Seismic Networks in Canada

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Canadian Hazards Information Service
Geological Survey of Canada (GSC)
Natural Resources Canada (NRCan)

Antelope Users Group meeting
San Diego, CA
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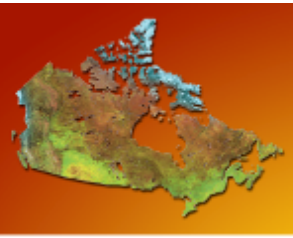
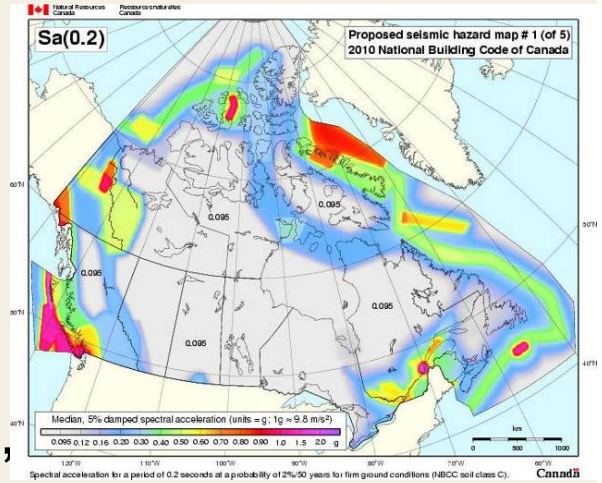


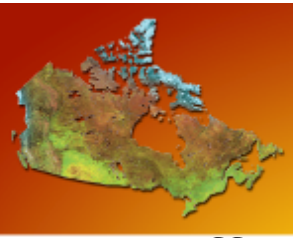
Organization, Mandate and Clients

- Natural Resources Canada (NRCan) – federal government
  - Earth Sciences Sector
    - Geological Survey of Canada (GSC-AWCB)
      - Canadian Hazards Information Service (CHIS)
        - Earthquakes Canada (monitoring)
      - GSC Pacific Division
        - Public Safety Geoscience (research)
- CHIS does more than just earthquakes – Natural Hazards
- CHIS Mandate from the Emergency Management Act
  - **"the provision of information on the actual or probable occurrence and intensity of earthquakes".**
- Clients:
  - Federal, provincial, and territorial Emergency Management Organizations (EMOs)
  - Critical Infrastructure (CI) operators
  - Media, Canadian public, researchers, other agencies

CHIS Earthquake Responsibilities

- Seismic Monitoring
- Collaboration with other agencies – data exchange
- Rapid Response for Earthquake Info
- Public Information
- Earthquake Hazard Assessment
  - Seismic hazard zoning maps
    - National Building Code
  - Advice for Critical Infrastructure
    - Hydro dams, Nuclear power plants
    - Pipelines, power transmission lines,

