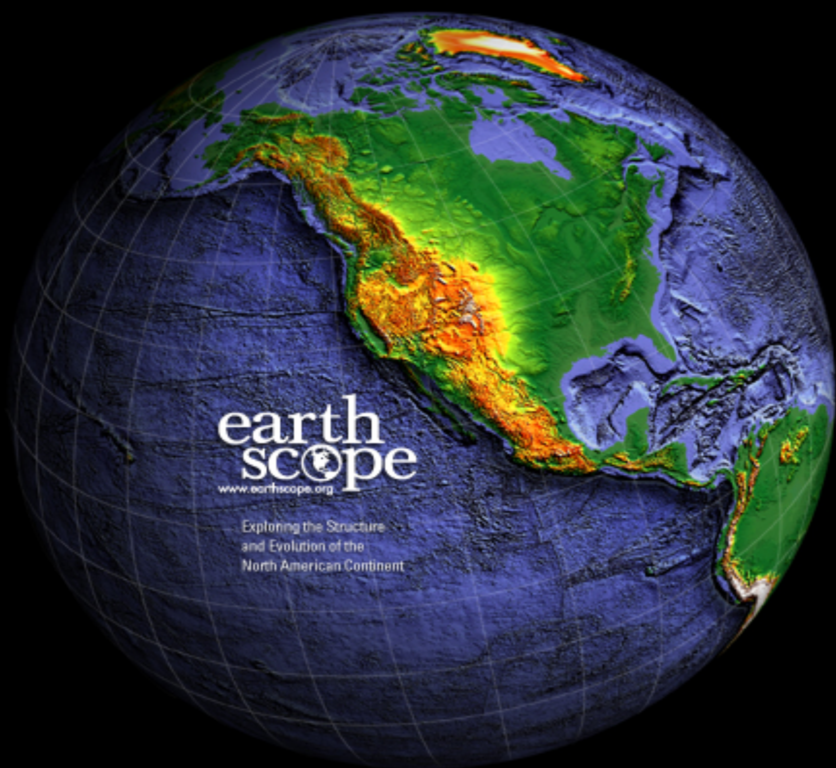
EarthScope's Transportable Array: Operations Overview



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Mediterranean and Gulf Countries Network Operators Meeting
March 12-14, 2009
Marakech, Morocco

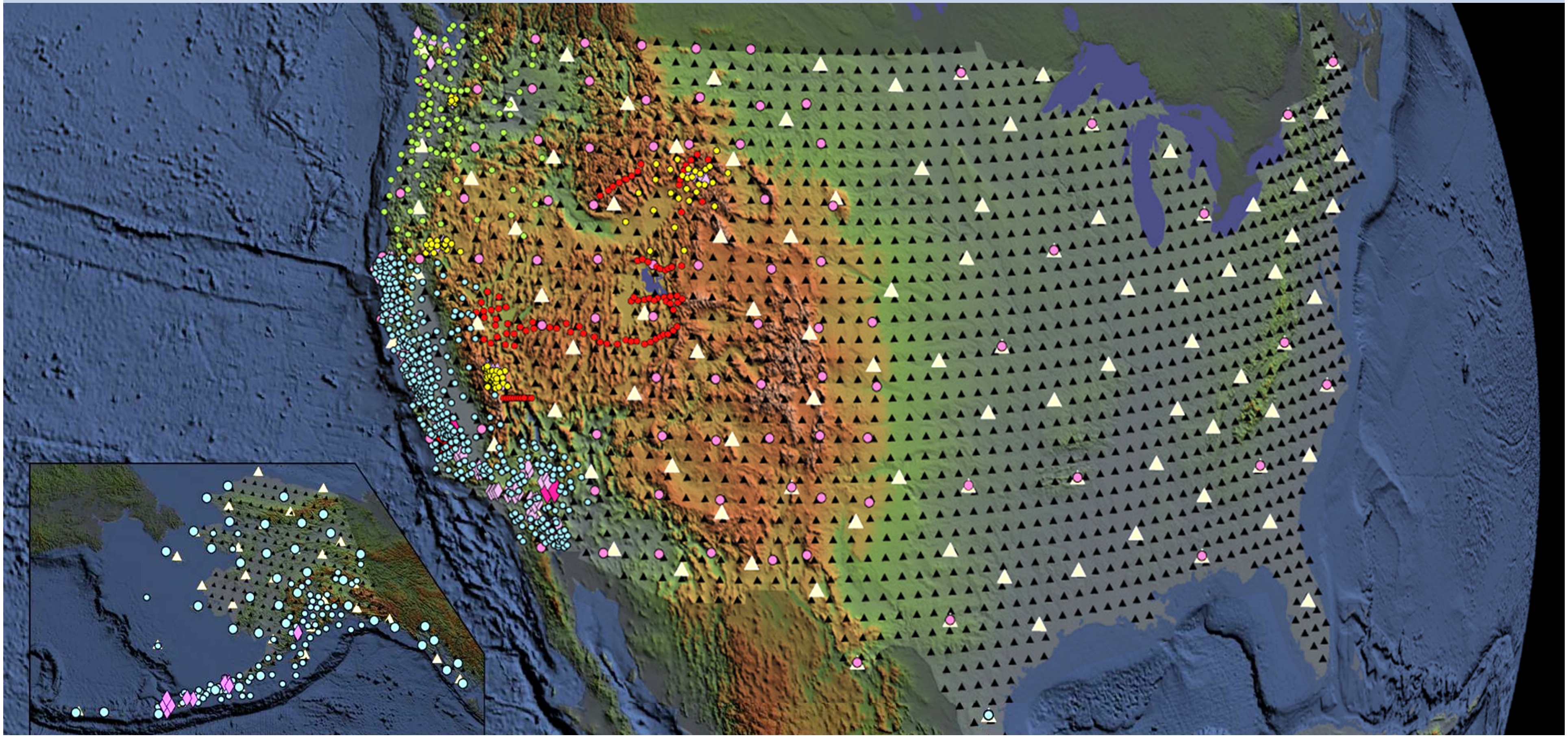
Presentation Outline

- Intro to EarthScope Project & Transportable Array
- Transportable Array operational experience
  - Select Details of Project execution
  - Some ongoing developments
- Key insights in design and operation

EarthScope Project

Study the three dimensional structure and evolution of the North American Continent

- 3.2 km borehole into the San Andreas Fault
- 875 permanent GPS stations
- 175 borehole strainmeters
- 5 laser strainmeters
- 39 Permanent seismic stations
- 400 transportable seismic stations occupying 2000 sites
- 30 magneto-telluric systems
- 100 campaign GPS stations
- 2400 campaign seismic stations



EarthScope Project

EarthScope Project Components

www.earthscope.org

Plate Boundary Observatory — UNAVCO

SAFOD — USGS science for a changing world

USArray — IRIS

USArray Observatory Components

The focus of this presentation

Transportable Array — 400 seismic stations, 70km grid

Flexible Array — 355 portable instruments, 1200 single component for PI driven experiments

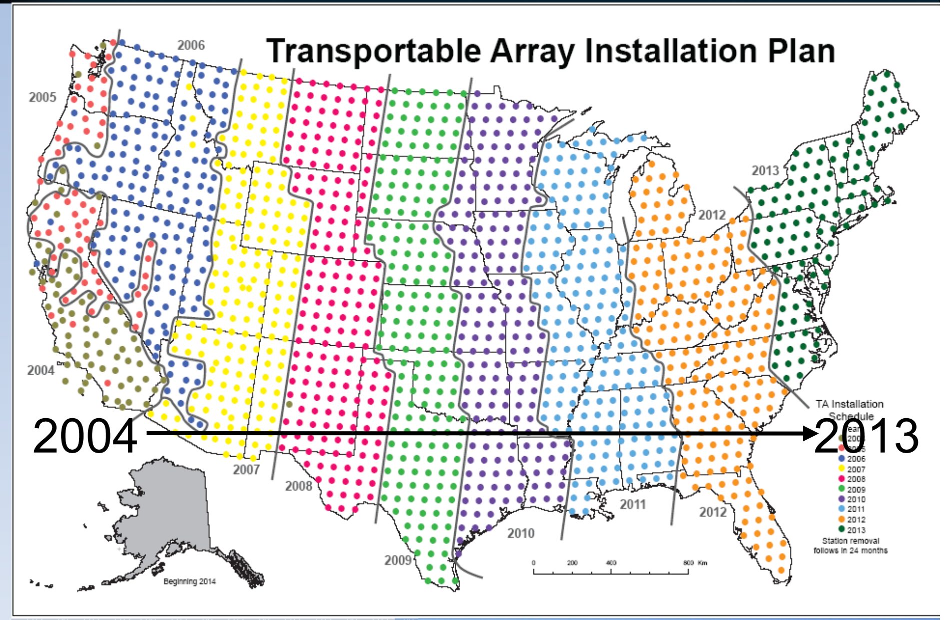
Reference Network — about 100 permanent seismic stations

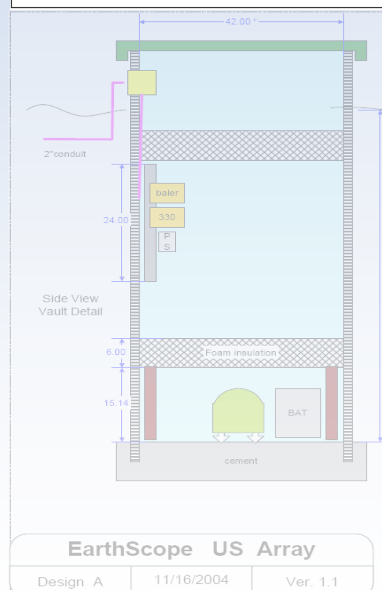
Magnetotelluric — 7 backbone stations and 20 portable instruments

Transportable Array Concept

- 400 broadband seismic stations
  - ~70 km spacing between stations
  - ~1500 x 800 km “footprint”
  - ~2 year deployments at each site, 1623 sites
  - Migrate across the country in 10 years
  - $8M / year budget

- Operational Goals
  - High-quality broadband data
    - On par with permanent network stations
  - Maximize data return (>85%)
  - Data to the scientific and regional network community in near real time
    - 40 and 1 sps continuous
  - Equipment redeployed five times



