Antelope Overview

Dr. Kent Lindquist

CTO, Boulder Real Time Technologies, Inc.

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Boulder Real Time Technologies, Inc.

- Founded 1996
- Based in Boulder, Colorado, USA
- Makers of the ***Antelope*** *Environmental Monitoring System*

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Antelope: Enterprise-grade Software for Earth Monitoring Operations

- “Enterprise” = Created to serve a clearly-defined mission
  - All further decisions made in subservience to that mission
  - Hardware, operating system, mission software, configuration etc.
  - Usually licensed, offers upgrades and support, “someone to call”
  - Supports virtualization and cloud computing
- “Operations” = 24/7 functioning with specific, quantitative requirements
  - Up-time, Output speed, Data completeness, Processing completeness, Downtime service windows, Possible hot-swap failover, etc.
- Turn-key operation on standard system

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Enterprise software creation

- Forces
  - Hardware technology advances to meet growing user compute needs
  - Large corporate entities move according to macro economics, not small scientific software companies. We're the passenger, not the driver.
  - Advances in hardware and user market needs drive Operating System advances
  - Computer science advances drive language change, compiler change, component-package changes
  - Hardware purchased for network operations ages, breaks, and gets decommissioned, requiring updates – to hardware, thus OS, thus software
  - Continual improvement of application software drives updates, on newer OS's; can't run on older OS's. Limited ability to support older versions due to hardware aging and irreplaceability of old machines.
  - "Software Rusts" *–Danny Harvey*
  - Software at its best: codified explanation of how to do monitoring task, in every detail, to both the humans and the machines. This understanding advances in sophistication. [N.B. 'Spaghetti code' loses the 'explain to humans' part]
  - Research-purposed software – has to adapt to varied ecosystems, impacting robustness and adding admin work.
  - Enterprise software aiming for *mission support*. Install it and it runs out-of-the-box. Tremendous amount of work to create this effect with sophisticated applications.

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What is Antelope

- *Software platform* for earthquake, geophysical, and structural health monitoring
  - Data Acquisition
  - State-of-health monitoring
  - Centralized Command and Control
  - Automated and manual processing
  - Research
- Scalable and Extensible
  - Used at most of the largest seismic networks and data centers, down to the smallest research and monitoring networks
- Dual mission:
  - The monitoring mission
  - The network operations mission

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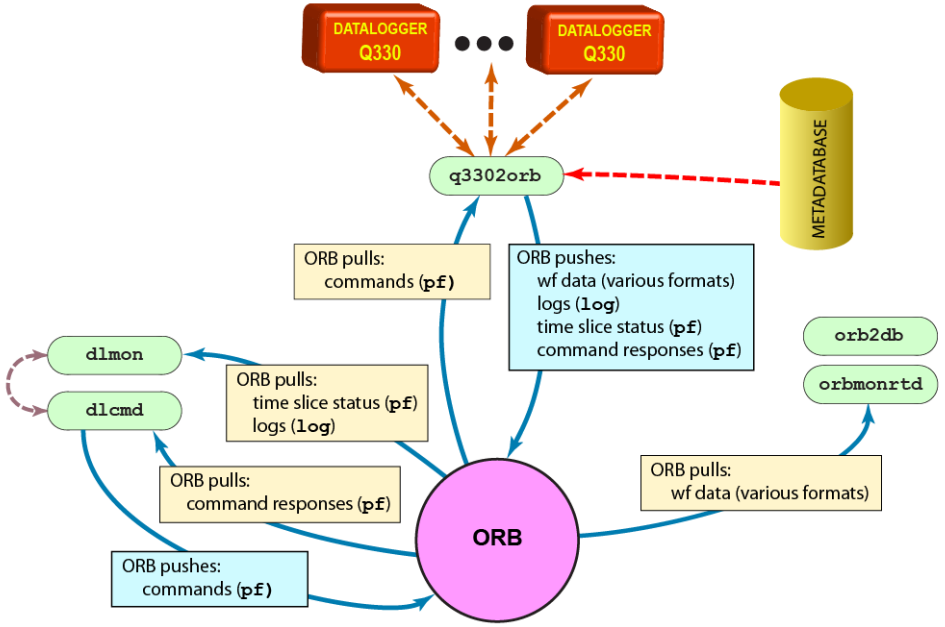
Data Acquisition: q3302orb

q3302orb

Over 2 years at USArray:

- 1166 dataloggers
- 10,292 physical data channels at multiple sample rates
- ~40,000 channels of SOH waveform data
- 8760 instance-days of software running
- 16 Terasamples of end user data collected (not including SOH)



- ***0 downtime, 0 lost data*** due to acquisition software failures
- 1 FTE to manage data center O&M
- ***99.5% data completeness***

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Data Acquisition: q8

orb2orb

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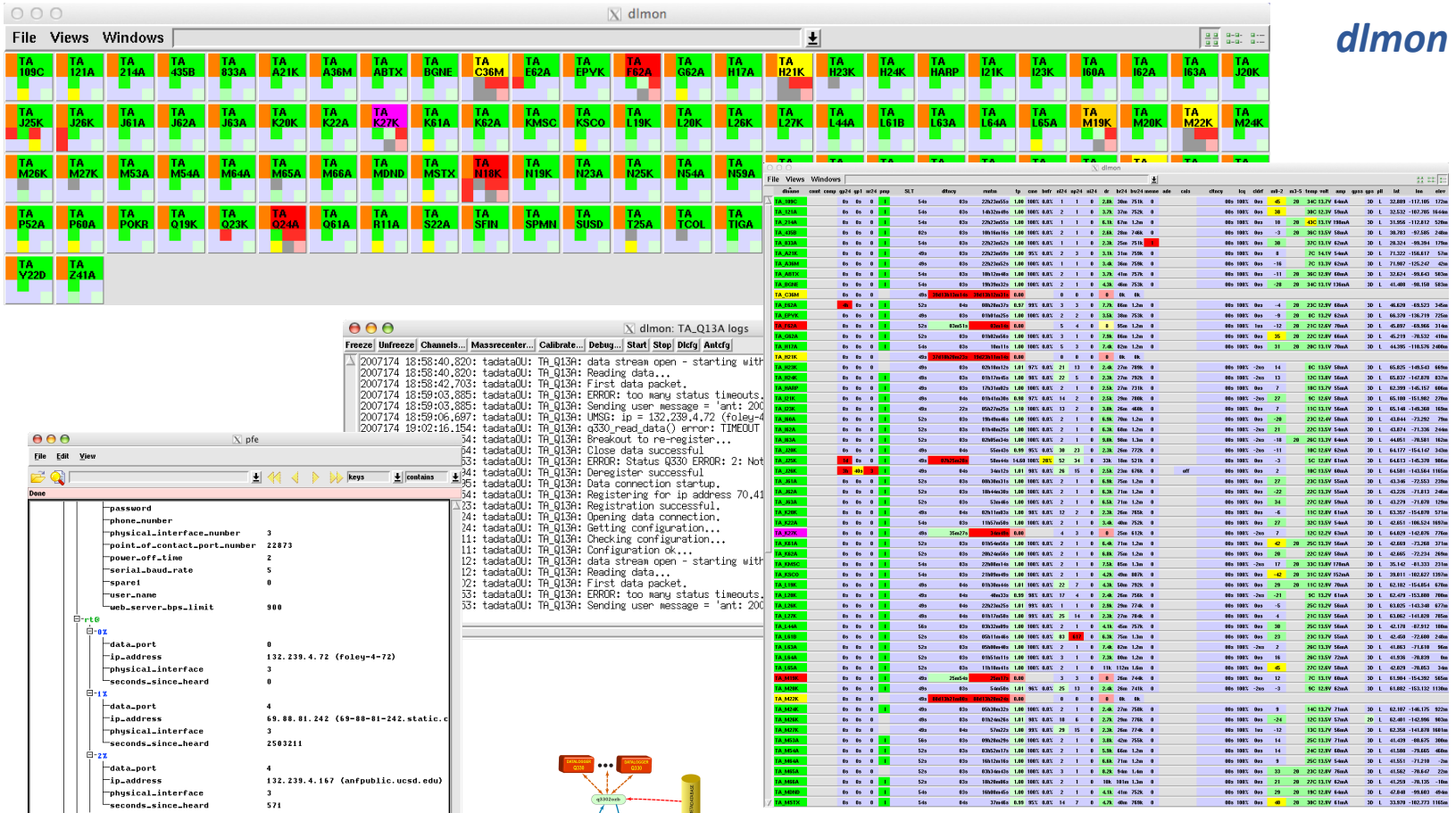
Dataflow SOH Monitoring



dlmon

High Success rate of Antelope acquisition:

- *Robust Software*
- *Sophisticated SOH Monitoring*

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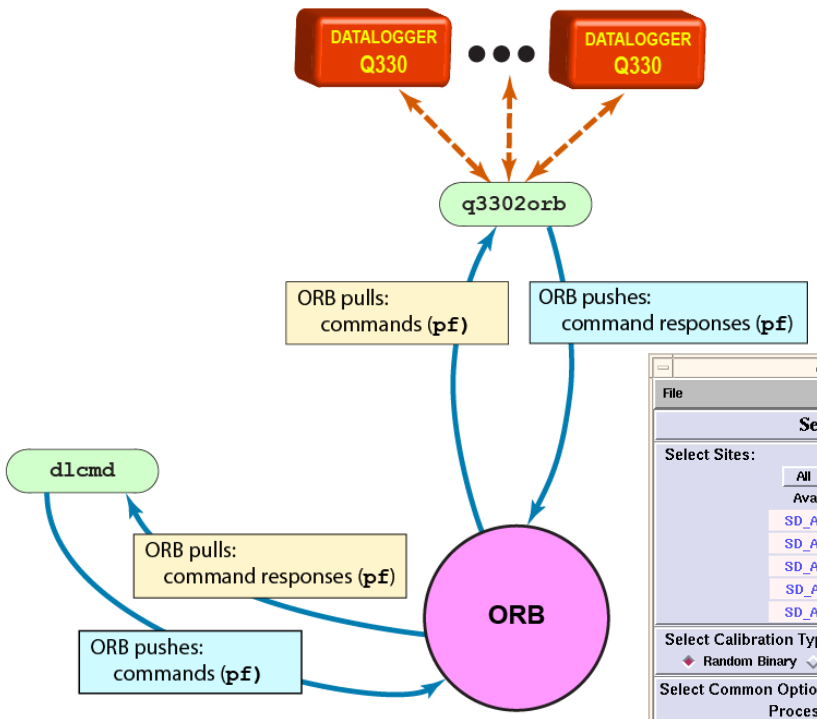
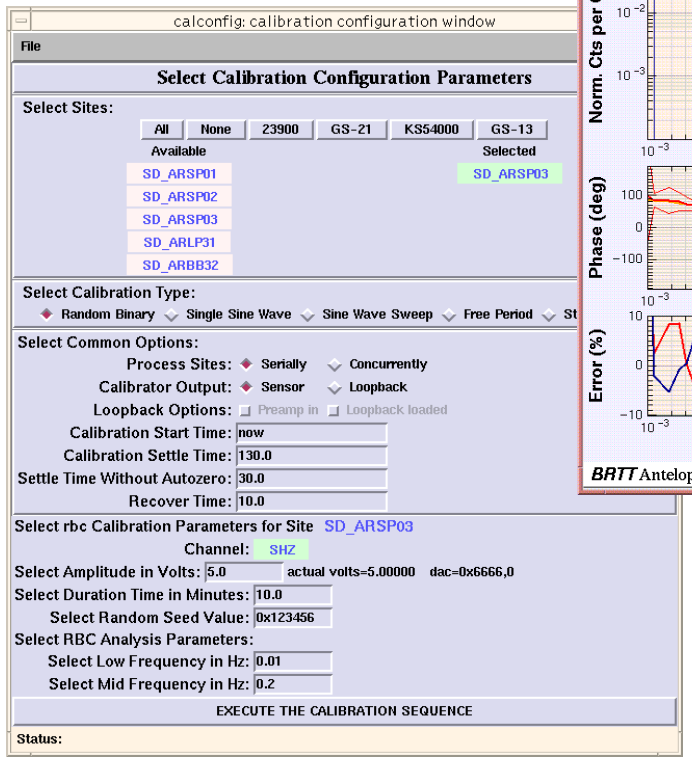
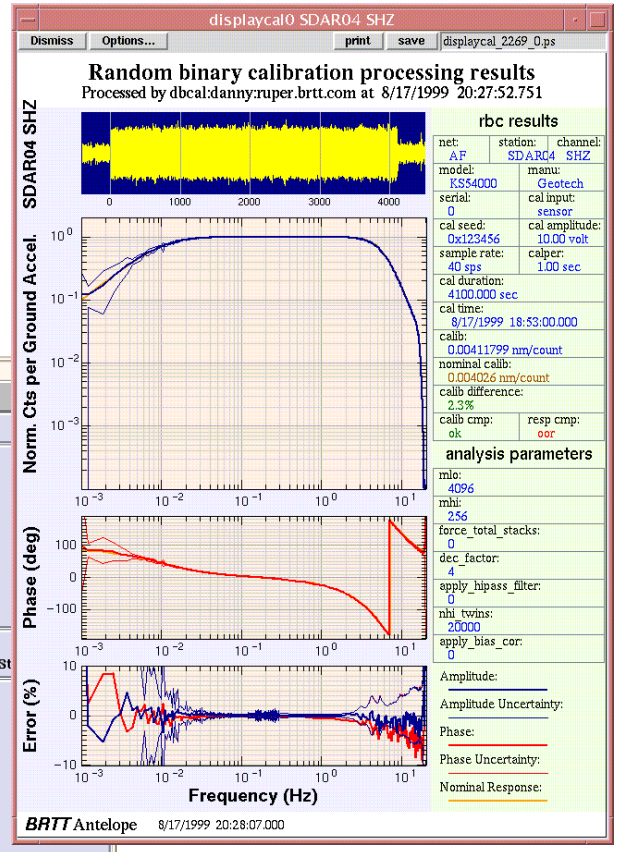
Datalogger Command and Control



