with data transmitted to the National Data Centre (NDC) in Ottawa in 10 min files, the Yellowknife array probably cannot meet the GSETT-3 requirements (though these are not yet specified) for timeliness, and modifications will be needed. The individual array elements send data to the array control centre in 6 s packets which are similar, but not identical, in format to those of the CNSN. Only the previous packet is buffered at the outstations, so there is only one opportunity to request retransmission of bad or missing packets. For GSETT-3, plans are to tap off the radio receiver at the control centre and forward the data packets to a separate system that will handle original and retransmitted packets, reformat them so that they conform to the CNSN formats and protocols, and transmit them to Ottawa almost immediately. Thus YKA will appear to be a separate CNSN site that has 33 separate data components (18 SP, 12 VBB and 3 HF). The new hardware and software at Yellowknife will buffer data so that data gaps and/or backlogs (due to bad

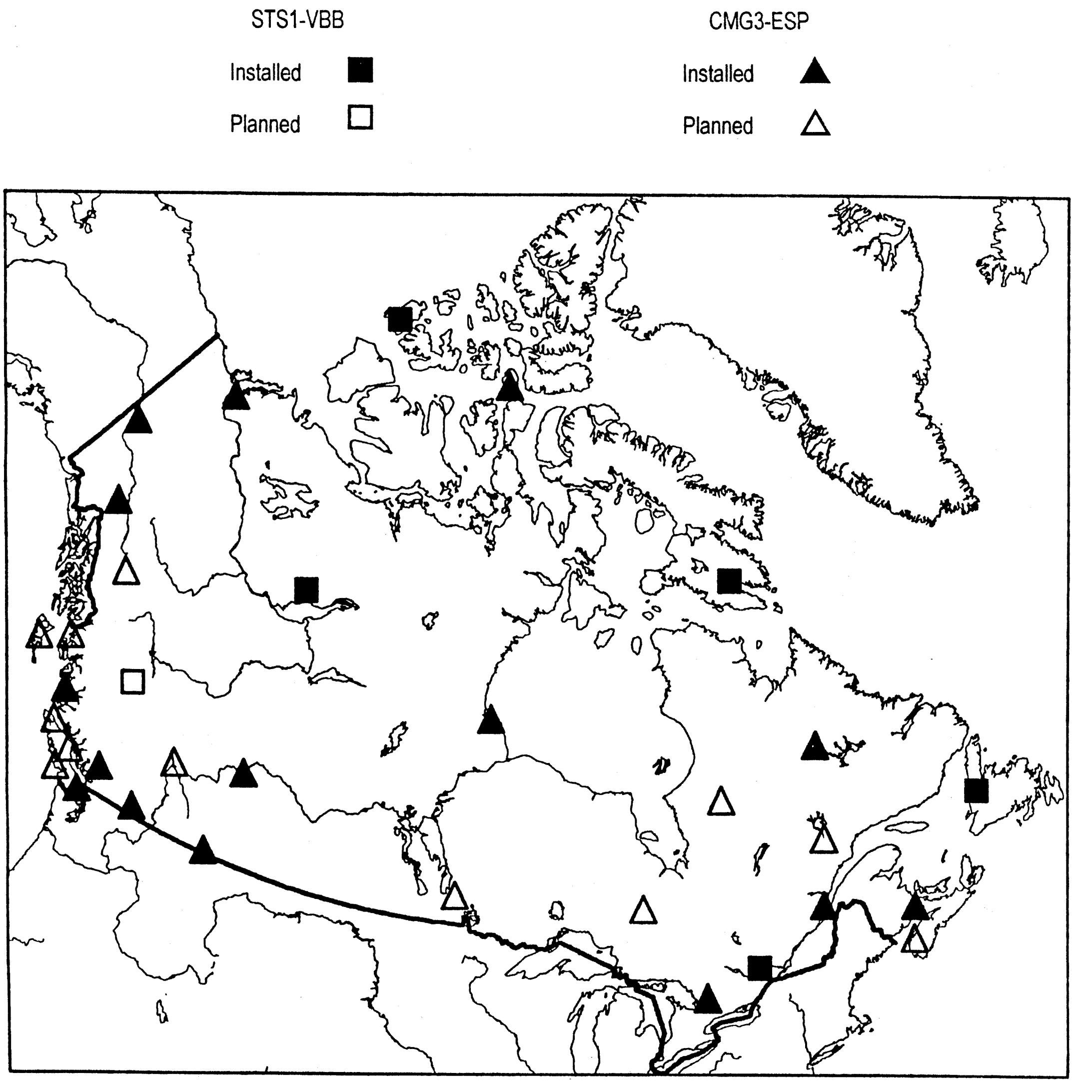

Fig. 1. Canadian National Seismograph Network (December 1993).

packets over the Yellowknife-Ottawa link; temporary link outages, etc.) are handled in exactly the same way as an individual CNSN station. Array control (timing, calibration, requests for packet retransmissions from the individual elements, etc.) will remain with the existing Microvax-based systems. The new system developed for GSETT-3 will send YKA data directly to the alpha server in Ottawa; the data will not be handled by the CNSN NAQS.

It is estimated that several months of software effort will be needed once the appropriate hardware has been identified and purchased. The latter must be able to handle essentially simultaneous interrupts on

Table I. Canadian National Seismograph Network: station status – October 1993.