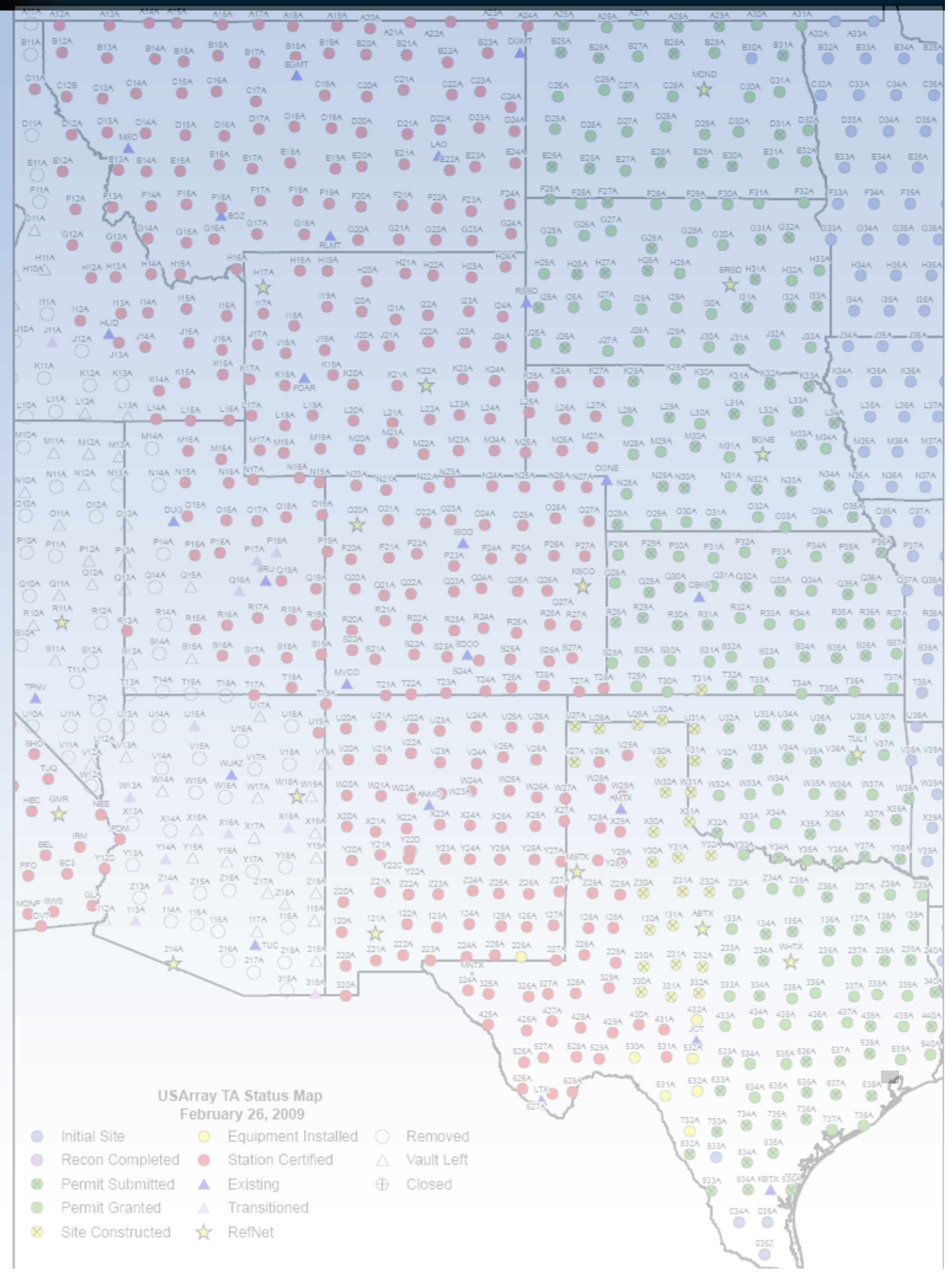


Status: Deployment

- On Schedule
  - 734 commissioned Stations
  - 442 operating Stations
  - 292 removed Stations
- Rolling eastward at a rate of about 400 km / year,   18 sta/mo
- North-south deployment strategy permits year-round operations

Stations going in . . .

. . . and coming out



Goals for Workshop

- Strengthen Contact between groups
  - Identify expertise among participants
  - Recognize common operational features
  - Share experience and technical resources
- Discuss approaches to similar issues
  - Station to network center communications
  - Equipment integration
  - Network Monitoring, useful diagnostics
- Awareness of new trends, software or products
  - Internal project developments
  - Quanterra developments

Topics elsewhere

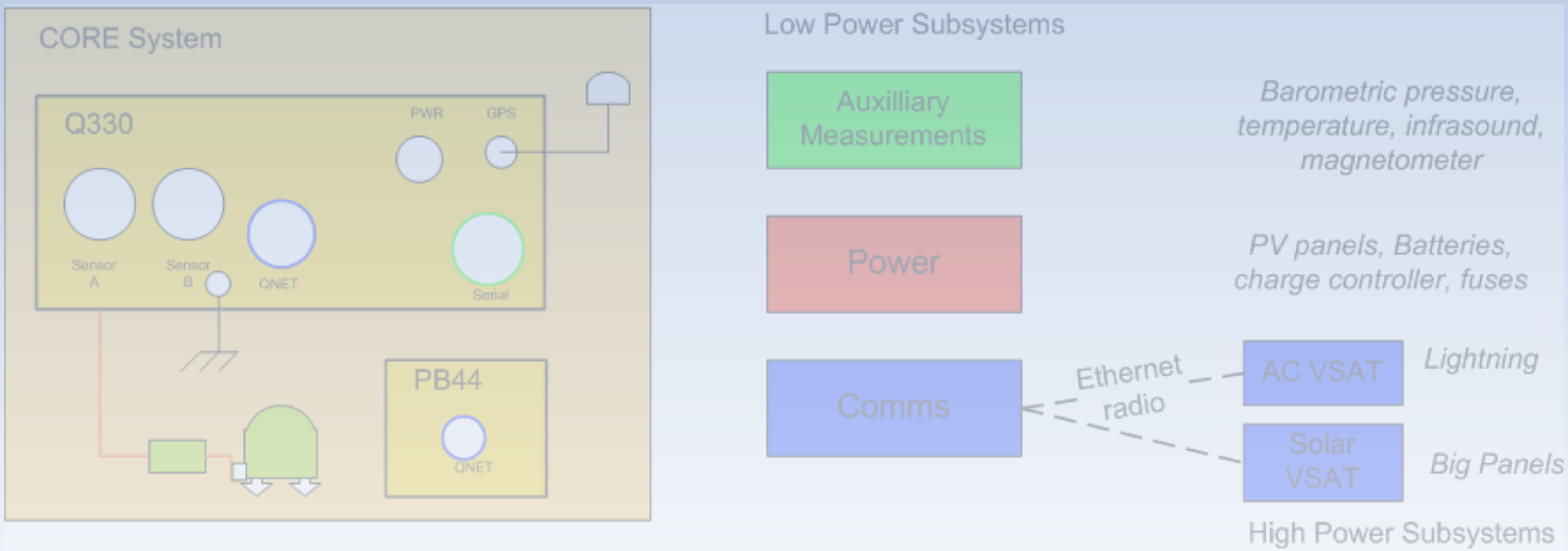
- Array Network Facility (ANF) details-Vernon.
- IRIS Data Management System archival.
- Stations Logistics- permitting, equipment inventory management, etc.
- SEED conventions.
- Adopting TA Stations.

Station Design

- Very Low power to avoid cultural noise sources and to maximize siting opportunities. 3-5W solar powered.
- Fast construction, material adapts to conditions, from ready sources.
- high quality LP data requires thermal isolation.
- High power communications separated from station power.
- Local recording, minimum complexity in uplink

Design Principles of Station

- Modularity in subsystems



Other Design Considerations

Global Networks:

- Long term stable operation
- integration of numerous sensors
- international shipping

National Networks:

- Earthquake monitoring for hazard, low latency.
- Public information, emergency response

Q330: Data Engine—Low power, small size

- Provides three essential functions;
- Digitizer, sensor controls, telemetry integration

Q330 notable advances for TA

- 8Mb original memory upgraded to 32Mb
  - 4 hours buffer to about 28 hours
- Integration and development of Antelope support
  - Q330util, webdlmon, SOH RRD
  - POC receiver
  - In situ Calibrations
- Configuration management
  - Configserver
  - Garfield firmware bulk loader
  - XML file templates
- Q330 auxilliary data channels
  - add low rate information into standardize processing flow

Station Building Tasks

- **Reconnaissance**- which may involve office evaluation, field visits, landowner interaction but ends with the selection of a Candidate Site-that is a site for which we will seek a permit. Produces a recon report, which includes the outline of how the specific station will be provisioned including power and communication strategy.

- **Permitting**- meaning the negotiation with landowner, paperwork necessary to obtain written permission to access the property and to install a station. Permits and the expertise to acquire them increase in complexity from a simple private landowner agreement, through cooperative ownerships, corporate ownership to state or federally managed lands.

- **Construction**- digging a hole, pouring concrete, trenching cables and erecting a mast. This task can be accomplished by a backhoe operator and a laborer assistant. While construction details are important for good quality data, the task itself does not require scientific expertise.

- **Installation**- installation of electronics, power system, communication system and sensor. Generally ends with data communication back to ANF. This step involves detailed understanding of seismic instrumentation, communications and power electronics and requires at least one highly trained person on site.

- **Release**-removal of the station and tank and preparing the equipment for shipping or transfer of the station to a new operator, releasing IRIS of landowner obiligations.

Organization Summary

34 Team Members

Management: 2.0

Recon: 5
- **2.5 office**
- **2.5 field team**

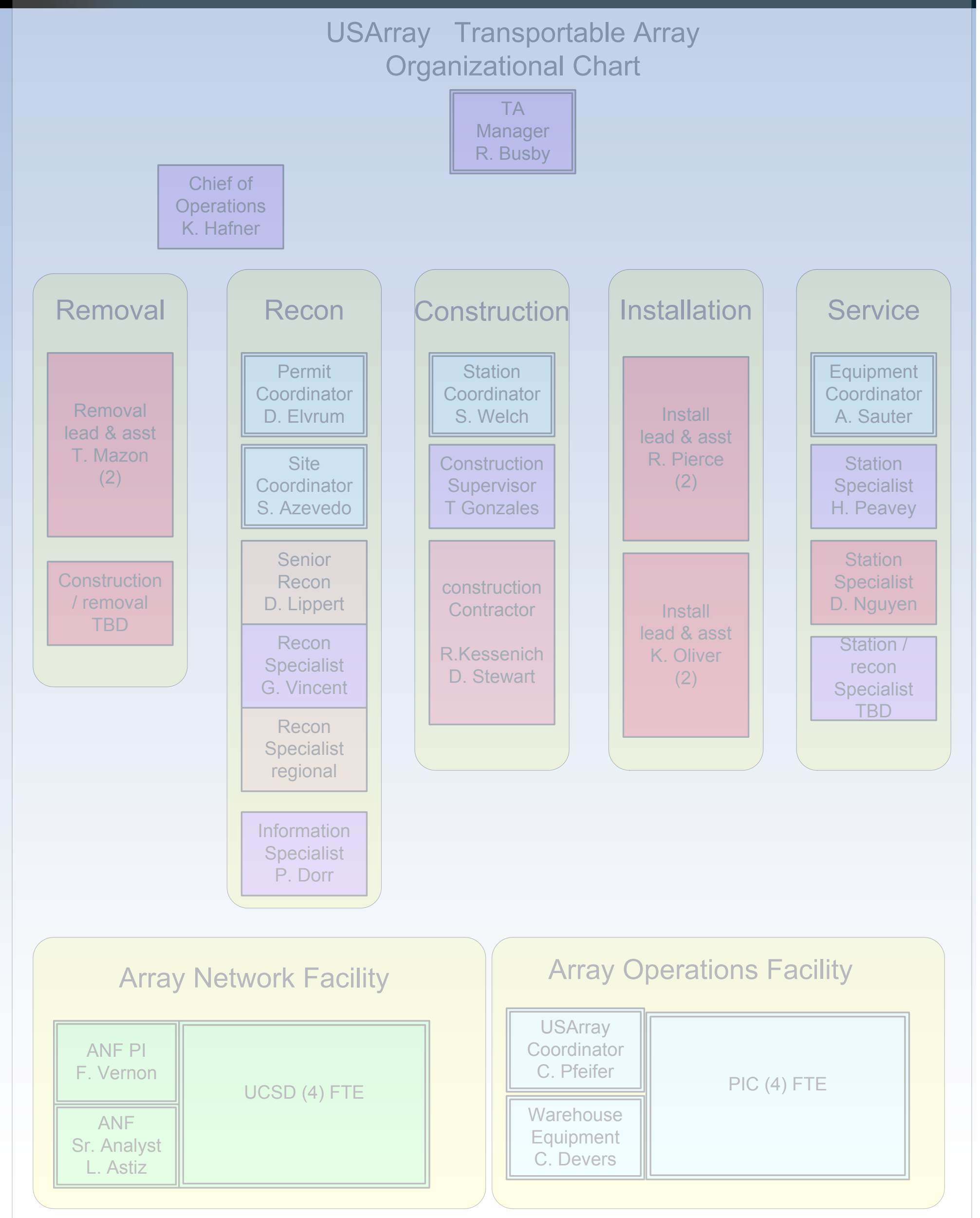
Construction: 4
- **1 office**
- **3 field crew**