dlcmd





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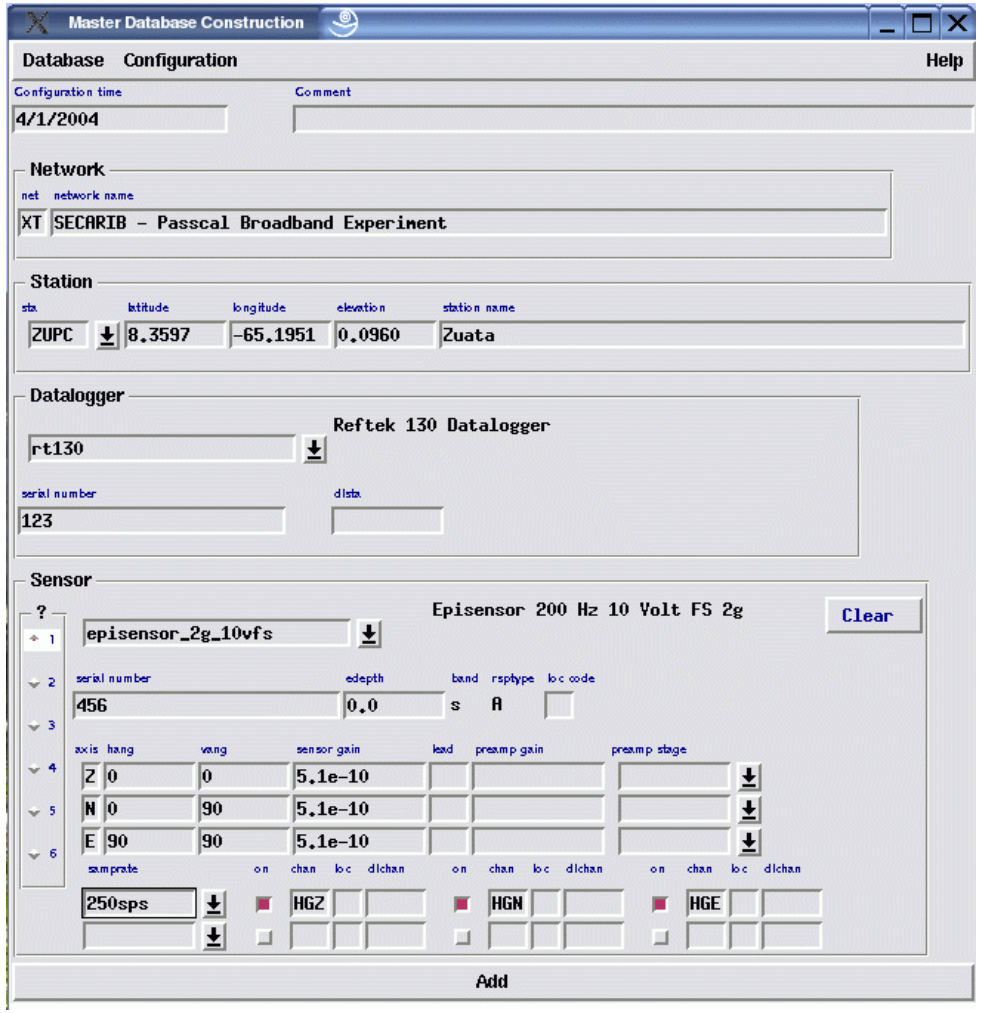
Station Metadata Management



dbbuild

- Program for building the "metadata" part of a Datascope database (*site*, *sitechan*, *sensor*, *instrument*, *calibration*, *stage* tables plus external instrument response files)
- Can operate in either interactive or batch mode.
- Can run from a master configuration file
- Based on well-documented ASCII files
- User-configurable single-stage response files
- set of parameter files that describe standard dataloggers, pre-amps and sensors

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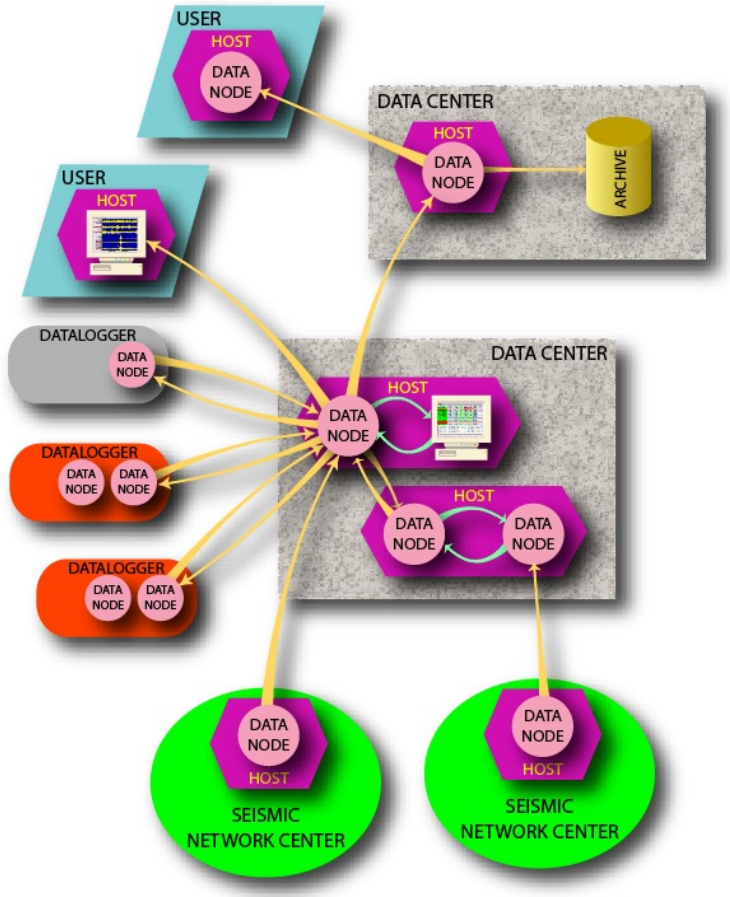
Data Transport Backbone

orbserver

- *orbserver* / *orb* protocol
- Network transparent
- Data-neutral
- Data-driven
- Extremely reliable
- Short-haul Inter-process communication
- Long-haul, low latency data transport
- Extension to standard networking stack:
  - IP = packet transport
  - TCP = reliable transport of bytes
  - Orb = reliable transport of monitoring-data packets



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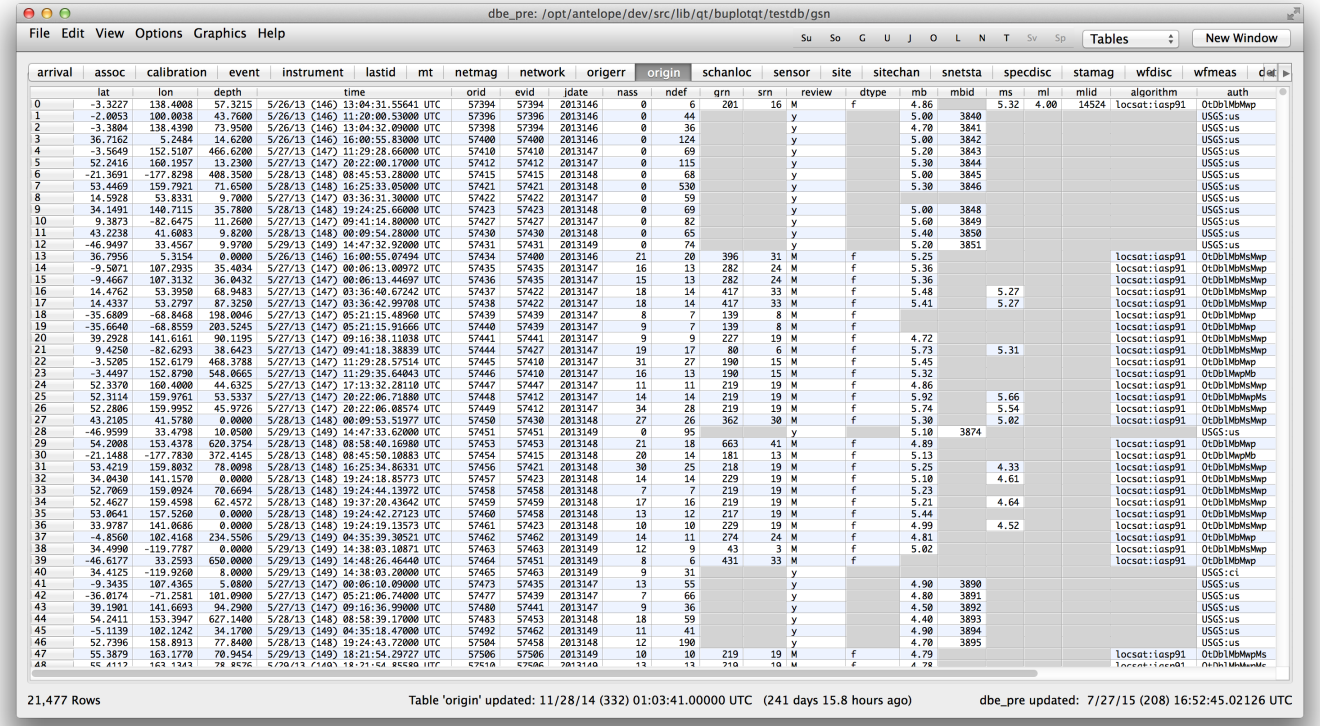
Embedded Relational Database

Datascope



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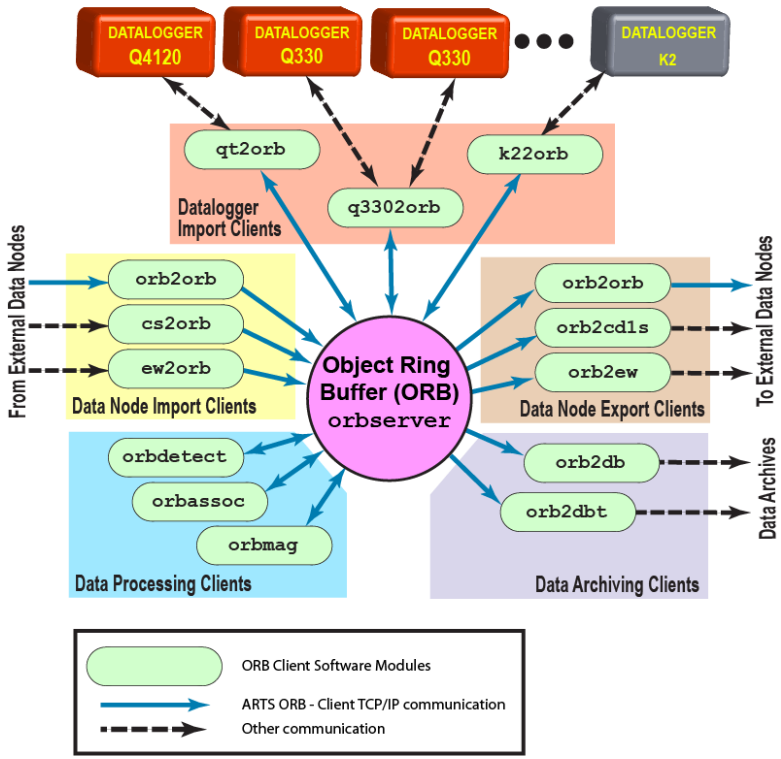
Real-time System