Code	Lat°N	Long°E	Elev (m)	Instrument
		Installed		
BBB	52.185	−128.113	14	CMG3-ESP
DAWY	64.053	−139.432	346	CMG3-ESP
EDM	53.222	−113.350	730	CMG3-ESP
EEO	46.641	−79.073	398	S-13 (Z only)
FCC	58.762	−94.087	39	CMG3-ESP
FRB	63.747	−68.547	18	STS1-VBB
GAC	45.703	−75.478	62	STS1-VBB
INK	68.307	−133.520	40	CMG3-ESP
LMN	45.852	−64.806	363	CMG3-ESP
LMQ	47.548	−70.327	419	CMG3-ESP
MBC	76.242	−119.360	15	STS1-VBB
PGC	48.650	−123.451	5	CMG3-ESP
PMB	50.128	−122.955	695	CMG3-ESP
PNT	49.317	−119.617	550	CMG3-ESP
RES	74.687	−94.900	15	CMG3-ESP
TBO	48.647	−89.408	468	S-13 (Z only)
WALA	49.058	−113.915	1400	CMG3-ESP
WHY	60.696	−134.882	1292	CMG3-ESP
		To be installed by the end of 1993		
YKW3	62.561	−114.616	198	STS1-VBB, Nov. 93
DLKN*	49.350	−57.600		STS1-VBB, Nov. 93
SADO*	44.753	−79.141	250	CMG3-ESP, Nov. 93
SCH	54.817	−66.783	540	CMG3-ESP, Nov. 93
WBO	45.000	−75.275	85	S-13 (Z only), Dec. 93
		Planned for 1994		
CBB	50.033	−125.365	317	CMG3-ESP, March 94
QCBC*	53.300	−132.100		CMG3-ESP, March 94
KEJN*	44.450	−65.700		CMG3-ESP, April 94
CKO	45.994	−77.450	190	CMG4+S-13 (Z), July 94
ULM	50.250	−95.875	281	CMG3-ESP, April 94
HYT	60.825	−137.504	1416	S-13 (Z only), July 94
PHC	50.707	−127.432	33	CMG3-ESP, April 94
OZB	48.960	−125.493	671	CMG3-ESP, Sept. 94
		Speculative (seismometers purchased for this number of additional BB sites)		
FSJ	54.463	−124.280	772	STS1-VBB
JAQ	53.802	−75.271	366	CMG3-ESP
RUB	54.326	−130.285	35	CMG3-ESP
MNB	52.199	−118.383	2271	CMG3-ESP
DLB	58.427	−130.060	1210	CMG3-ESP
KAO	49.448	−82.485	198	CMG3-ESP
MNQ	50.533	−68.774	610	CMG3-ESP

* Unregistered code; coordinates approximate only.

Plus many (45+) short period (three-component or vertical only, S-13) sites to be added in SE and SW Canada.

25 separate serial ports, and will require either a PC – or Unix (Sun) – based system with programmable front-end processors. The cumulative delays of packet handling, filtering, waiting for retransmission, and transmission are such that data arriving in Ottawa will be between 30-40 s old.

4. Alpha station server

This will acquire data arriving over satellite links from CNSN stations and from the Yellowknife array. All data are in 6 s packets in CNSN protocol. The data from CNSN stations will also be acquired by the NAQS, which will be responsible for requesting the retransmission of bad or missing packets. The new system in Yellowknife will handle retransmitted packets, requested by the control centre from the field outstations, but the data arriving in Ottawa from Yellowknife will not be acquired by the NAQS and thus recovery of bad and/or missing packets from Yellowknife (lost or garbled over the satellite links) is the responsibility of the alpha station server.

CNSN data packets will be converted to data frames conforming to the (yet to be agreed) specifications for alpha stations and then sent to the IDC using TCP/IP over what will probably be a dedicated 56 kbaud telephone line. Because of the nature of the CNSN systems, packets from some or all stations may arrive at the alpha server out of order, late (up to 6 h) or not at all. Since most retransmission requests are made because arriving packets are garbled, and are satisfied almost immediately, it may be wise to buffer data in the server for a short time (say 1 min) so that most bad packets are replaced by a good version, before forwarding the data to the IDC. Delayed or missing data (due to short link outages, for example) may be recovered up to 6 h after real time, but at some point (to be decided) is too late to be of use in routine IDC processing, though it may still be worth forwarding in order to make the IDC archive as complete as possible.

The anticipated platform for the alpha server is a UNIX-based system, probably assisted by a front-end processor or terminal server that is capable of handling the interrupt rate on the input serial ports. The software effort will depend upon the programmability and built-in intelligence of the front-end processor. Although only a limited subset of CNSN sites will act as alpha stations, the server will probably be able to handle many more and make them available as additional or replacement (if a designated alpha station fails or local noise levels increase suddenly) stations almost immediately.

5. Beta stations

Data from all CNSN stations are stored in a 3-4 day on-line ring buffer, as well as being continuously archived to optical disk. A data extraction program provides selected channels and station data from this buffer for any specified time intervals. Interfacing this code to a data request mechanism to allow any site(s) to function as GSETT-3 beta stations will be very simple.

At present we are planning to provide beta station data through a mail-based system that will be essentially similar to the Swiss AUTODRM, and understand that several other countries will be adopting this approach. Internet mail, through either normal channels or employing the direct link installed for the Canadian alpha stations, will be used. The same software will be installed in Sidney so that it can serve as a backup to Ottawa for beta station access.

6. Schedule

This is dictated largely by the availability of funding for the hardware procurement and software development needed. Funding has been received for a contract to develop the software for the alpha server and this will start in January and be completed by March 1994. Software for the beta stations will be developed in-house, since the same code can be used to provide general access to CNSN data by the general seismological community, and this too can be completed by March 1994. Additional funding will be needed for the hardware and software required to provide YKA data to the alpha server, for the direct link to the IDC in Washington, and for at least one new staff member to maintain the new facilities and analyze and provide feedback on IDC products. No commitment has been made to provide this new funding, and until it is received there can be no guarantee that Canada will be able to participate in GSETT-3.