Installation: 4
- **4 field crew**

Service: 4
- **4 field crew**

Removal: 3
- **3 field crew**

Support Facilities: 12
- **AOF NM Tech 6**
- **ANF UCSD 6**



Construction





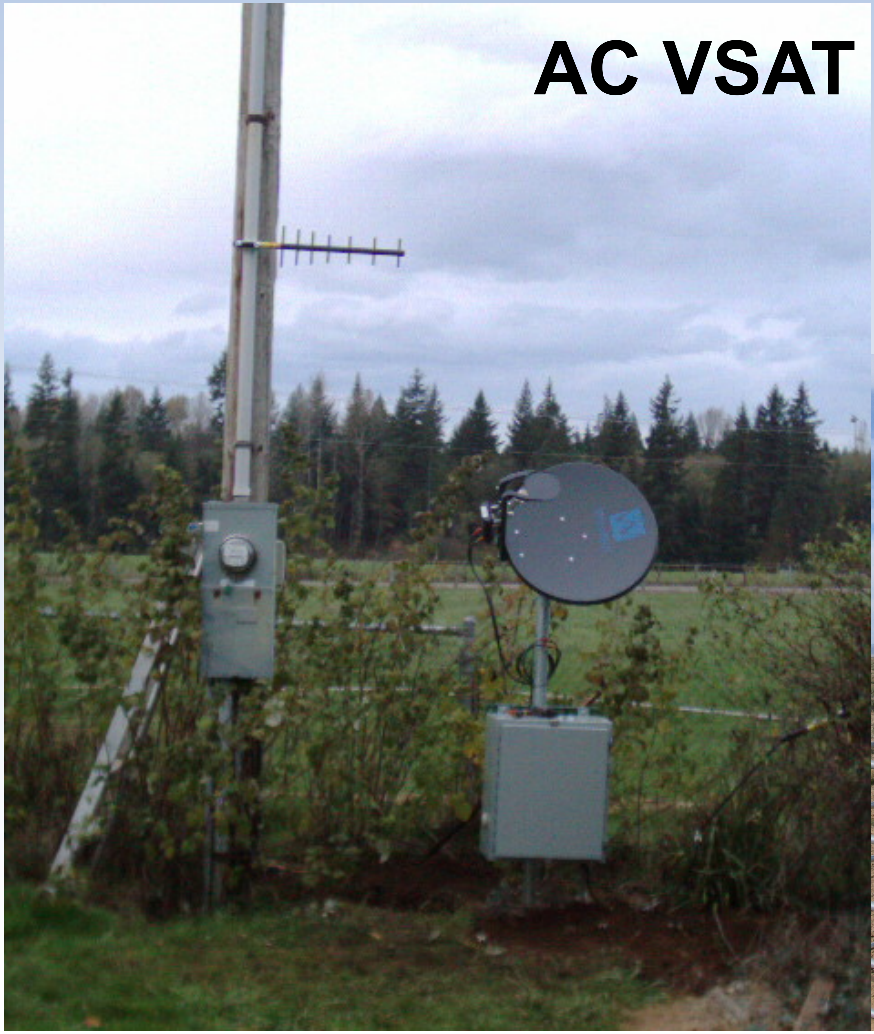

… No Student Involvement

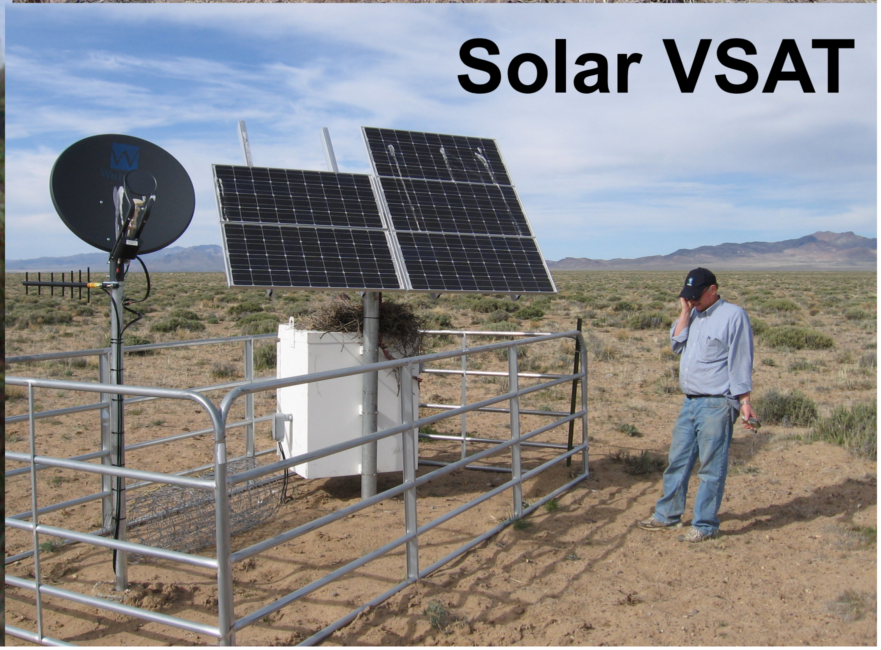
Onsite 3 hours

Construction Complete

Modularity in Communications

71% Cellular
20% AC VSAT
8% Solar VSAT



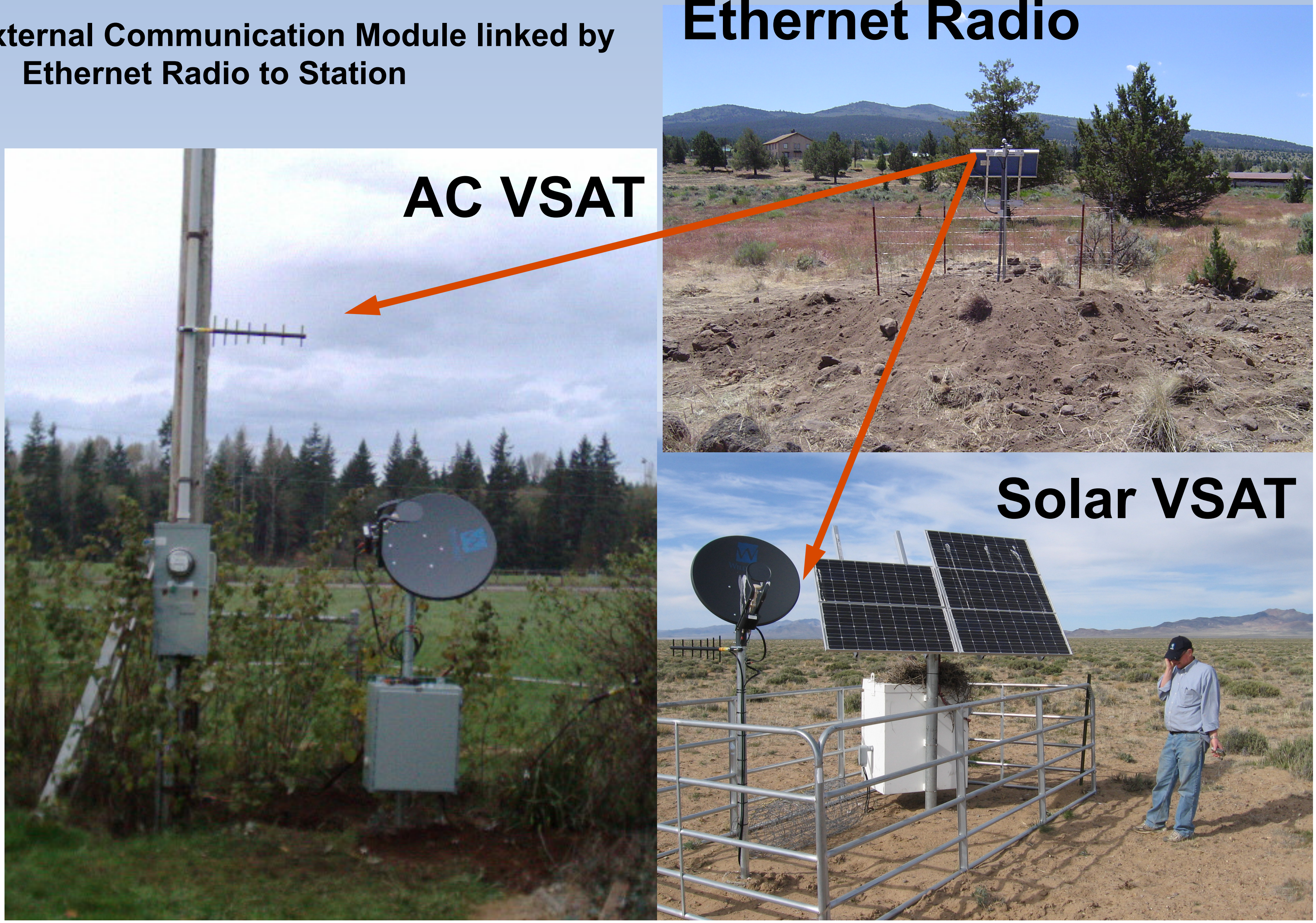


Communication Variety

- Cell modems ---71%
  - 191 Verizon CDMA ($720/year)
  - 20 Alltel CDMA ($830/yr)
  - 57 AT&T GSM ($850/year)
- VSAT systems -- 28%
  - 103 Wild Blue Enterprise ($1079/year)
  - ~20 of these Solar powered, 8 Cycled
  - Abandoned Hughes, SpaceNet
- Broadband providors
  - (4) DSL, (1) Cable, (2) WiFi
- Internet via Host --1%
  - Research Campus, schools, city (3)

Modularity in Communications

External Communication Module linked by Ethernet Radio to Station



Cell Service Providors

Verizon

- CDMA 1X, EVDO rev a.
- 70/70 150/450 kbps respectively
- Static IP address
- Excellent account management
- 5 Gbyte/mo, continuous connection
- Roaming issue at international borders

AT&T

- GSM, EDGE, HSDPA
- 40/40 kbps
- Static IP address, SIM cards
- Complex account setup, create APN
- 5 Gbyte/mo, continuous connection
- Roaming issue depending on carrier agreement

Cell Modem Choices

Airlink Raven

- Serial Interface
- Grounding issues
- unsealed
- PPP connection to Q330 serial 1.
- PPP connection to network.
- Modem manages NAT, simplifies Q330 config.
- 2 Watts, timed watchdogs

Sierrawireless Raven X

- Ethernet Interface
- Signals transformer coupled
- unsealed
- Single address forwarding
- DHCP server
- 2.5 Watts, less inclined to get stuck.
- 3G protocols

Proxicast, Digi, Multitech, etc

Cell Modem Operation

Airlink, now Sierra Wireless ---Support software

- Wireless ACE configuration tool
  - Free
  - Single modem action
- ACENET bulk device management application
  - Expensive
  - Does up to 250 at once
- Both gather diagnostics
- Both download configurations

- ACENET uploads firmware

Cell Modem Operation

AceNet - [TA_VZW_jan2008.acn]

File Edit View Modem Window Tools Help

Name	Address	Modem Type	RSSI	Result	Date and Time	Phone Number	Modem EID/IMEI	ALEOS Software Version	Modem Soft
TA_I14A	166.161.119.226	Raven CDMA	-86	Success	11/15/2007 05:59:08	7742832041	F60E05A0	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_L20A	166.241.252.250	Raven X EV...	-98	Success	11/15/2007 06:00:59	5085051720	603CD6AD	V4221_3.1.3.059 Mar 29 2007	p2005700,50
TA_I03A	166.159.115.121	Raven CDMA	-87	Failure: Can't reach m...	11/15/2007 06:20:15	3397888025	09900956799	C3210_3.1.5.064 Oct 17 2007	R2_1_0_6SE
TA_R19A	166.161.112.9	Raven CDMA	-91	Success	09/16/2007 15:17:13	3397888624	F60D8AC1	WCR200603B05 Apr 17 2006	S/W VER: V
TA_M20A	166.139.17.237	Raven CDMA	-82	Success	11/15/2007 05:43:27	3397887644	09900911511	C3210_3.1.5.064 Oct 17 2007	R2_1_0_6SE
TA_Z18A	166.161.106.228	Raven CDMA	-78	Success	11/15/2007 05:48:34	3397888413	F60D1A53	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_G15A	166.161.98.231	Raven CDMA	-78	Success	11/15/2007 06:11:29	3397888467	F60D0F78	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_X15A	166.139.136.17	Raven CDMA	-91	Success	11/15/2007 06:34:11	3397887725	09900911718	C3210_3.1.5.064 Oct 17 2007	R2_1_0_6SE
TA_T18A	166.161.112.28	Raven CDMA	-90	Success	11/15/2007 05:58:03	3397888628	F60D78CD	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_319A	166.159.101.7	Raven CDMA	-75	Success	11/15/2007 05:54:58	3397888288	F60CC0DF	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_J17A	166.161.119.253	Raven CDMA	-84	Success	11/15/2007 06:00:59	3397882221	F60E389E	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
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TA_H11A	70.203.103.133	Raven CDMA	-80	Failure: Can't reach m...	11/15/2007 06:14:41	3397888631	F60D89D5	WCR200603B05 Apr 17 2006	S/W VER: V
TA_S13A	166.161.113.25	Raven CDMA	-105	Success	11/15/2007 06:10:09	5082089793	F60DB3AE	WCR200603B05 Apr 17 2006	S/W VER: V
TA_H04A	166.159.115.115	Raven CDMA	-82	Success	11/15/2007 06:04:11	3397888018	09900956792	C3210_3.1.5.064 Oct 17 2007	R2_1_0_6SE
TA_M14A	166.161.113.26	Raven CDMA	-83	Success	11/15/2007 05:54:11	5084680436	F60DAEF7	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_C12B	166.161.119.225	Raven CDMA	-103	Success	11/15/2007 06:01:34	7742832040	F60E2956	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_X14A	166.159.101.8	Raven CDMA	-101	Success	11/15/2007 06:13:04	3397888289	F60CC13B	WCR200603B05 Apr 17 2006	S/W VER: V
TA_117A	166.139.17.240	Raven CDMA	-81	Success	07/23/2004 20:48:39	3397887647	09900911702	C3210_3.1.5.064 Oct 17 2007	R2_1_0_6SE
TA_Q18A	166.161.113.21	Raven CDMA	-89	Success	11/15/2007 05:54:11	5082088781	F60DB3C6	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_I17A	166.161.119.247	Raven CDMA	-86	Success	11/15/2007 05:55:18	3397882215	F60E38AE	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_N10A	166.159.101.10	Raven CDMA	-92	Success	11/15/2007 06:16:02	3397888291	F60CC6A8	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_T14A	166.161.113.30	Raven CDMA	-77	Success	11/15/2007 06:14:19	5084680656	F60DB3AA	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_B15A	166.161.119.250	Raven CDMA	-93	Success	11/15/2007 05:55:19	3397882218	F60E38B1	C3211_3.1.5.064 Oct 17 2007	S/W VER: V
TA_D08A	166.161.106.237	Raven CDMA	-80	Success	11/15/2007 05:57:49	3397888422	F60D1A40	WCR200603B05 Apr 17 2006	S/W VER: V