- Unix building-block design
  - Hundreds of small, well-designed programs, each with a clear job
  - Shared-object libraries of generic and specialized tools
- Framework to customize solutions
- Scalable
- Network-transparent
  - Allows local deployments
  - Allows distributed processing
- Demonstration system based on GSN
  - Learning and Testing
  - Augment small networks with global processing for context
  - Basis for rapid configuration of larger operations



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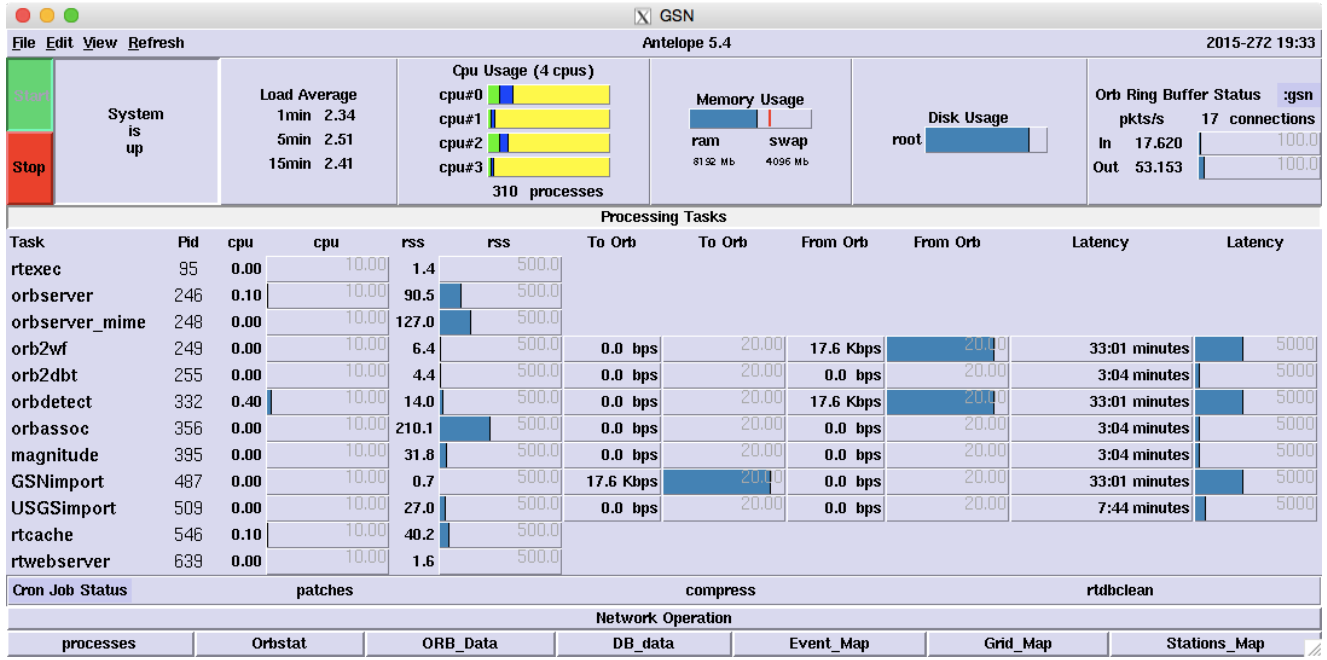
Real-time Executive

rtexec

rtm



- System Command-and-control
- Run-time monitoring
- System State-Of-Health
- Comprehensive logging
- Alerting on hardware infrastructure, RT system, and process-status
- Headless, enterprise server operation with optional graphical front-end
- Turnkey reboot capability
- Cooperates with advanced deployments – high availability, redundant failover networking etc.

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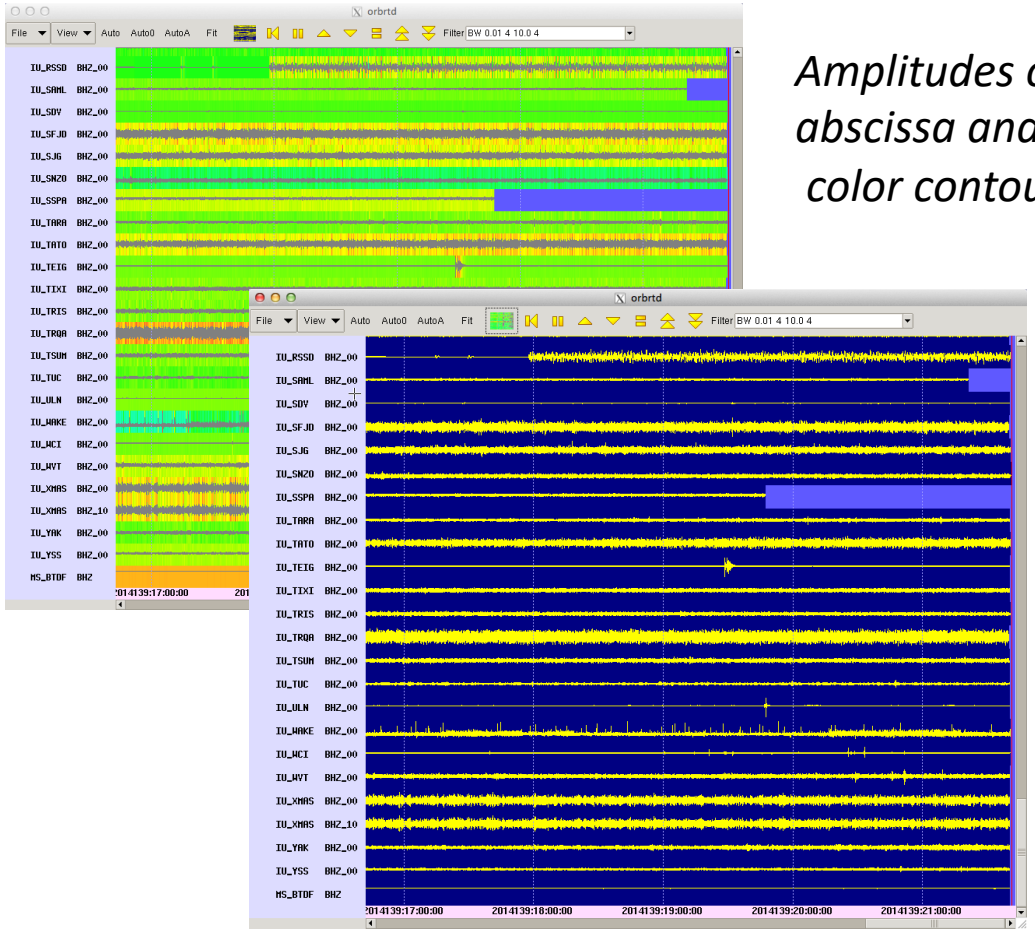
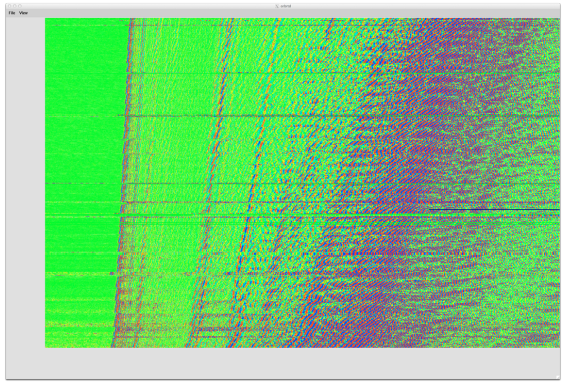
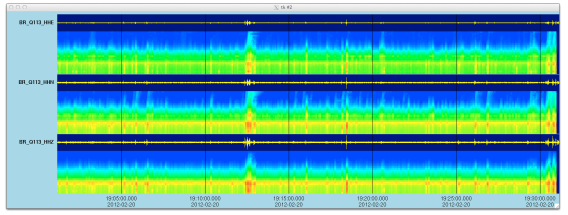
Streaming Time-series Display

orbrtd



Amplitudes on abscissa and/or color contours





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Continuous Waveform Archiving

orb2wf

- *orb2wf* writes waveform data from ORB ring buffer to continuous database
- Efficiently handles gaps and out-of-order data with automatic healing
- Dynamically handles anomalies such as sample rate changes, calibration changes for channel
- Vets data for unstuffing and timing errors
- Optionally morphs data SEED codes
- Configurable output format

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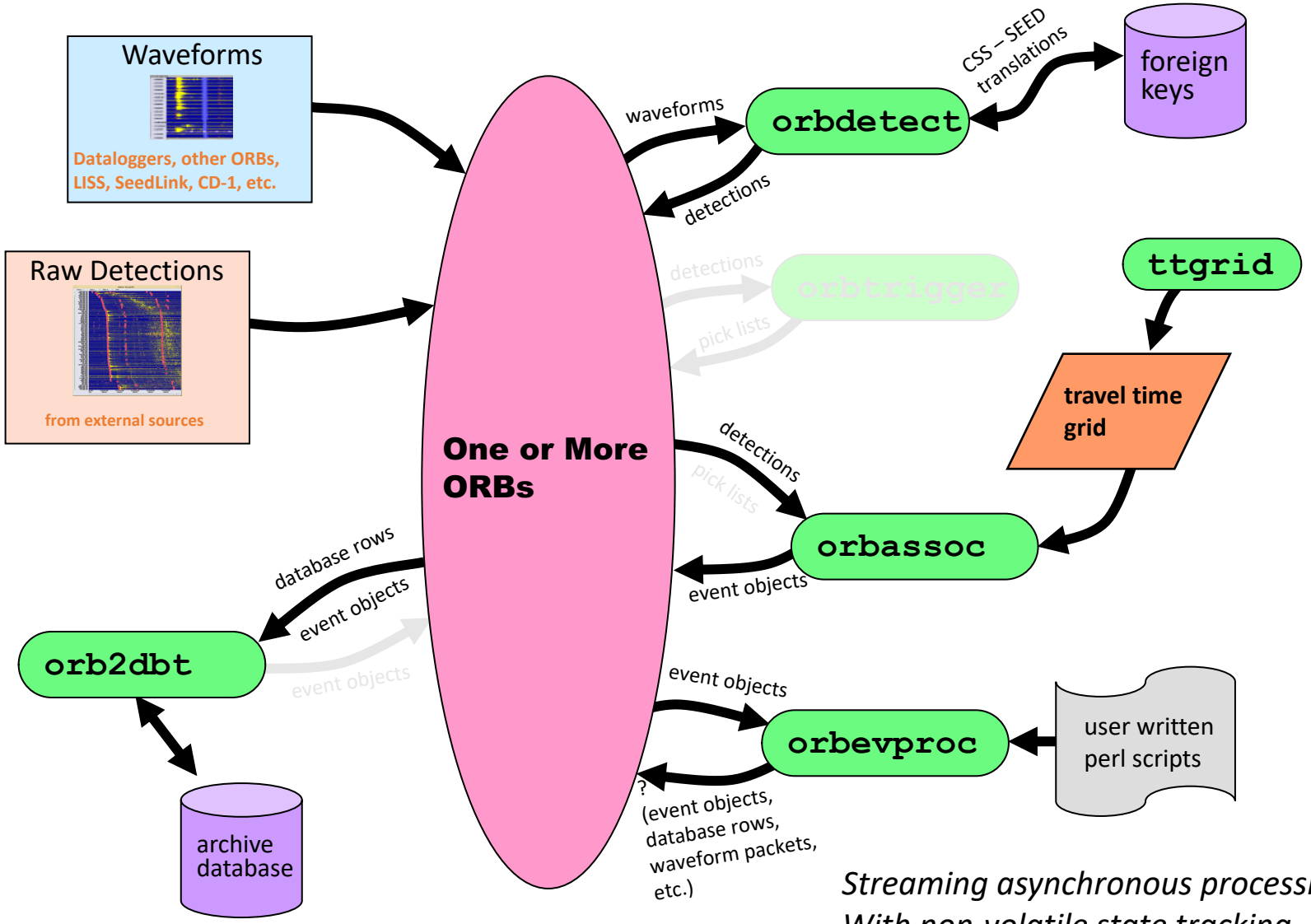
Antelope Automated Event Processing