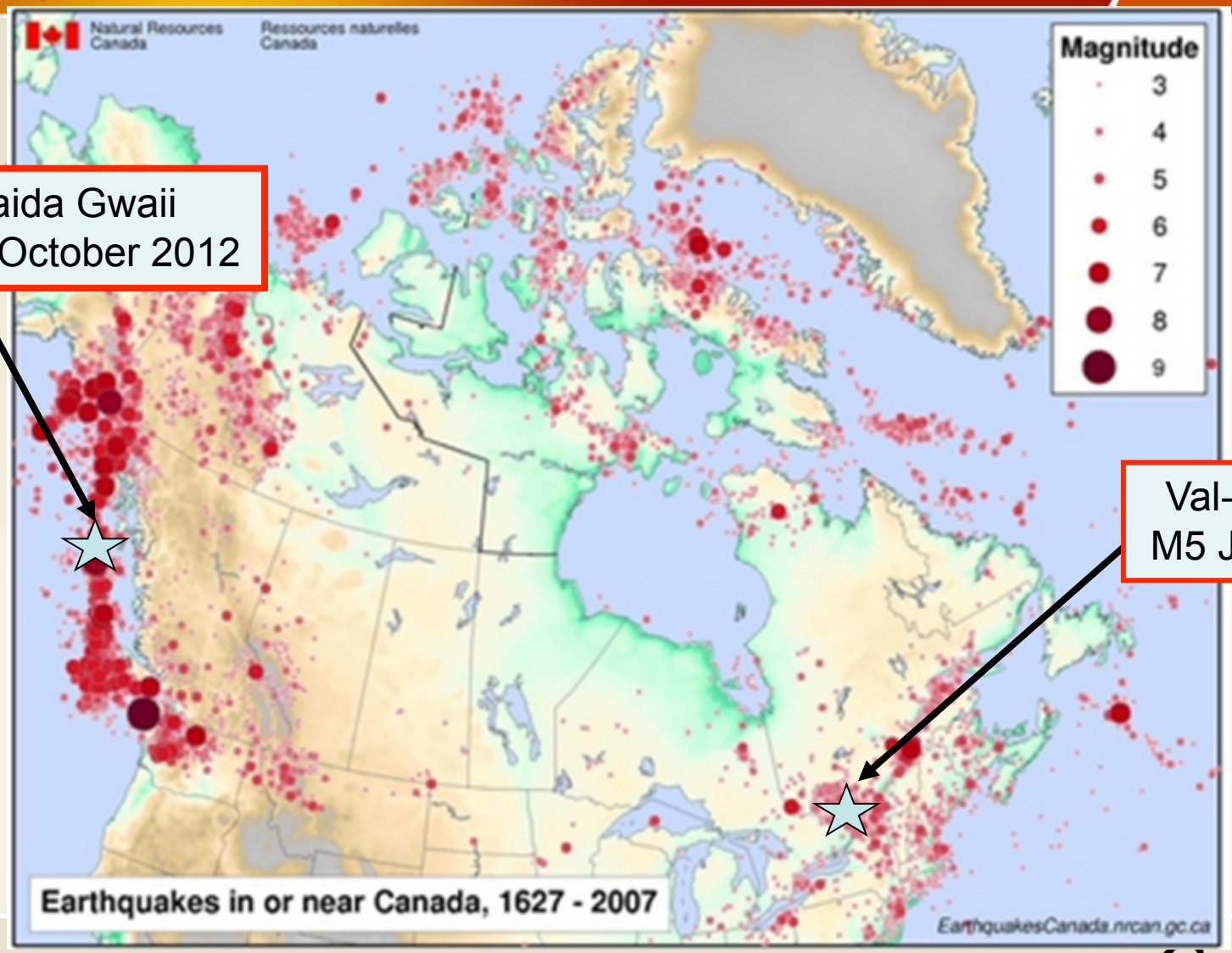


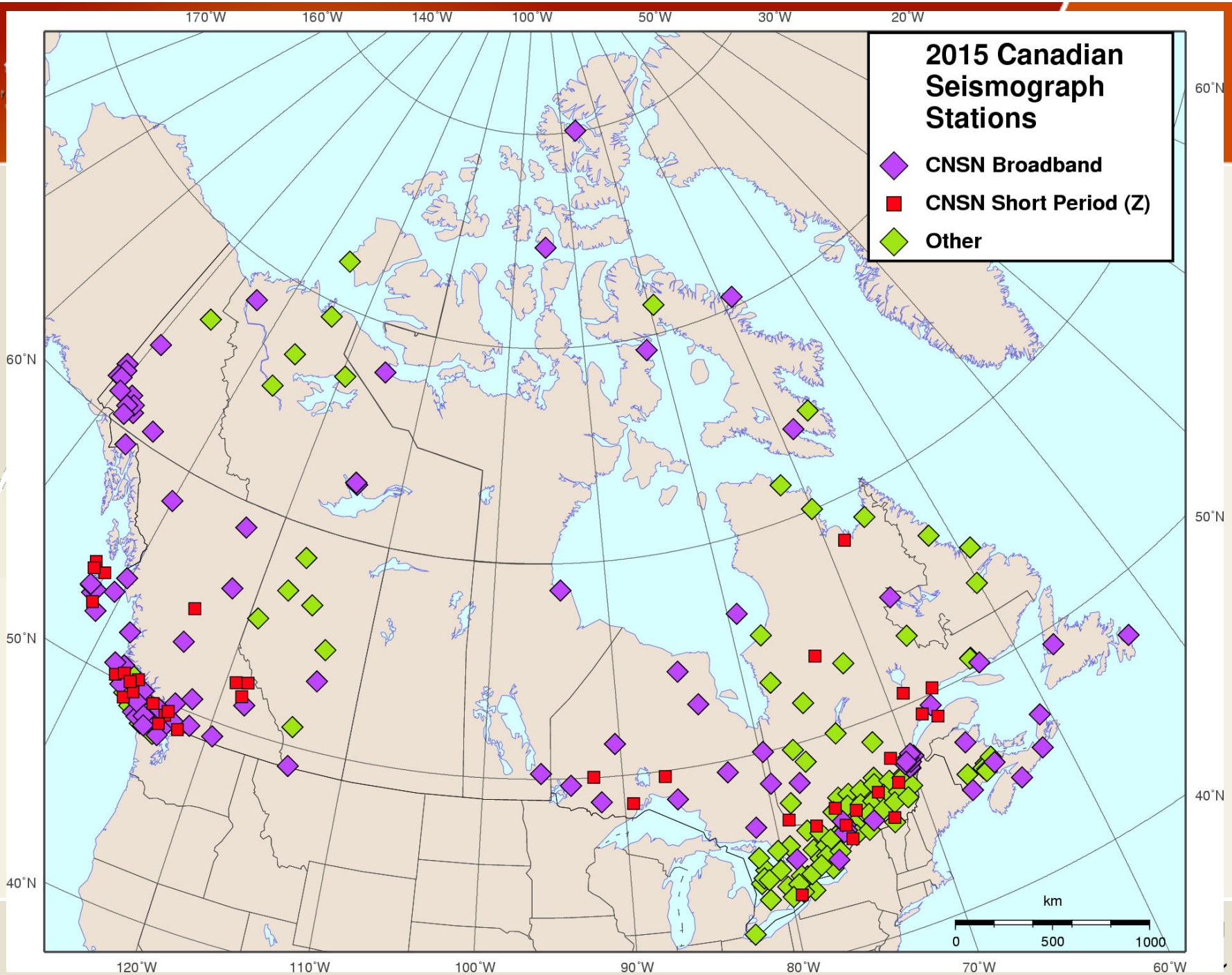


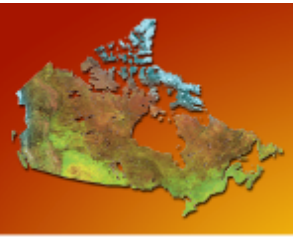
CHIS Seismology Staff and Budgets

- 4 offices (Ottawa, East Ottawa, Sidney, Yellowknife)
- 0.75 permanent seismologists + 2 contractors
- 4 Scientists (plus other researchers for on-call work)
  - building codes, magnitudes, explosion monitoring, infrasound
- 4 IT specialists
- 2 Operations staff
- 7.75 Field technicians
- ~$500k per year plus one time “capital” requests
  - In 2011, lost $750k/year + 3 IT staff to Shared Services Canada (consolidate IT data centres & communications)
  - Salary costs not included

Seismicity in Canada

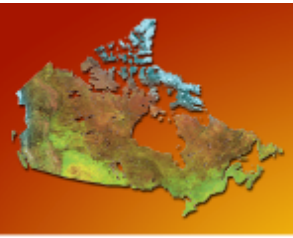



2015 Canadian Seismograph Stations
CNSN Broadband
CNSN Short Period (Z)
Other
170°W
160°W
140°W
100°W
50°W
30°W
20°W
60°N
50°N
40°N
120°W
110°W
100°W
90°W
80°W
70°W
60°W
km
0
500
1000



Seismic Networks

- Continuous, real-time, weak-motion data from:
  - Canadian National Seismograph Network (CNSN)
    - ~150 digital, observatory-grade, permanent stations
    - network > 20 years old
    - recently secured funding for network refreshment