VSAT Operation

Wild Blue

Ka band spot beams

Small (0.6m) dish size, eases transport and wind load

modems are single DC level (30VDC)

Can be provisioned at remote site without contacting VSAT Network Operations Center.

Shared Master station-data delivered via internet

Online technical portal for service history

Provisioning Details -

2 year service agreement, annual fee $1070/yr

Enterprise level: static IP, 5Gbyte/mo upload

Throughput rarely surpasses 50kbps.

Communication Power Modules

- AC based system for housing Wild Blue VSAT, Cable Modem or DSL modem
  - Must be located within line of sight to vault and near power. Prefer pole mounts near out buildings.
  - Has heater / cooling fan for electronics.
- Solar Powered module designed for 30W load.
  - Commercial design is Robust, Large and expensive; 300-800W PV, 600-900AH battery
  - Sometimes duty cycled: 2 hour on / 6 hour off
  - Simpler systems do not use active heating / cooling.

VSAT Operation

Station Installation tricks

- Power cycle system 5 minutes once a day
- Compact Router handles DHCP/port forwarding
- Rotate arm to reduce snowbanks

Equipment Refinements

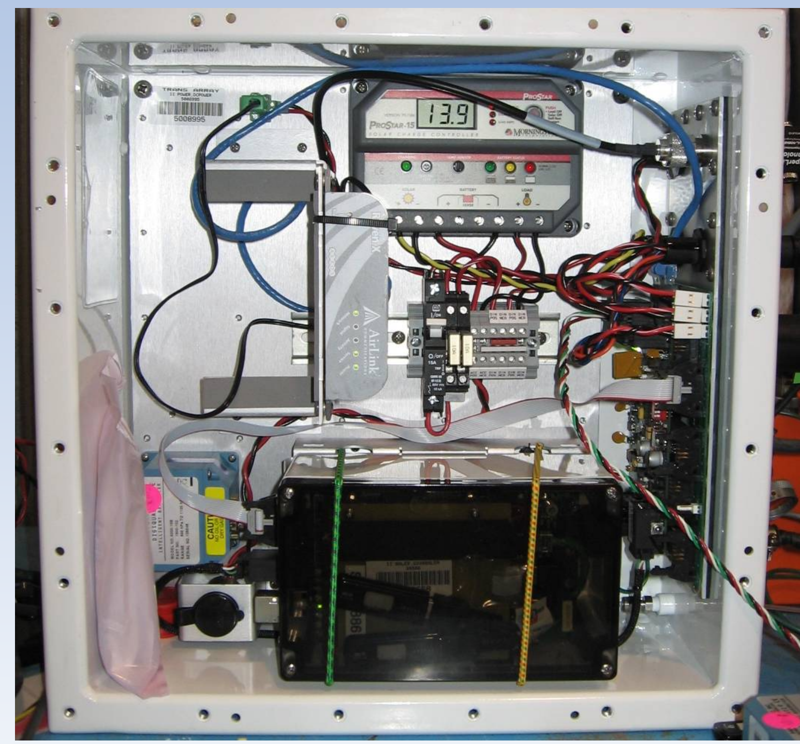
- Vault interface Enclosure
  - Protect equipment from humidity, increase reliability of comms equipment
  - Standardize connections
- Cell modem replacements as networks upgrade
- Baler44 phased into stations, replacing Baler14
- Add meteorlogical measurements

earthscope

Equipment Improvements

Vault Interface Enclosure (VIE, Ibox)

- 16x16x8” Enclosure, hangs inside vault.
    - IP68, 0.5” Lexan Clear lid, bulletproof!
- Q330 interfaces converted to industrial standard connections;
    - IDC flat ribbon, RJ45.
- Custom power regulation circuit
    - Faultfree switchover to alkaline backup battery
    - Signalling via existing data channels for power SOH
    - Sensor power regulation, filtered power for Q330 and Baler
    - High efficiency regulation, load shedding/mode switch on backup power
    - Independent fault isolation of powered devices.
- Station Integration
    - Integration of new Baler44CT, Environmental sensor
    - Simplified Data collection via new Baler44
    - Reset power cycle for comms equipment
    - Remotely controlled power interrupt for sensor
    - Monitor and signalling of pump operation
- Protected housing for electronics and auxiliary equipment-allowing better flexibility and increased reliability.
    - Allows economical packaging choices for small ancillary devices
    - Protects commercial modems, charge controllers and circuit boards.
    - Simplifies troubleshooting, acts as a field replacable unit.
- Uniform cabling for installation
    - MS style connectors, molded termination
- Commercial production in large runs; Enclosure, cables, PCB, testing, etc
    - Custom cable fabrication, custom metal, factory assembly and testing.



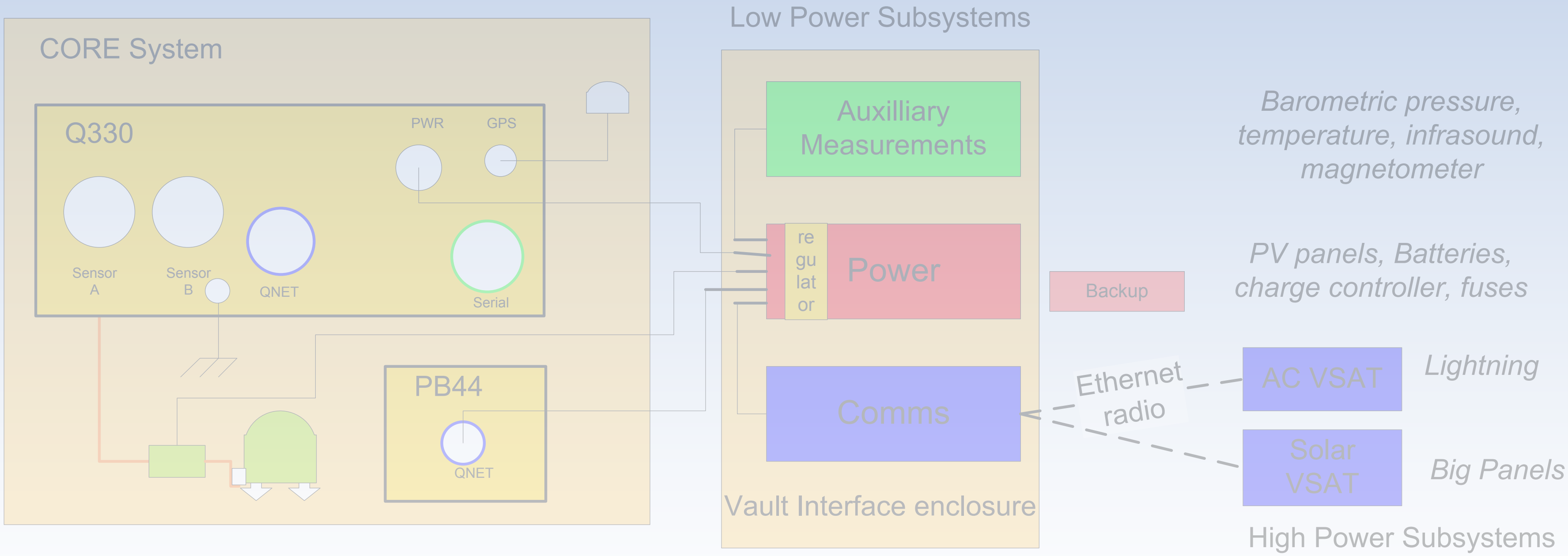
the IRIS CONSORTIUM

SOLARCRAFT POWER PRODUCTS

QUANTERRA, INC.

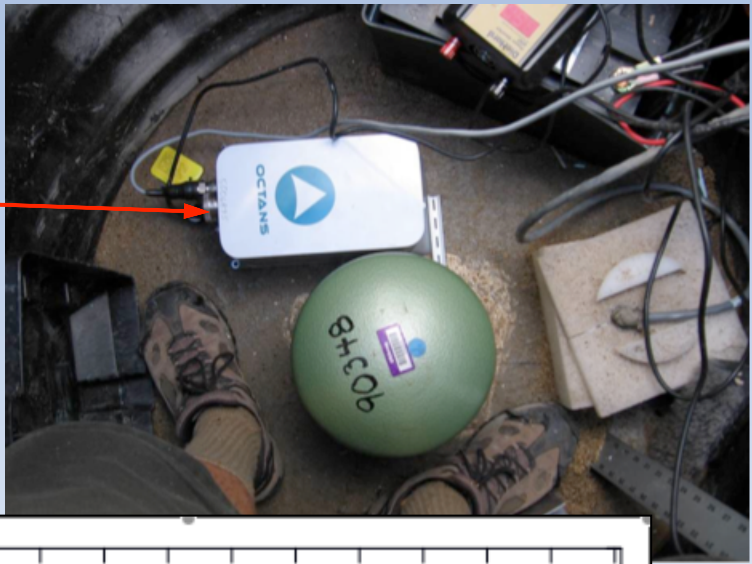
Station Regulator

- Independent regulation / distribution
- Power control of comms device
- Switching of backup power

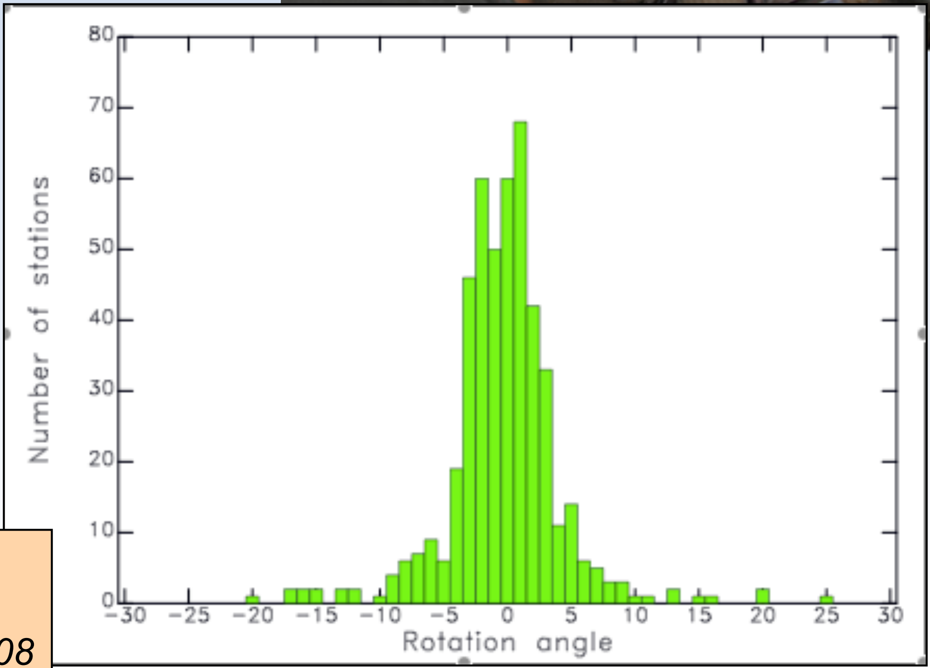


Procedures: Orientation

- **Direct measurement of orientation of all stations**
  - Using fiber-optic gyroscope IXSEA Octans IV, *Nonmagnetic orientation accurate to < 0.2 degrees*
  - Used at all new station installations
  - Used when existing TA stations are removed