Streaming asynchronous processing
With non-volatile state tracking

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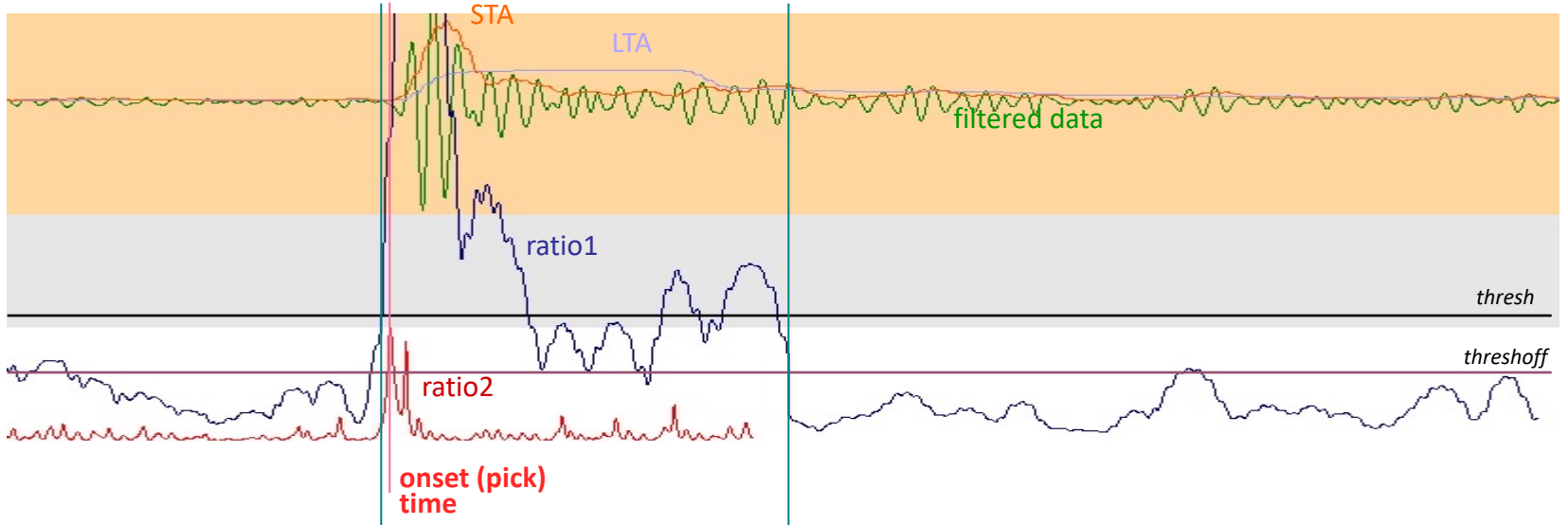
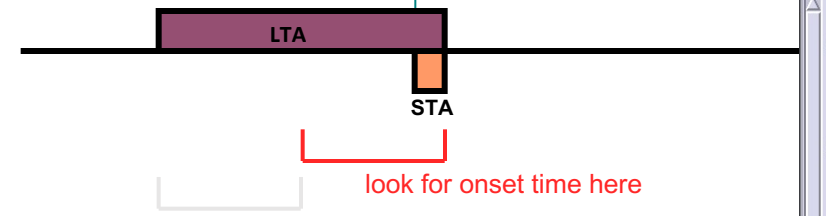
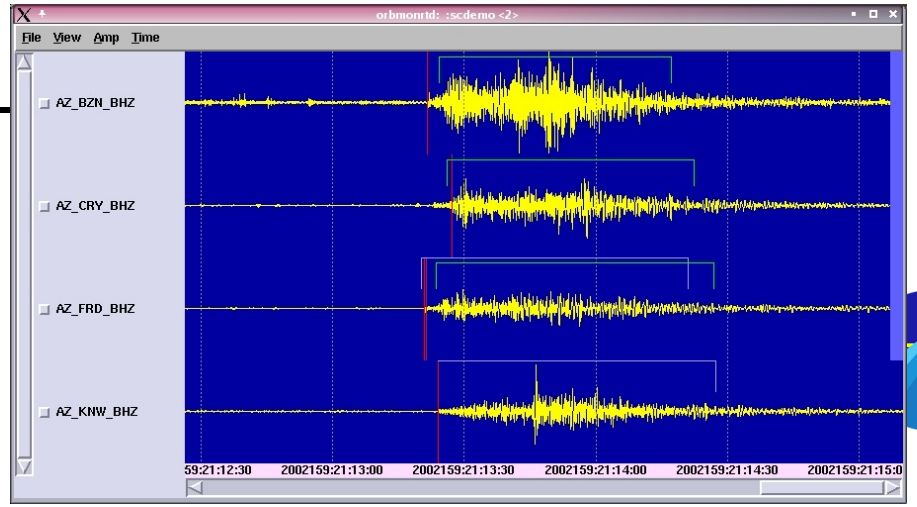
Real-time Phase Detection



orbdetect



compute ratio2 noise floor here



Industry-standard approach

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Real-time event locator

- *orbassoc* – State-of-the-art, sophisticated grid-based associator
- Tunable all the way from Earthquake Early Warning to Catalog Production
- Multiple simultaneous grids: local; regional; universal teleseismic (more dense around PDE seismicity)
- Engineered in close coordination with multi-band detector
- Works for small networks, volcanoes, volcano chains, regional networks, global events, tsunamigenic quakes, aftershock sequences
- Four main revisions, through 2007; operations-hardened on many different network sizes and types around the planet
- Many sophisticated parameters available to tune for your network geometry and application

orbassoc

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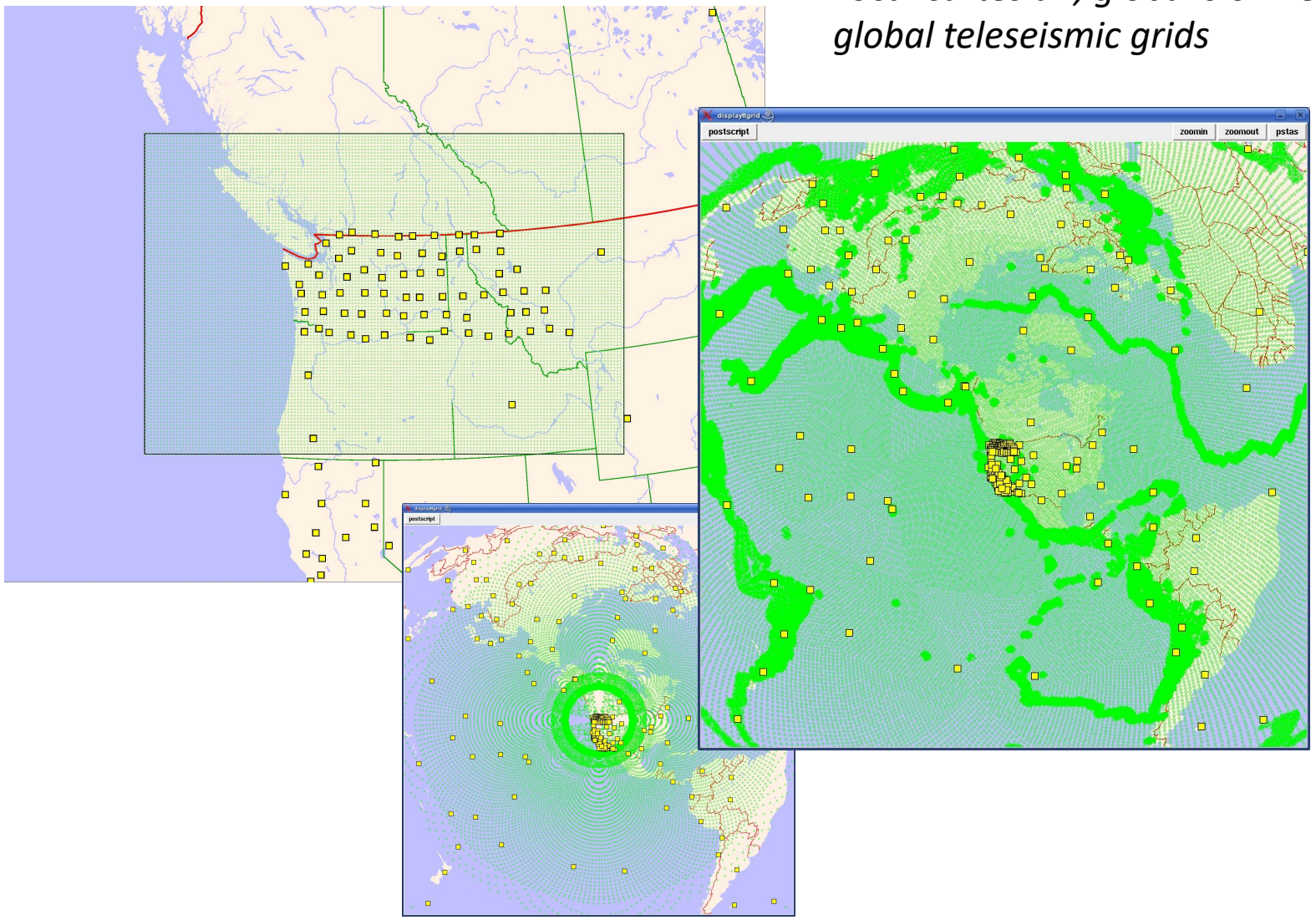
Travel-time Grids

Local cartesian, global slowness, and global teleseismic grids



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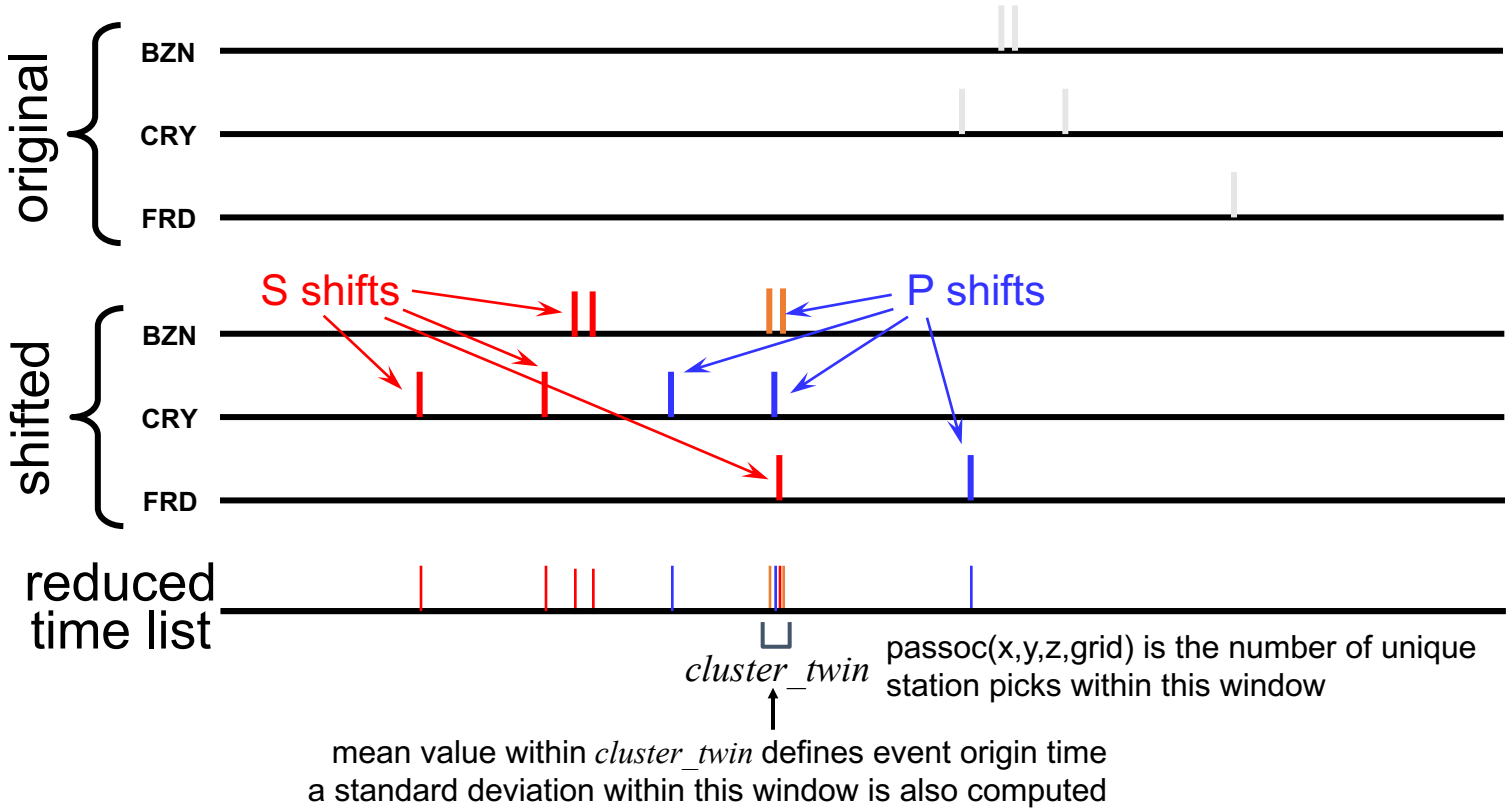
P-wave Processing