  - Other special deployments within NRCan
    - ~40 (temporary) stations for research
  - University stations (ex-POLARIS stations)
    - ~30 (temporary) stations for research
- Strong motion monitoring
  - ~120+ stations in Canada



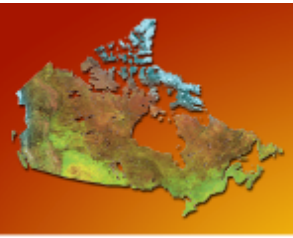
Seismograph Equipment

- Primary equipment used in CNSN
  - **Digitizers designed in-house and use CNSN protocol – cnsn2orb**
  - ~40 CNSN SPD Vertical-only Short Period sampled at 100 s/s
    - S13 seismometers
  - ~70 CNSN GD 3 Component Broadband sampled at 40 or 100 s/s
    - Guralp CMG 3ESP, 3T seismometers, STS1 seismometers
      - Various bandwidths 50Hz - 30s, 60s, 120s, 360s & NSN; 360s for STS1
- 3C BB Libra/Trident & Taurus digitizers (40 or 100 s/s)
  - **ApolloServer seedlink connection; slink2orb to import into Antelope**
    - **hope to develop np2orb**
  - Guralp CMG 3ESP and Nanometrics Trillium seismometers
    - Various bandwidths 50Hz - 60s, 100s (POLARIS standard), 120s
- Yellowknife array – 18 SP & 2 BB sites, upgraded to Guralp equipment
  - CTBTO primary seismic station
  - **CD 1.1**, use seiscomp3 to convert to seedlink to stream to antelope – **slink2orb**.