- **Validation of empirical orientation determinations**
  - Empirical estimates from surface and mantle wave polarization techniques



TA station orientation, relative to north, from empirical analysis
Results from Ekström and Busby, SRL, 2008

Orientation

Ekstrom measurements are found and described at:

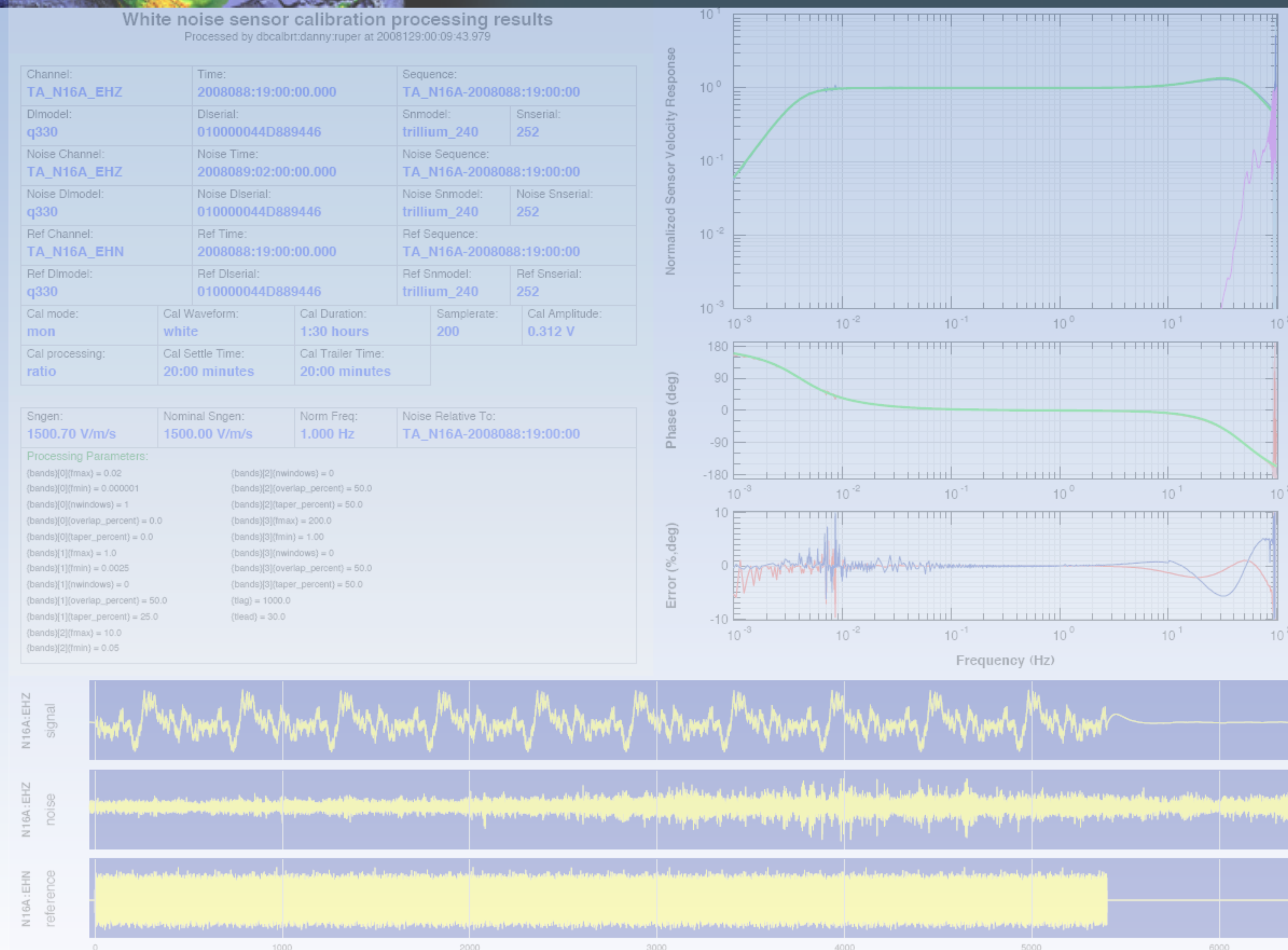
http://www.ldeo.columbia.edu/~ekstrom/Projects/USARRAY/POLARIZATION

Network	# Obs.	0°–3°	4°–6°	7°–9°	10°–90°
All	467	75.4% (352)	14.1% (66)	6.0% (28)	4.5% (21)
TA	358	79.6% (285)	12.8% (46)	4.8% (17)	2.8% (10)
US	43	53.5% (23)	23.3% (10)	7.0% (3)	16.3% (7)
CI	41	56.1% (23)	17.1% (7)	17.1% (7)	9.8% (4)
BK	20	90.0% (18)	10.0% (2)	0.0% (0)	0.0% (0)
Other[a]	5	60.0% (3)	20.0% (1)	20.0% (0)	0.0% (0)

[a] These five stations are from the AZ and NN networks.

Procedures: Calibration

- Automated process for command, capture, and analysis of cal signals
- Analysis of calibration signals to verify amplitude and phase response
- Will apply to all TA stations at beginning and end of deployment
- Network-wide calibration for sensor statistics



Results from BRTT Antelope software

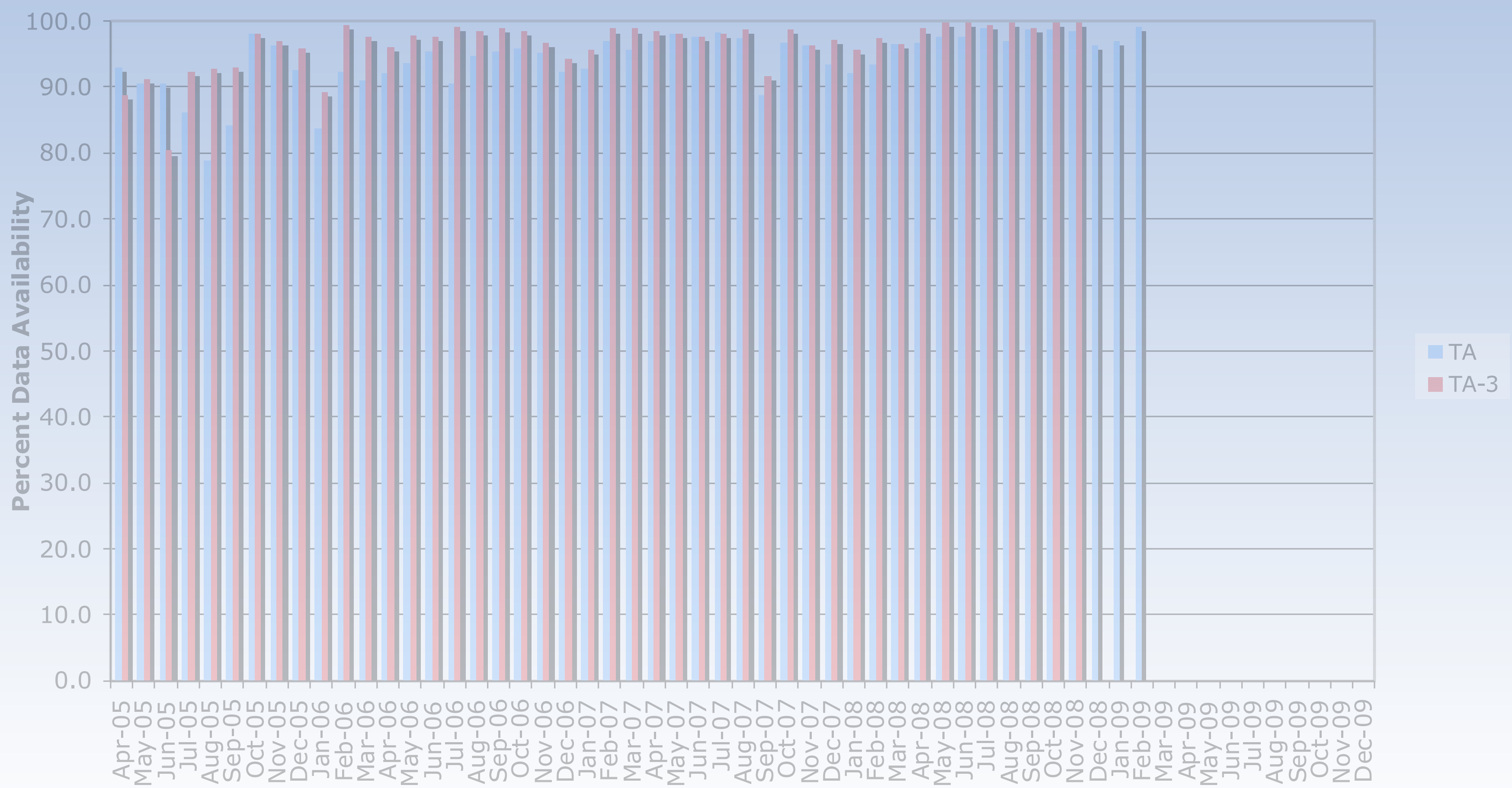
Performance Metrics

- Metrics must have meaningful relationship to science
- Exploit measures already being computed - i.e., data mining from ANF and DMC databases

Integrity
Accuracy
Quality
Performance

Metric	Description	Who
Mass position	Percent of time offscale (Bob B. will provide scale). Requires scan of mass position channels.	ANF
Mass Recenter	Number of mass recenters & time between recenters	ANF
Clock quality	Statistics of clock quality LCQ channel. Requires scan of LCQ time series.	ANF
Clock error	Statistics for times when clock error exceeds 1% of sample interval. Requires scan of LCE channels.	ANF
Latency	From data tracked at ANF	ANF
PDF by sensor type	PDFs aggregated by sensor type (Streckeisen, Guralp, Trillium). PDFs and mode vs frequency.	DMC
Mode calcs for large events	Provides low frequency calibration	ANF
Tidal amplitudes	Provides low frequency calibration. Likely only reliable for stations away from coast (e.g., won't use ocean loading calculations).	DMC
Calibration of network	Calibration results for entire network, with calibrations performed over a relatively short time period (e.g., one week).	ANF
Availability	Results for monthly, 3-month, and final data availability. Final data availability derived from stations for which we have completed post-station-removal baler backfill.	DMC
Gaps: gaps / day	Perhaps a histogram of gaps/station-day (i.e., x axis is # of gaps/station day; y axis is # of station days). This histogram would then (presumably) show that most station days have zero gaps, that the large majority of station days have very few gaps, and there are some outlier station days with many gaps. (will compare DMC and ANF results)	DMC/ ANF
Gaps: # days with no gaps	This metric could be addressed by the histogram described above. (will compare DMC and ANF results)	DMC/ ANF
Detection threshold	Perhaps based on magnitude? Consider variation of this, but based on event detection/formation statistics.	ANF
Event coherency	Measure coherency from teleseisms & regional ? events across the array for body & surface waves	ANF
Detections/station	Statistics on station detections & use DMC statistics to compare to other networks (quack)	ANF/ DMC