For each grid-source location node:

1. All of the times in the pick list are reduced by the phase travel times to an equivalent origin time.
2. These reduced pick times for each travel time phase are put into a reduced time list for subsequent time-clustering analysis:



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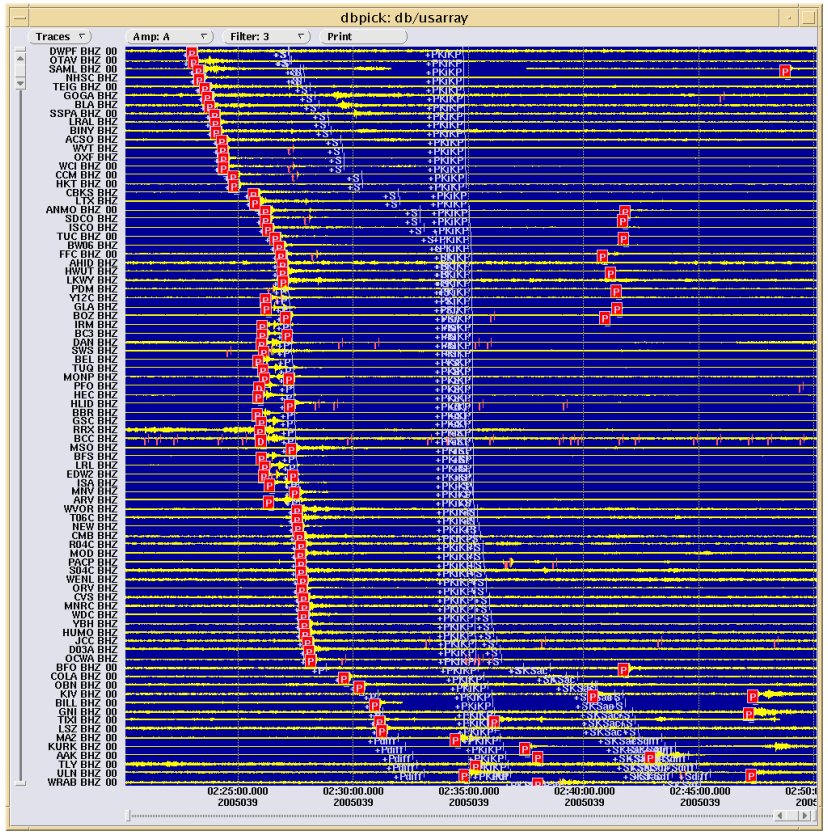
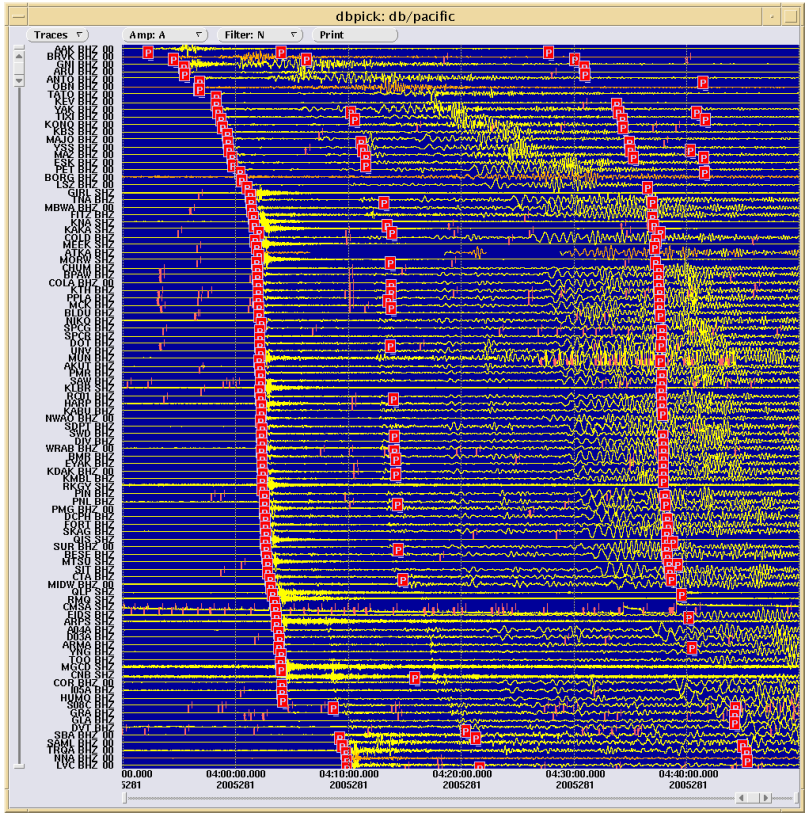
Recursive Pick Processing



Best-fit identification of overlapping events



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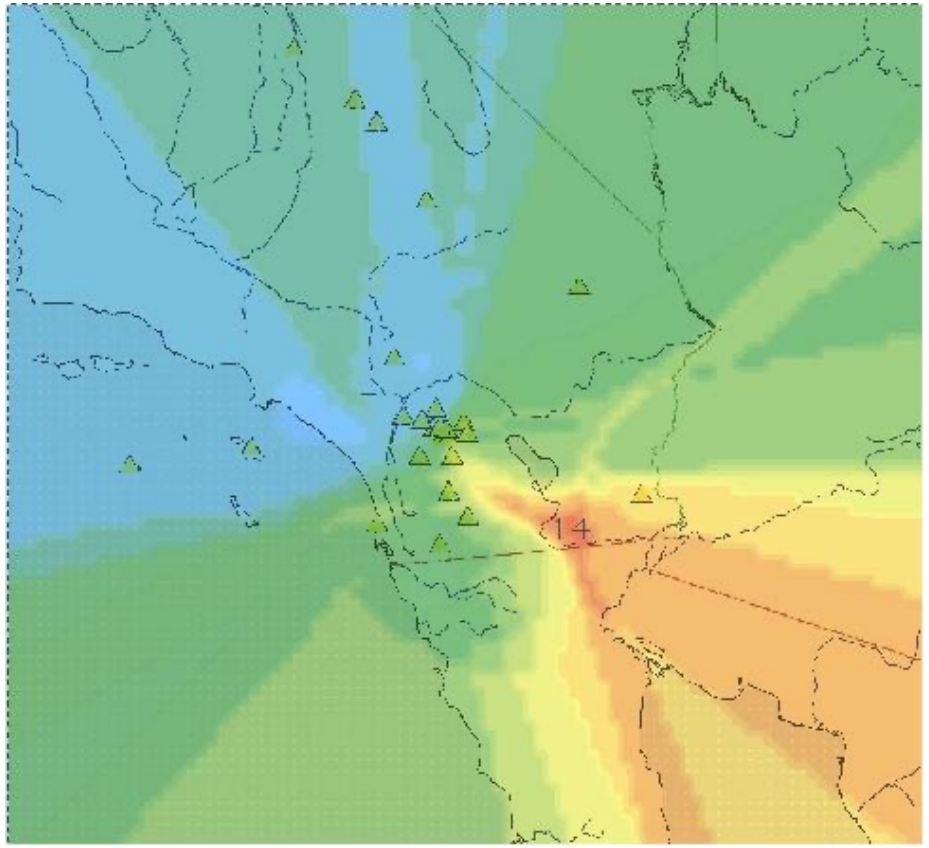
Location Grid in Action

orbassoc

- *Peak grid point chosen as earthquake location*
- *Latest version of orbassoc allows Geiger-method refinement (dbgenloc)*



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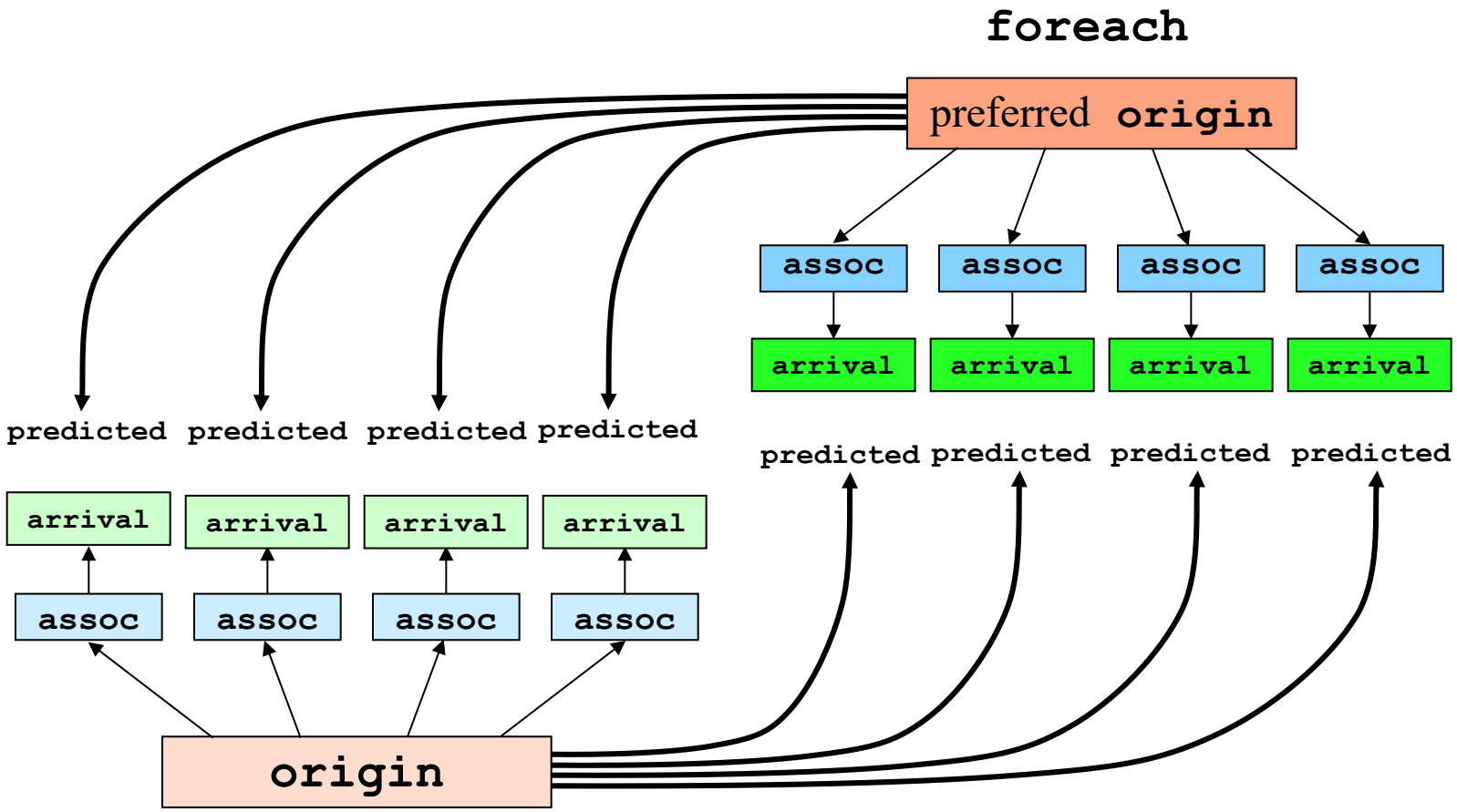
“Smart” Event Association