Strong Motion Monitoring

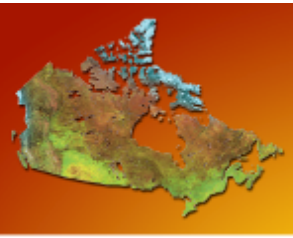
- ~100 Internet Accelerometers
  - ia2orb for data access
- Some Nanometrics Titan
  - At Libra or Taurus weak-motion sites
- ~20 Kinemetrics Altus Etna
  - Non-realtime

- Future – increase in strong motion stations, including co-located with weak motion stations



Telecommunications Network

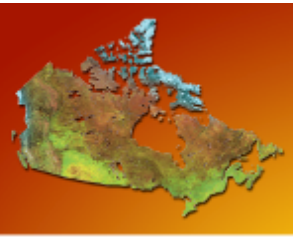
- Acquisition of continuous, real-time CNSN data requires operation of a national telecommunications network (SeisWAN) involving:
  - VSAT satellite links
  - UHF/VHF radio
  - spread-spectrum radio
  - dedicated telephone/modem links
  - cell modems
  - T1 links
  - Frame Relay links
  - Internet (DSL)
- Heterogeneous on purpose!
- Mostly, but not all, IP-based
- ~60 Nanometrics Libra stations (satellite-based comms) in CNSN and ex-POLARIS use Carina Hub for master earth station and ApolloServer software for acquisition, which is then streamed to Antelope via SeedLink feed.



CHIS Data Centres

Two data centres: Ottawa, Sidney

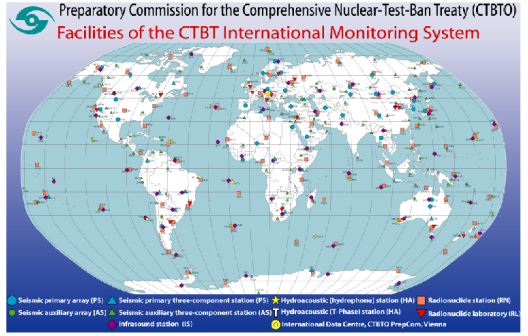
- Will move to SSC data centres eventually
- Parallel, Independent Operation
  - Station data sent directly to each DC
    - Send data once by multicast or twice by unicast
- Redundant Systems & Communications
- Change control procedures
  - 2 man rule, in-house ticket tracking system, GIT for change control
- Operate on a 24x7 basis with on-call IT systems staff
- Legacy systems – Sparc/Solaris zones with in-house software
- New systems – Intel/Linux CentOS VMs with BRTT & Nanometrics software. Use Python, Perl and C.



CHIS Data Centres

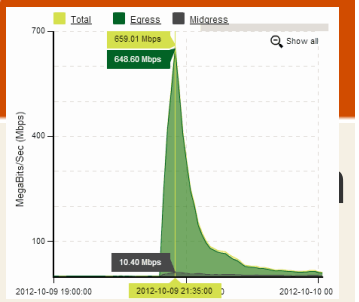
- Acquire, process & archive over 5 GB/day of waveform data
- Waveform Archive (22+ TB) – separate from Antelope
  - Use **orb2wf** and **trexcerpt** for creating channel-day miniseed files
    - Want “true” miniseed files with gaps
    - Multiple passes – early, medium and late
  - All wf data is sync’d between data centres (smart merge)
  - For merging use **miniseed2db** & **trexcerpt**, or **miniseed2orb**
- National Earthquake DataBase (catalog), Ingres RDBMS moving to Postgres (Multi-master replication)
- Automatic and analyst reviewed processes to locate earthquakes
  - On-call Seismologist (1 east, 1 west) provide 24x7 coverage

Collaboration with Other Agencies – Data Exchange



- Forward real-time data from 10 IMS stations to CTBTO in Vienna (under contract with SLA's)
- Disseminate Wave Form and Earthquake data to other agencies and researchers including:
  - Tsunami Warning Centres
  - USGS
  - IRIS
  - US Regional Networks
- Import and export via various formats
  - CD1.x, orb2orb, earthworm, seedlink, etc. Ringserver coming soon for export
- Earthquake Catalog
  - Sent to ISC when complete
  - Bulletins from US networks imported via Antelope
  - Working towards better real-time integration with USGS (PDL)