Data Return - TA



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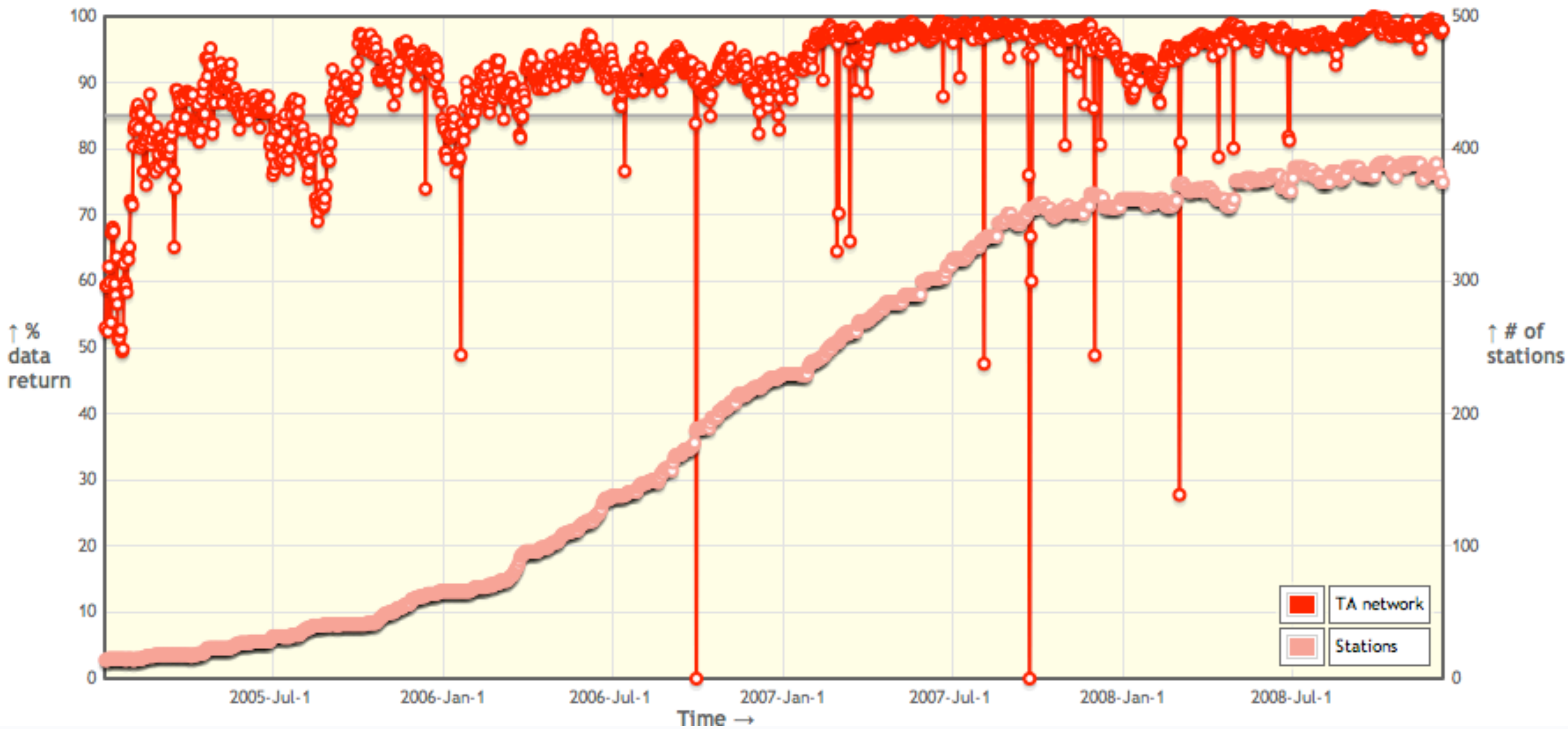
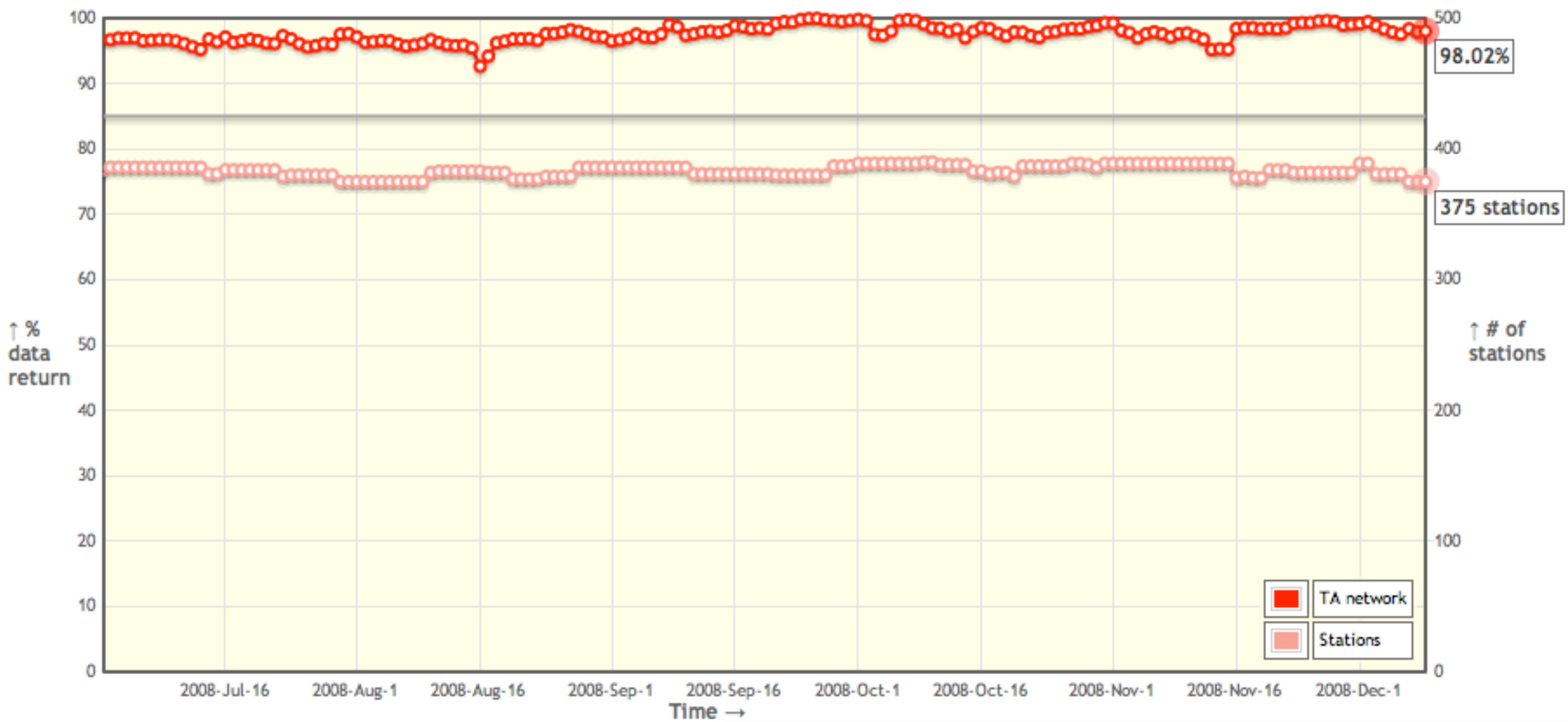
Status: RT Performance