From event object

From archive database

orb2dbt



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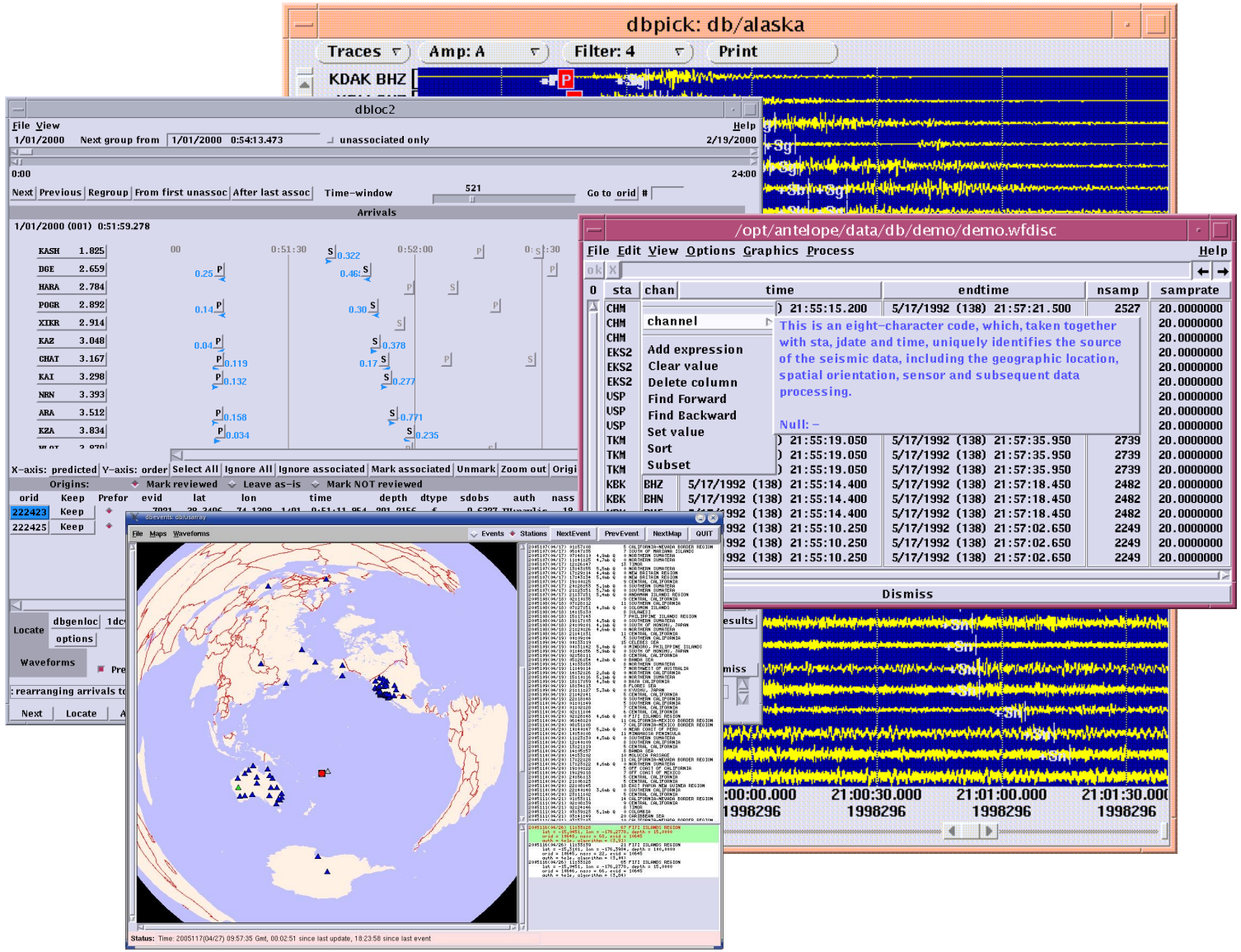
Analyst Event Location and Review

dbloc2



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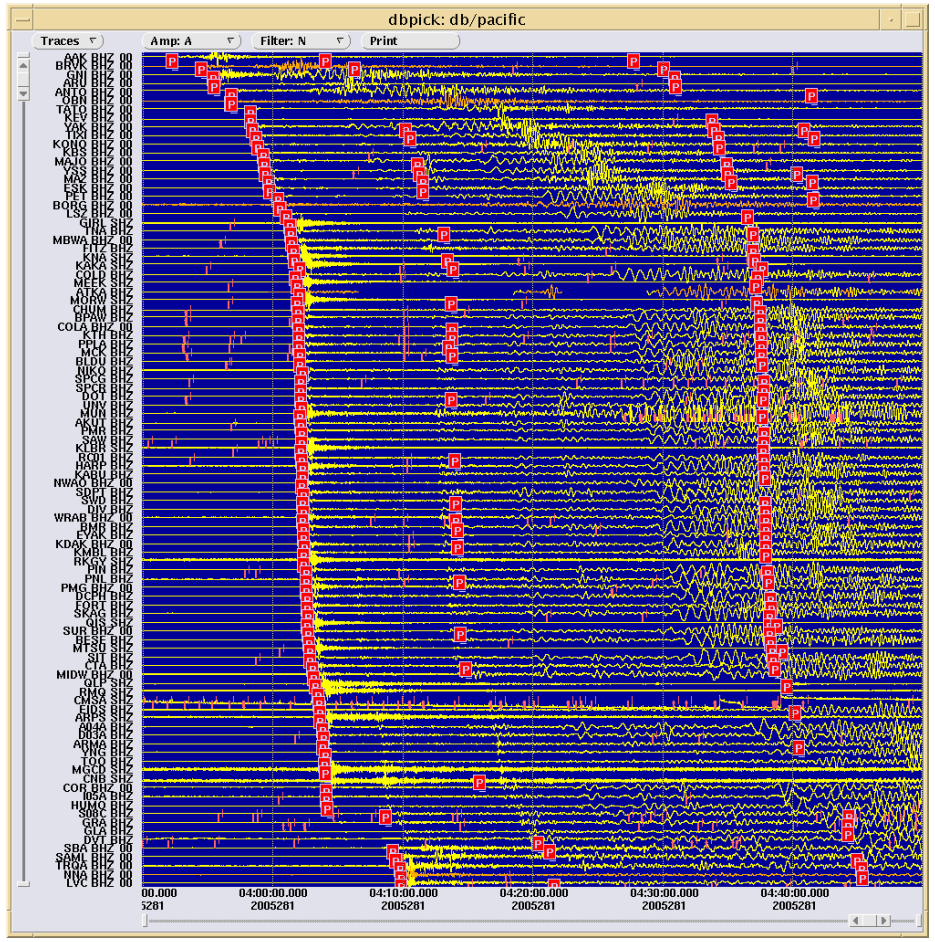
Waveform viewing and phase picking

Dbpick and traceview

- Runs locally or over ssh connection
- Customizable filtering
- Configurable phase naming
- Amplitude measurement
- Small networks or hundreds of station deployments



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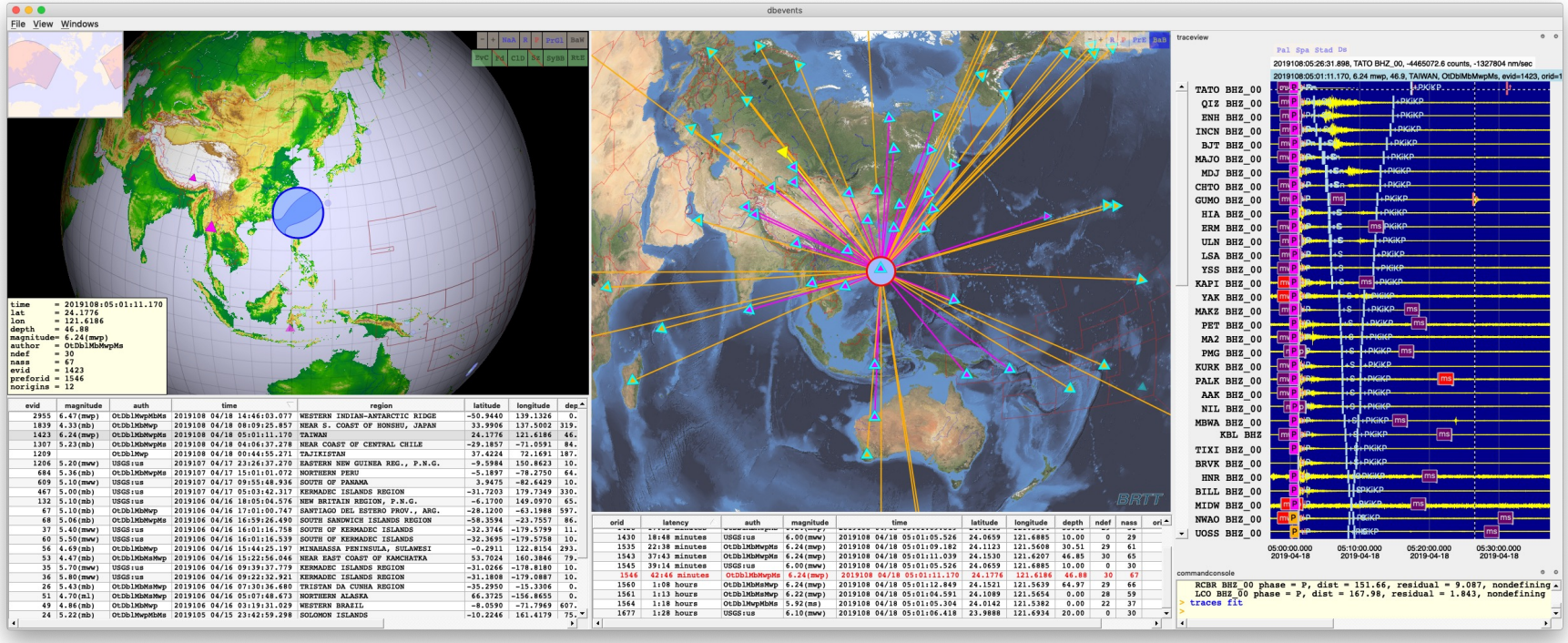
Event Display

dbevents



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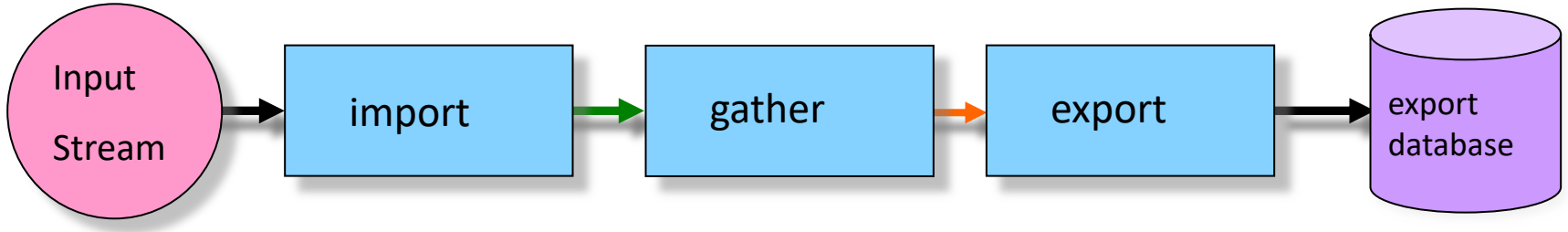
Generic Stream Processing Framework

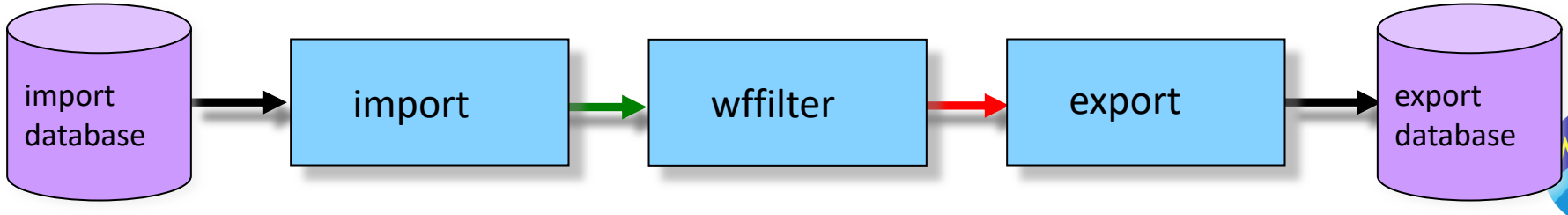
- Framework for arbitrary waveform computations
- Open-source C code program *orbwfproc*
- Configurable ‘tasks’: building-block construction of processing chains
- BRTT provides multiple algorithms, filtering, etc.
- Extensible with client-written algorithms
- Streaming (*orbwfproc*) and Batch (*dbwfproc*) mode

orbwfproc

Heal waveforms (data out of time order, overlapping data, gaps, etc)
Create defragmented export database:



Resample or filter waveform data (e.g. change SEED codes):