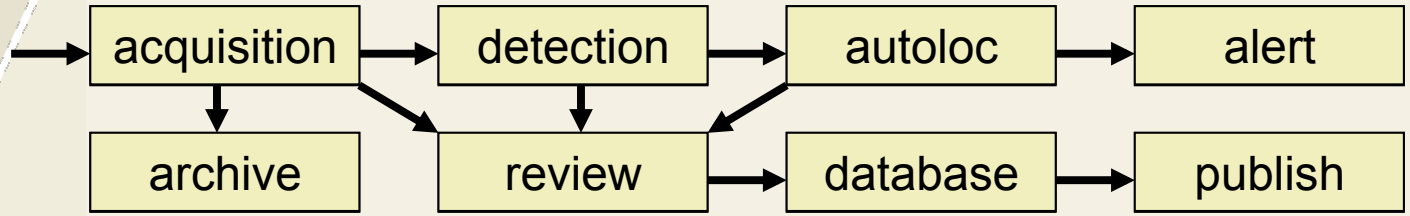
Rapid Response for Earthquake Info and Public Information



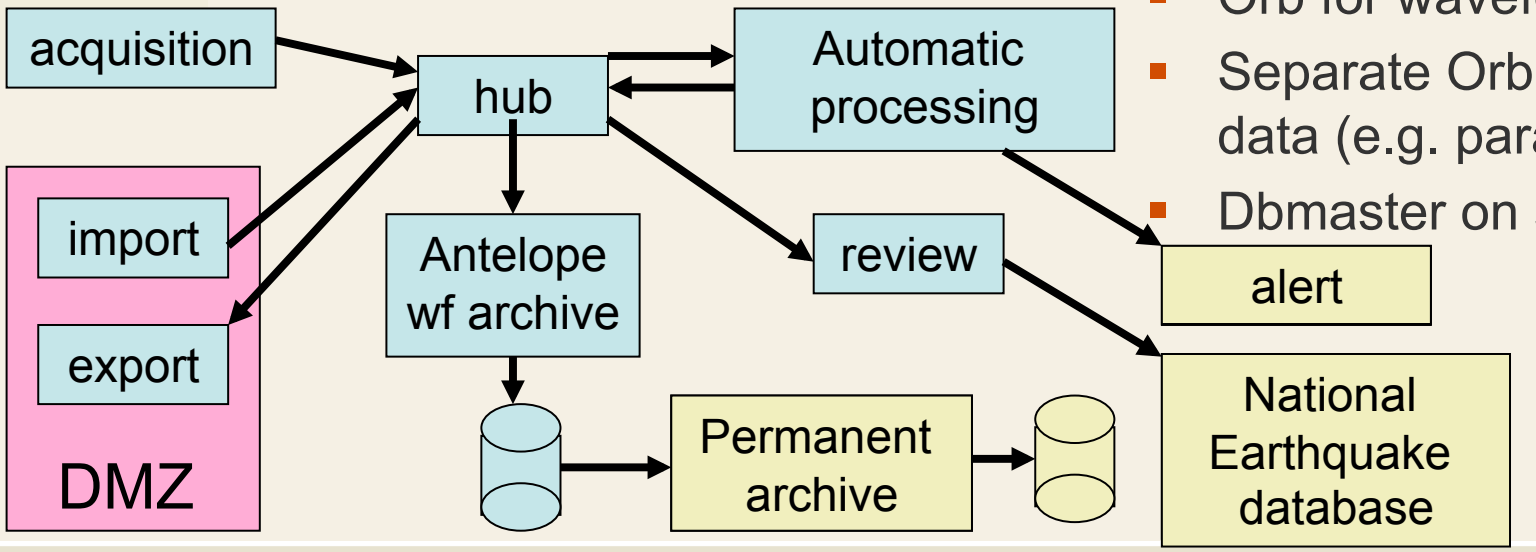
- 24x7 on-call seismologists provide rapid information [illegible] earthquake location, magnitude, aftershocks
- Earthquake reports, maps & lists @ www.earthquakescanda.ca, DYFI
- Tweet automatic and reviewed earthquake notifications on Twitter
  - English: @CANADAquakes, Français: @CANADAseisme
- AEneas (Automated Event Notification and Eq Alert Service)
  - Alerts Customized for client's facilities and thresholds
    - sent via email, scp, SMS, ftp, fax
  - Eg: send "STOP/SLOW TRAINS" alerts to railways within minutes
- Earthquake alerts to Multi-Agency Situational Awareness System (MASAS) using open standards, e.g. Common Alerting Protocol (CAP)
  - sharing of location-based situational awareness information and alerts between issuers, first responders & emergency management agencies