TA performance 2005 01 - 2008 12



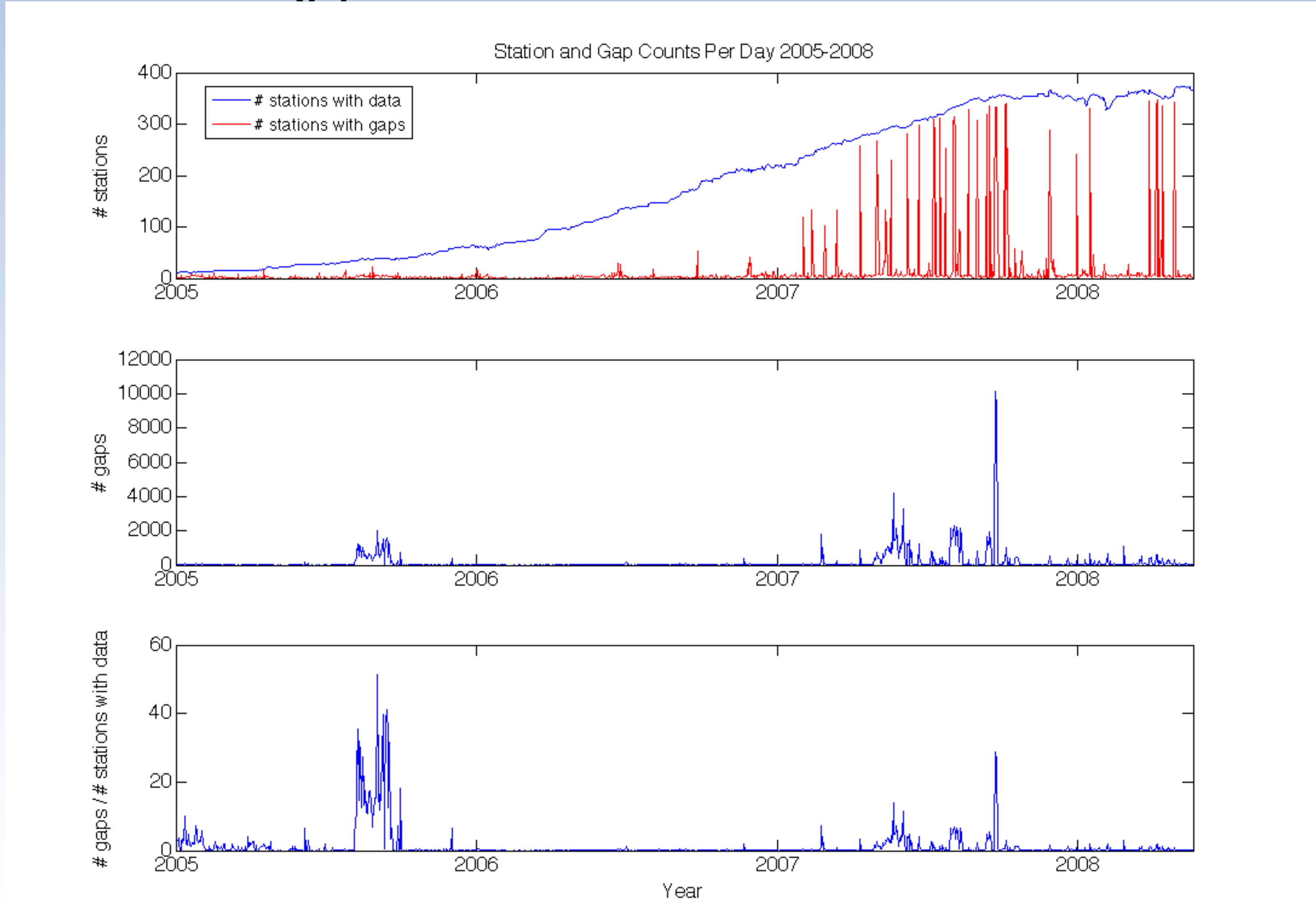
Status: RT Performance

TA performance 2008 07 - 2008 12

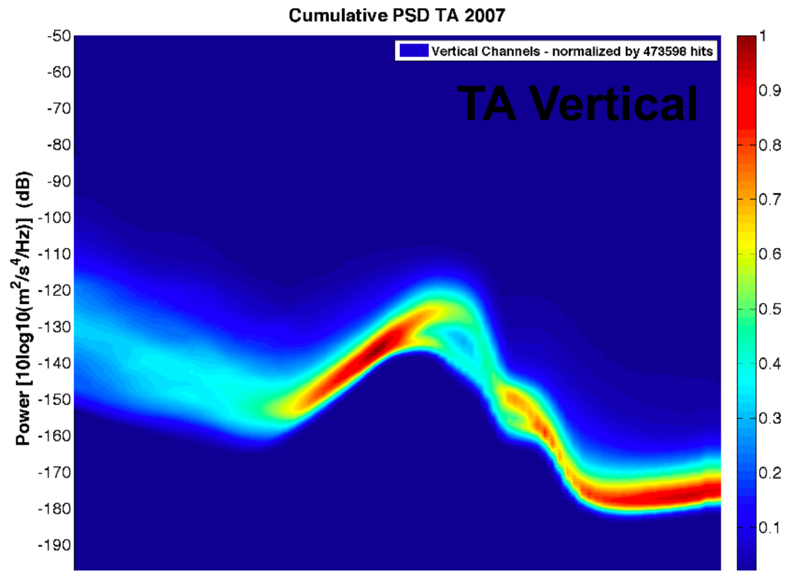


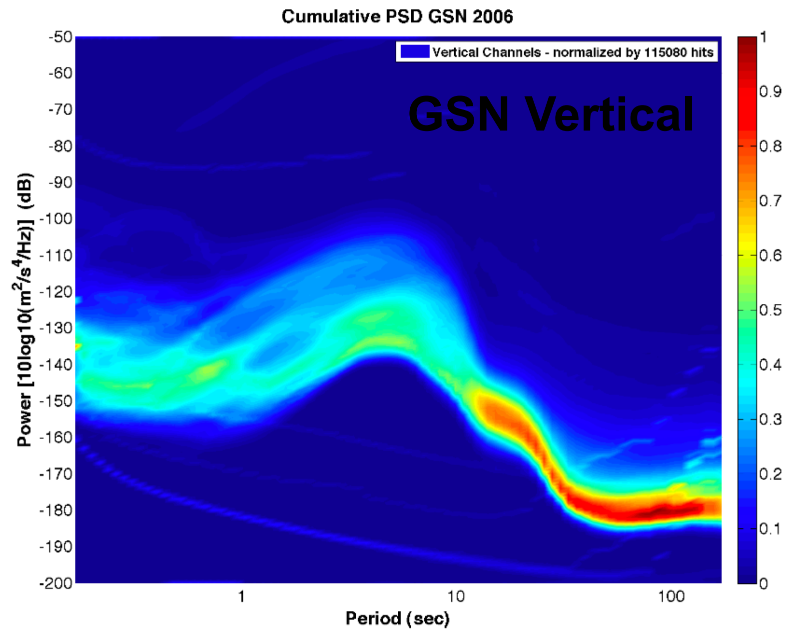
TA Gaps

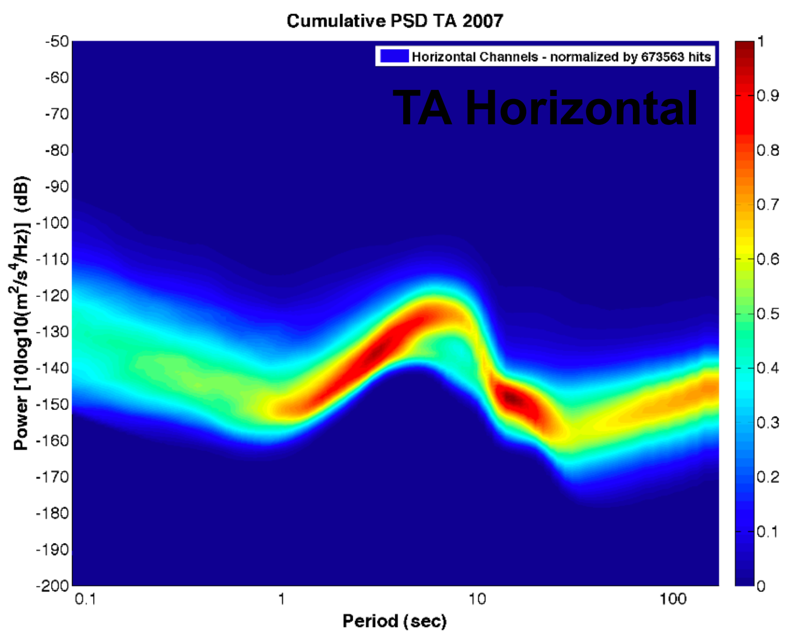
- **Examined data gaps as a function of time**
- **Examined cumulative gap statistics**

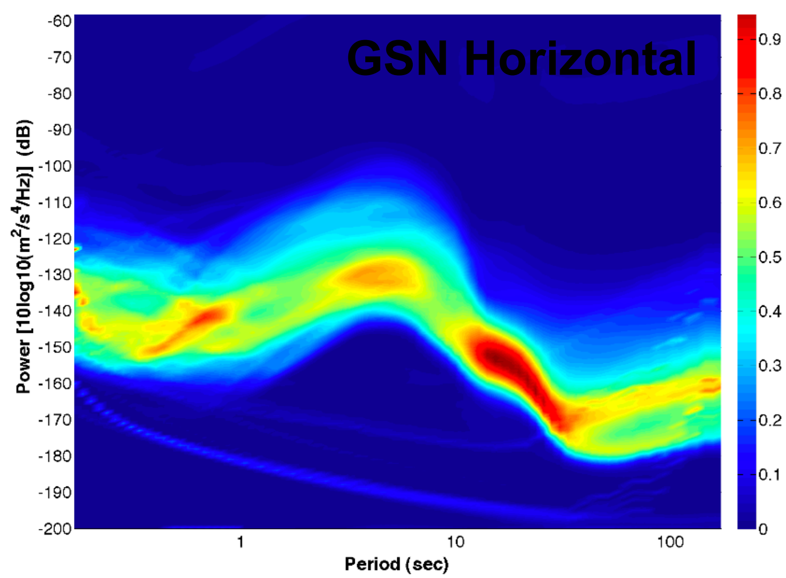


Power Density Functions





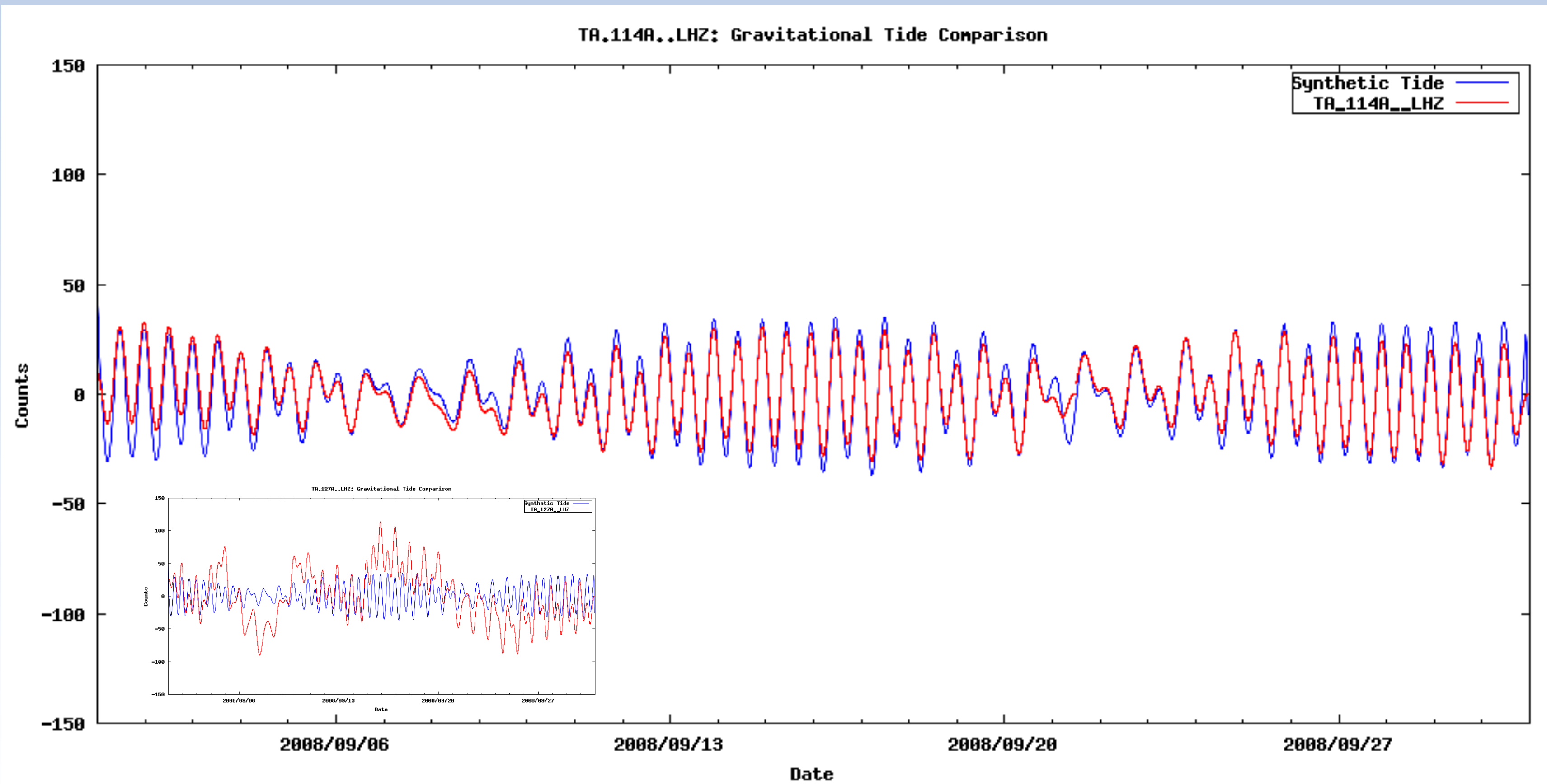




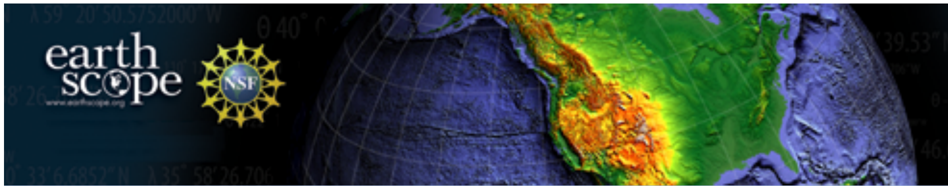
Tides

- All TA LHZ channels are compared to Earth tide synthetics
- The majority of stations have excellent fit to tides
- Small numbers of stations have transients
  - Mass re-centers
  - Temperature fluctuations

http://crunch.iris.washington.edu/synthetics/tide/



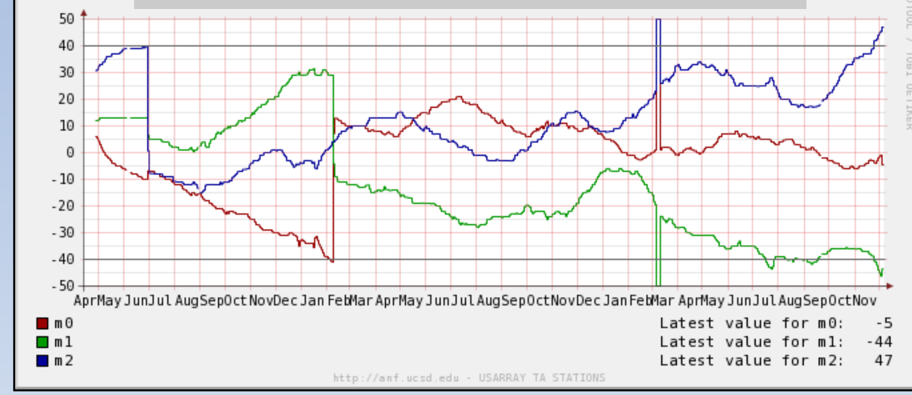
one month



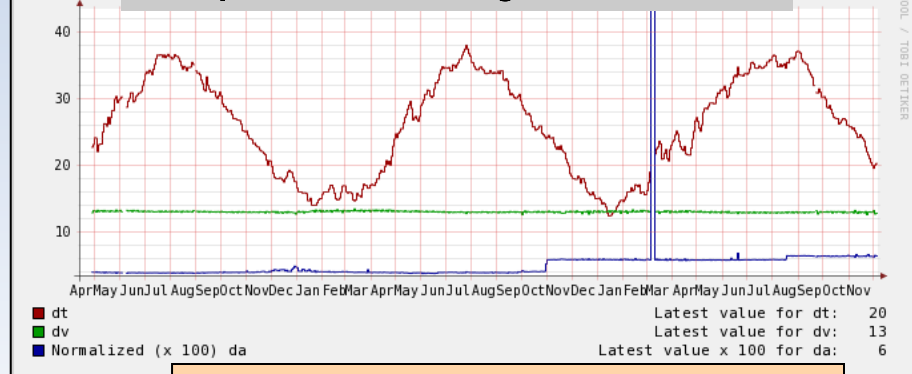
State of Health Review

- Real-time monitoring of SoH
  - Detect problems
  - Initiate corrective actions
- Station QC & SoH on the web
  - SoH channel displays for near-real-time and summary
  - Metrics for arbitrary time intervals