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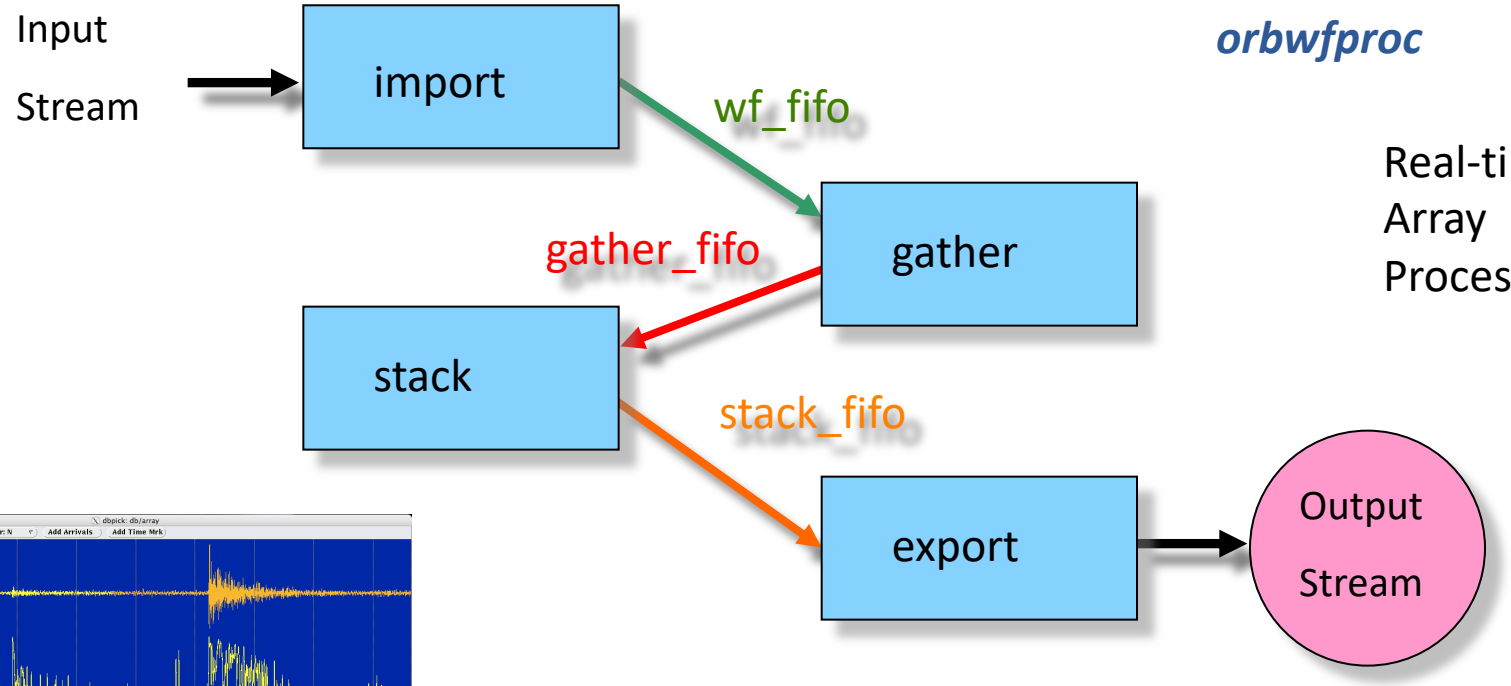
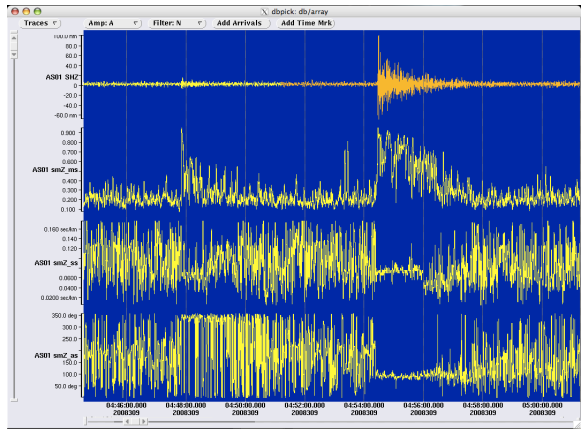
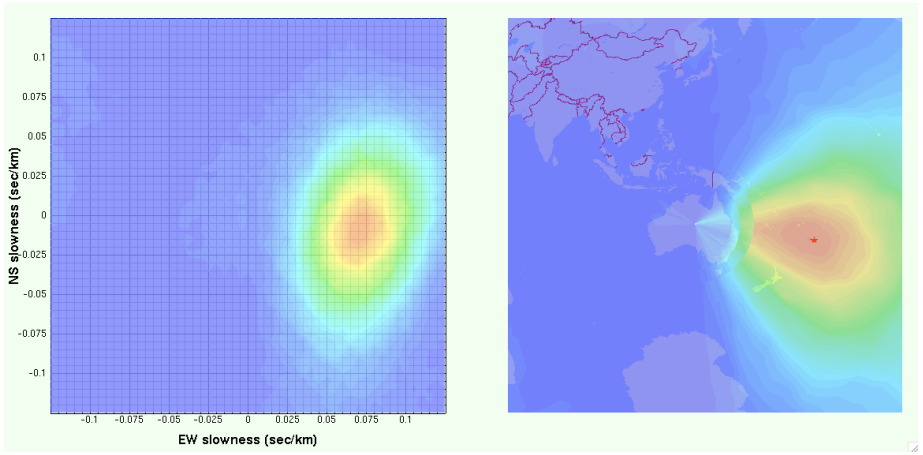
Generic Stream Processing Framework



orbwfproc

Real-time
Array
Processing





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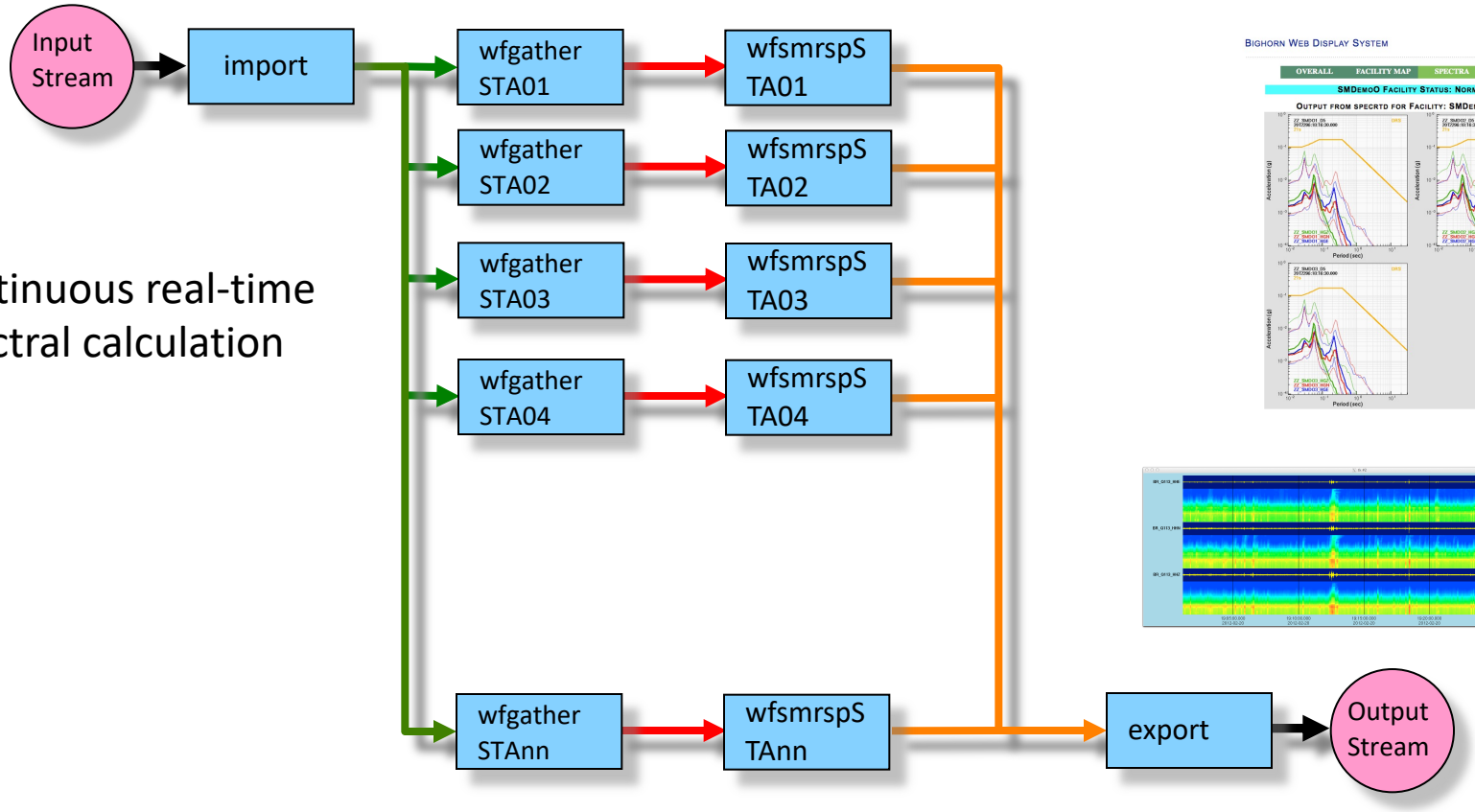
Generic Stream Processing Framework

orbwfproc



Continuous real-time
Spectral calculation

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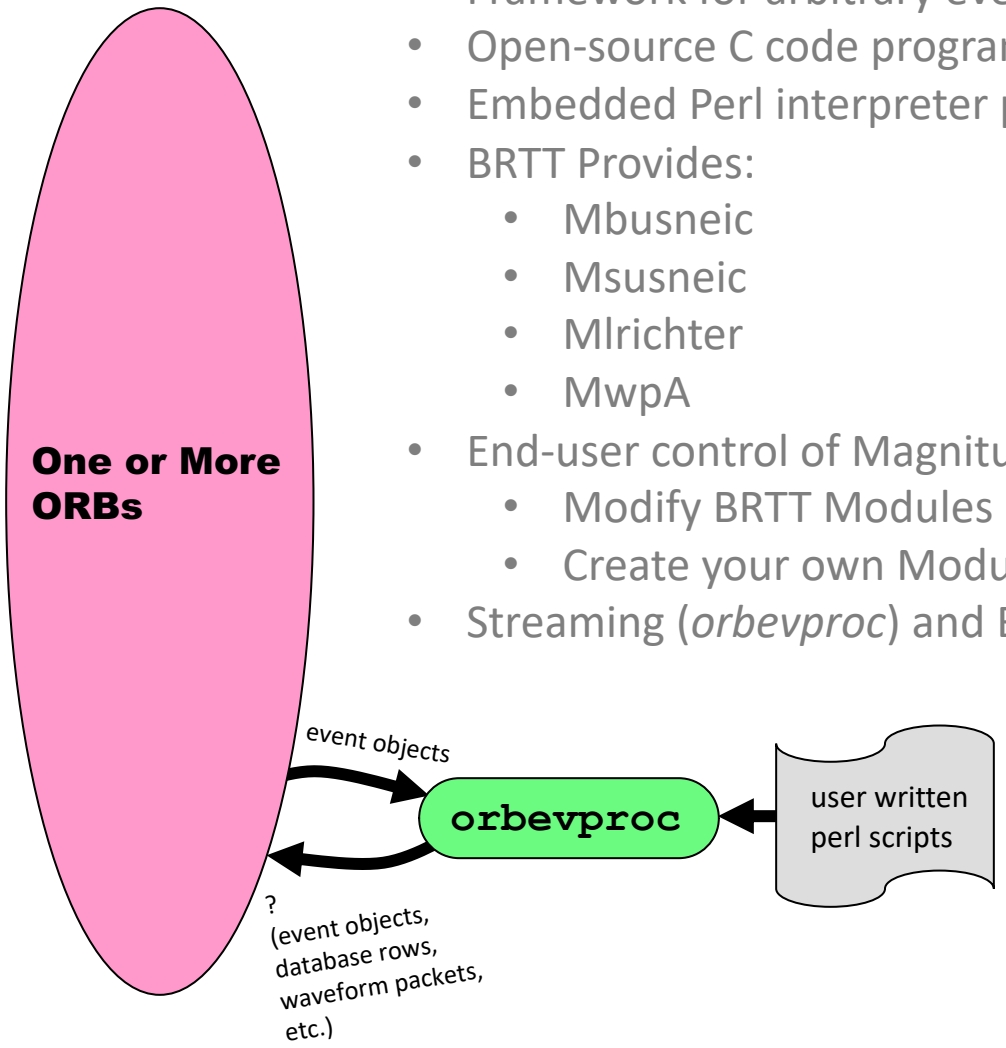
Generic Event Processing Framework

- Framework for arbitrary event-driven computations
- Open-source C code program *orbevproc*
- Embedded Perl interpreter processes algorithms
- BRTT Provides:
  - Mbusneic
  - Msusneic
  - Mlrichter
  - MwpA
- End-user control of Magnitude calculation
  - Modify BRTT Modules
  - Create your own Module
- Streaming (*orbevproc*) and Batch (*dbevproc*) mode