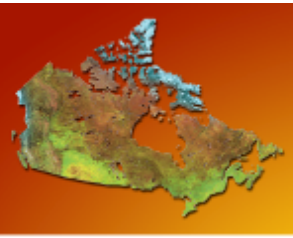
Processing System

- Legacy Data Processing System – developed in-house



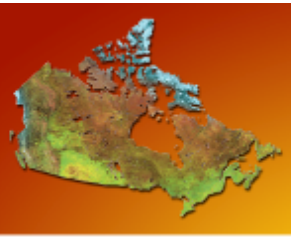
- Current Antelope 4.x System – all on one computer
- New Antelope 5.4 System – partially implemented
  - Orb for waveform
  - Separate Orb for other data (e.g. parametric)
  - Dbmaster on select zones





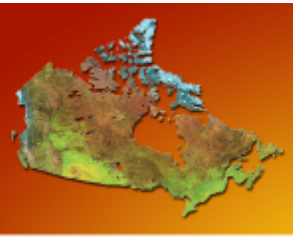
What We Need to Do

- Improve data import from Guralp and Nanometrics digitizers (e.g. np2orb), and handle SOH
- Switch Eastern seismologists to Antelope for review
  - If we ever hire new staff
- Upgrade to latest version of Antelope across the country
- Fully implement automatic locations and alerting
- Feed Shakemap for project with PSG and universities
- Integrate with USGS NEIC PDL
- Continue experimenting with Peregrin (chanstats2json)
- Finish implementing webservices for wf data
- **Implement Network refreshment**



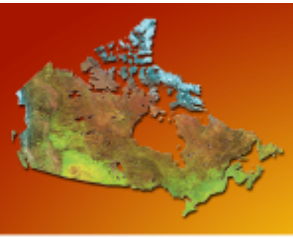
Network Refreshment - 1

- ~$11.4M CDN + overhead over 5 years
  - Started April 2014, money flows April 2016
  - Cash only, no new on-going funding for O&M
  - Shared Service Canada (SSC) not involved, therefore
    - No new data centre hardware or funding
    - No changes in telecommunications (ouch!)
- This is not meant to be an upgrade of network capability, but a refreshment of end-of-life equipment
  - Exception for additional strong motion (SM) sensors
  - Exception for faster auto-locations



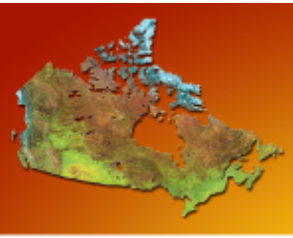
Network Refreshment - 2

- About 150 weak motion (WM) stations to be refreshed
  - Includes sensors and digitizers
  - Probably upgrade all short period vertical to 3C BB
  - May add strong motion (SM) to some or all WM stations
  - No new WM stations (except for special cases)
    - Request for 30 new Arctic stations rejected
- Can add about 40 new, targeted, stand-alone SM sites
- Some investment for GPS sites (~10)



Network Refreshment - 3

- Money to upgrade civil works at about 10% of sites
  - But ~40 existing SP Vertical sites need new vaults
  - May want to consider shallow (~2-4 m) postholes
    - Reduce site noise and thermal instability
    - Cheaper than surface vault civils? Bias?
- Communications dilemma
  - Extra bandwidth needed, but might not be available:
    - 1 or 3 channels changing to 3 or 6 channels
    - Modern protocols have more overhead than CNSN
    - Serial changing to IP; IP and UDP/TCP overhead
    - SOH data
  - Might need to reduce sample rate or use triggered
- Which data format and telemetry protocol?



Network Refreshment - 4

- Goal to reduce auto-locations from ~4 minutes to ~1 minute in targeted regions
  - Money for software and/or software development
  - May change acquisition and/or processing software
- Not required to provide Earthquake Early Warning (EEW) system, but must be compatible with one
  - Separate funding request pending
- Need to improve QC and procedures (e.g. SQLX)
- One big integrated tender or multiple tenders?
  - e.g. separate seismometer and digitizer orders
  - What do other agencies do?