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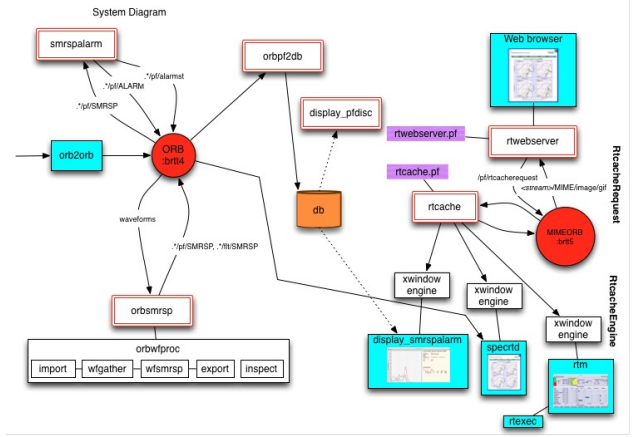
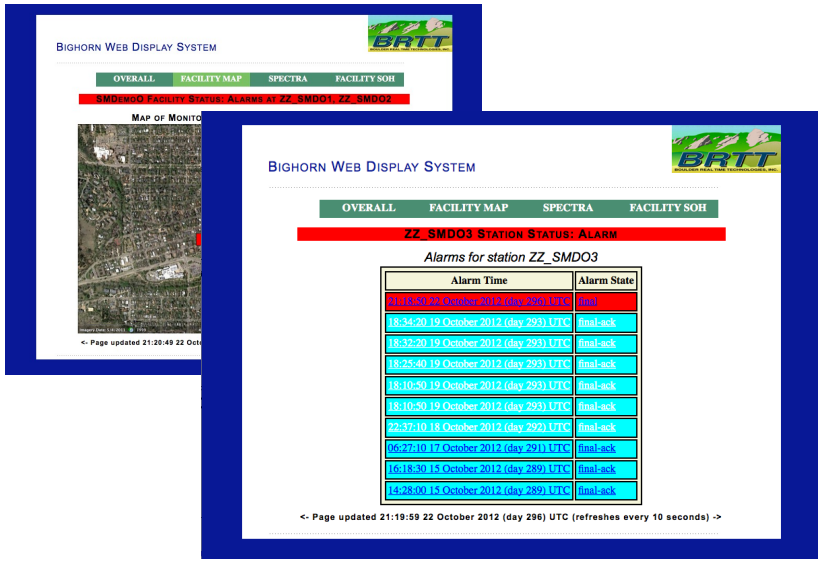
Structural Health Monitoring: Bighorn

- Alarms based on exceedence of Operating Basis Earthquake (OBE)
- Building-block nature of Antelope/Bighorn system and open-architecture APIs allow construction of wide variety of systems for Structural-Health Nowcasting, Earthquake Early Warning, and Post-Earthquake Response (e.g. Aramco/APEAS Facility alert / Alarm Acknowledgment system)





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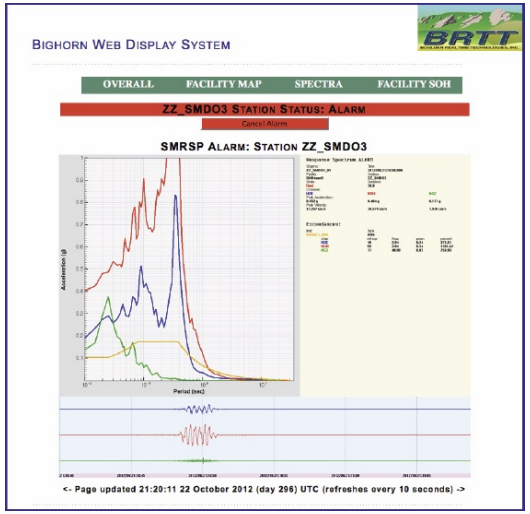
Bighorn

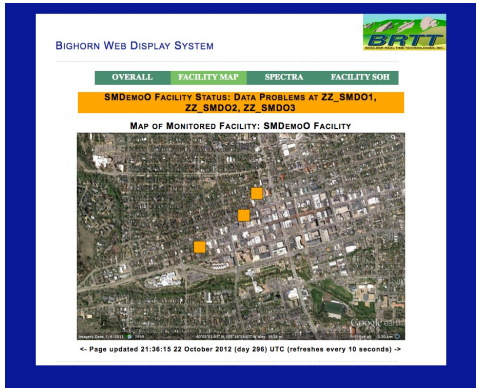
Main Features

- ***Now-casting*** of wavefield spectral content
- Real-time, continuous response spectra exceedence
- Immediate results tailored for response team
- Automatic alarms against engineered criteria (Structural Health Monitoring)
- ***Independent of Earthquake Location***
  - No need to wait for location
  - Applicable for non-earthquake sources
  - Very close to Earthquake Early Warning
- Quantitative, ***critical decision support***



Facility Monitoring

Bundled into Antelope



State-of-Health Monitoring

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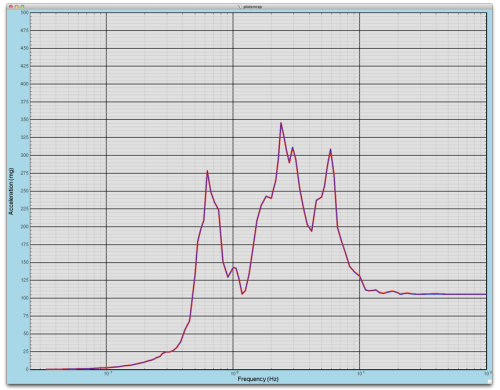
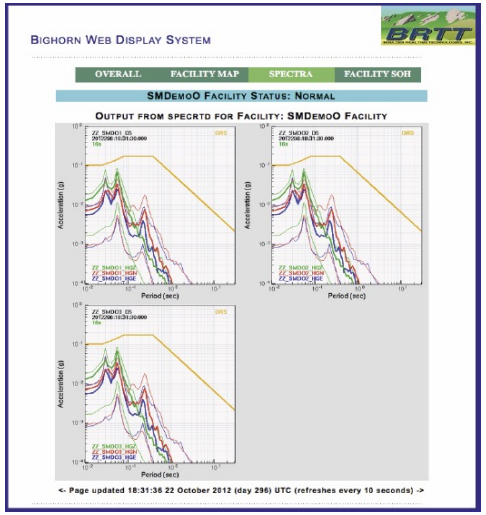
Bighorn

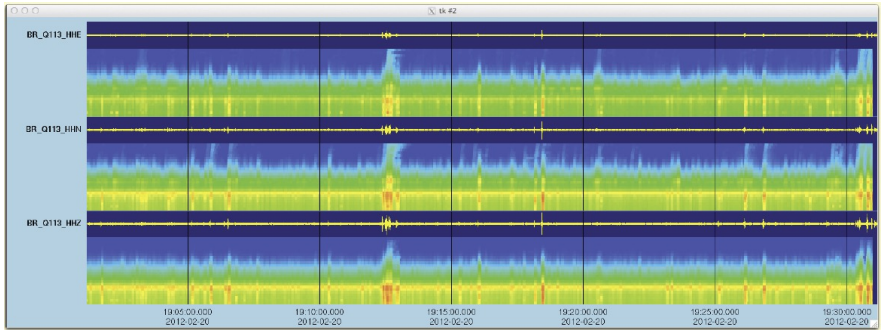
- Method vetted by Nuclear Regulatory Commission
- Faithful translation from
  - After-the-fact event-based review; to
  - Streaming, real-time, continuous now-casting



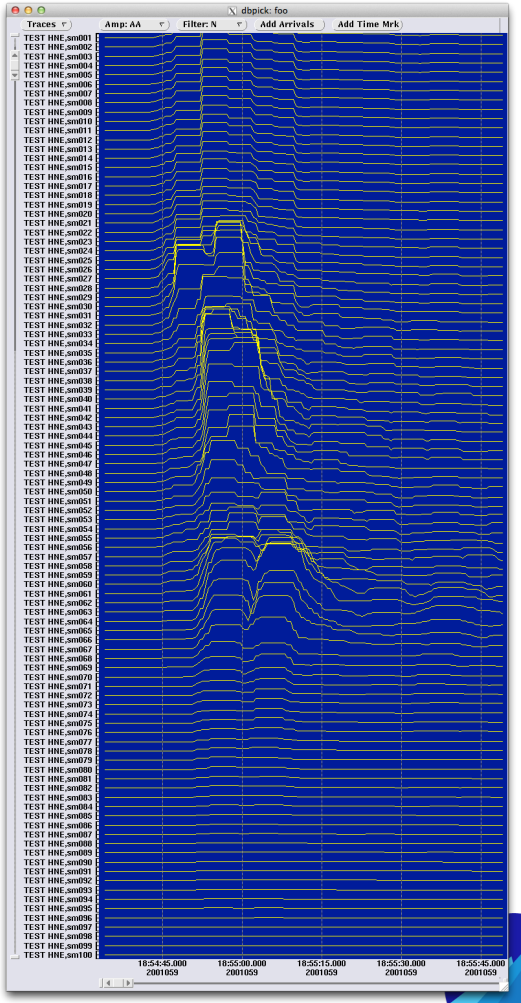
Blue: Traditional post-processing
Red: Streaming real-time processing
(or vice versa…)

-> Synthesize
Real-time
Spectral
Calculations





Multiple
Time-domain filters
Of incoming wavefield



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Extensive Development Environment

- Fully developed command-line build tools
- Extensive man-pages, web documentation, online reference guide
- Compiled language interfaces
  - C
  - C++
  - Fortran
- Scripted language interfaces
  - Shell
  - Perl
  - TCL/Tk
  - Python
  - (PHP)
  - MATLAB
- Powerful interactive capabilities
  - Command-line tools
  - Interactive Python
  - MATLAB

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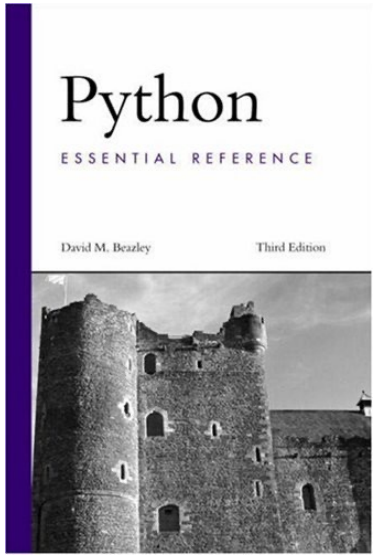
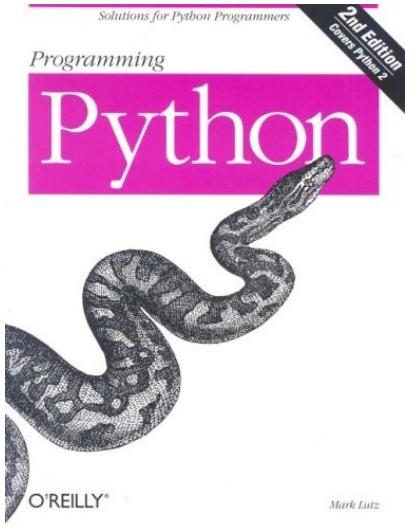
Python

- Python: Object-oriented scripting language
  - http://www.python.org
  - Dynamic
  - Powerful
  - Extensible
  - Fast





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Open-source Community

- http://www.antelopeusersgroup.com
- http://www.github.com/antelopeusersgroup
- Advances
  - Custom earthquake alarms
  - Alarm-response tools
  - Enhancements to Antelope utilites – dbpick etc.
  - S-wave and polarization detection
  - Moment-tensor computation
  - Real-time gridded moment-tensors
  - Cross-correlation tools

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Antelope Key Points

- Complete software package for traditional seismic network operations and SHM
- Extensible Middleware Framework for interconnecting data sources with data processing to create custom earth monitoring systems
- Store-and-forward packet system enables reliable transport, processing, dissemination
- Embedded relational database system
- Core utilities available for both streaming and batch-mode processing
- Has been applied to numerous environmental monitoring domains
  - seismic, tsunami, volcano, strong-motion, sensor-web, structural health
- Open architecture, with both closed and open-source components
- High performance and reliability
- High scalability
- High interoperability
- Minimum processing and communications latencies (early warning)
- Productive development environment for new/extended functionality
- Coherent engineering throughout creates highly robust, highly functional, low cost-of-ownership system – only available from commercial code

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Obtaining Antelope

- Evaluation copies, subscriptions or upgrades to Antelope 5.13:
  - Contact Kinemetrics, Inc.:
    - ***sales@kmi.com***
- Technical questions about Antelope:
  - Contact BRTT:
    - ***support@brtt.com***

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Thank You

support@brtt.com

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