Mass position - life of station

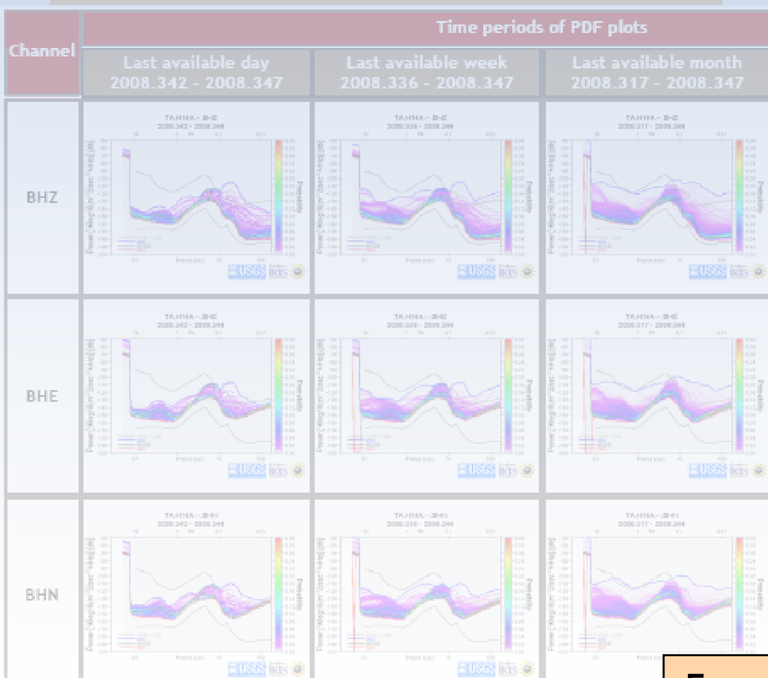


Temperature and voltage - life of station



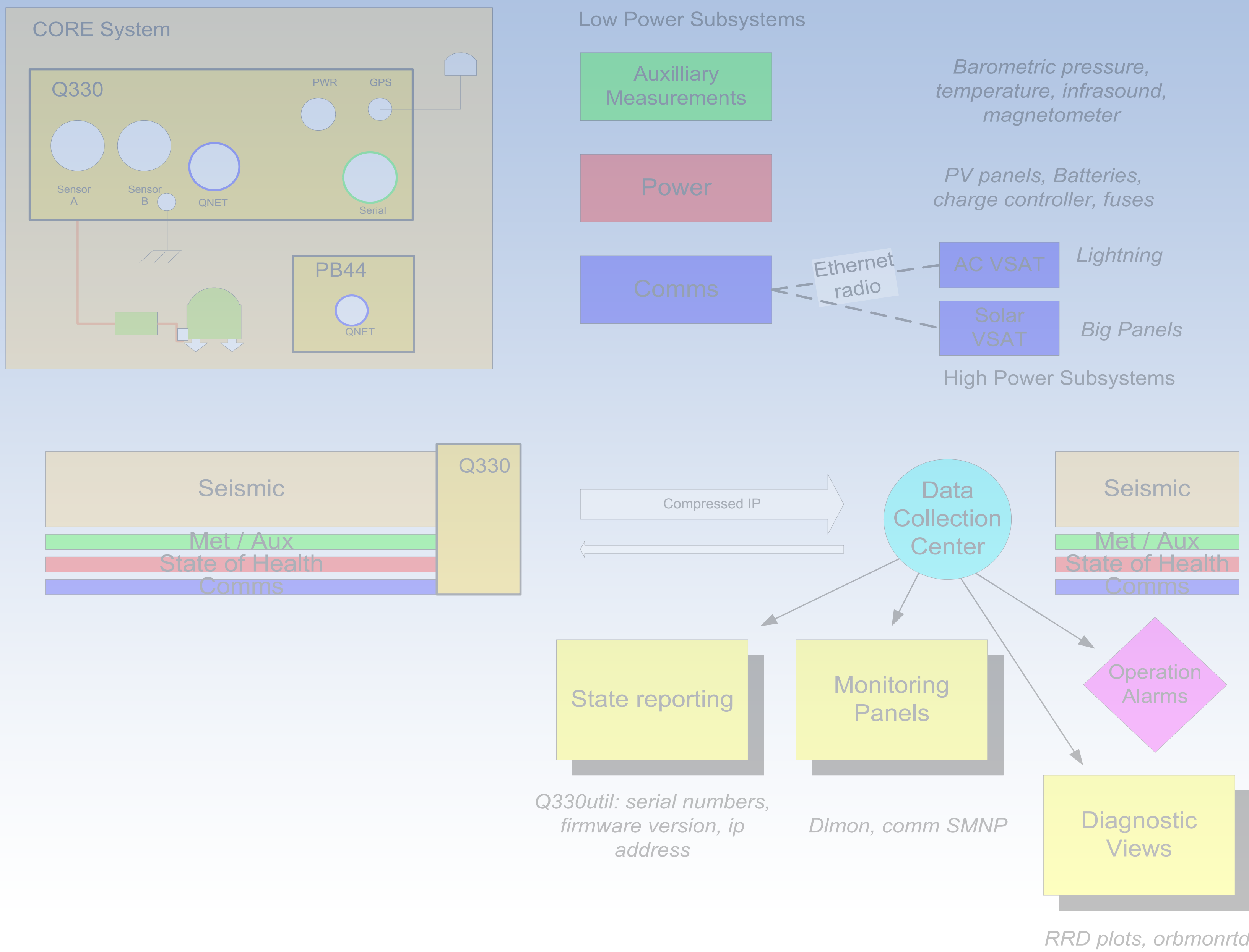
From ANF station status web pages

PDF noise analysis by station-channel



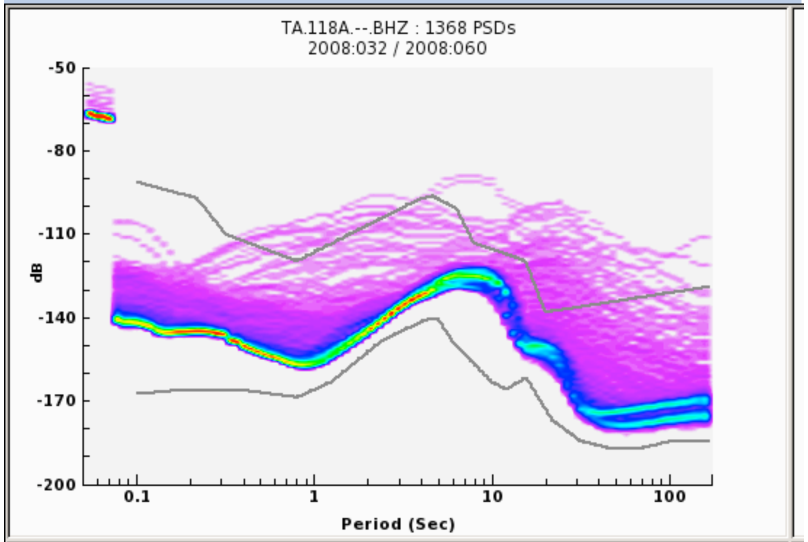
From DMC QUACK tool

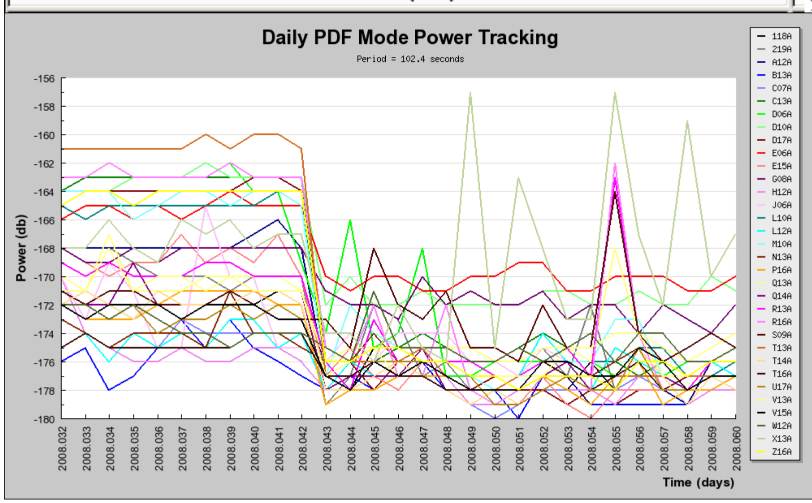
Design Principles Seismic Network

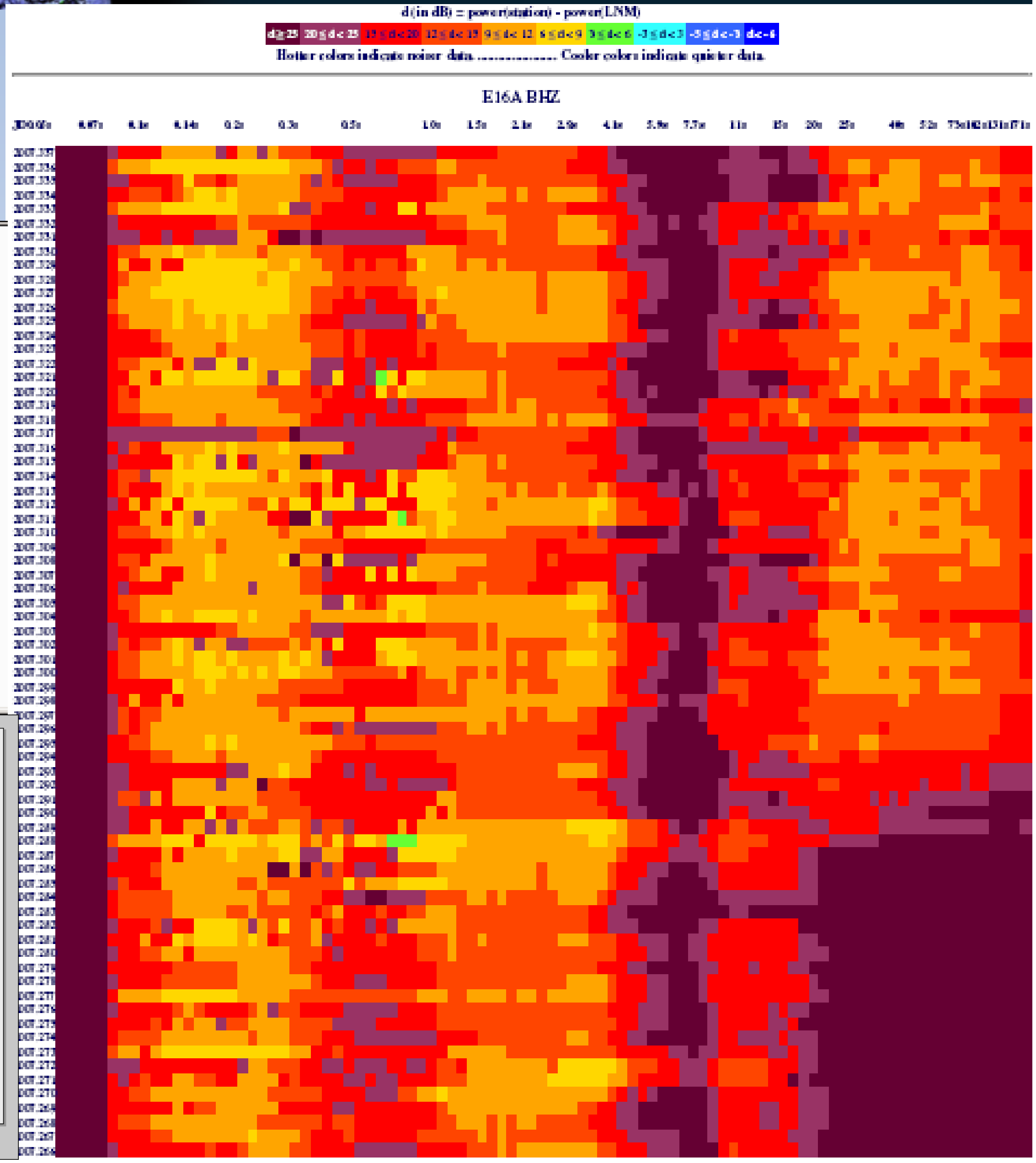


Diagnostic View: Discovery!

Guralp Vertical:
mass position vs noise







Key Insights from TA

Design:

- Core systems should be based on well established, well integrated equipment
- Subsystem performance should be verifiable
- Uniformity and Field Replacable Units are cost effective

Execution:

- Stable, repeatable process in all phases of operation.
- Station Design is blended from mature technology in seismic system but incorporates rapid modern innovations in communications and engineered elements.
- The scale encourages development and application of new "best practice" techniques for SoH monitoring, calibration, orientation, SOH visualization.
- Exchange of techniques, procedures and software to improve the science.

For more information

EarthScope	USArray	TA Array Network Facility
www.earthscope.org	***www.iris.edu/usarray***	***anf.ucsd.edu***

Acknowledgements

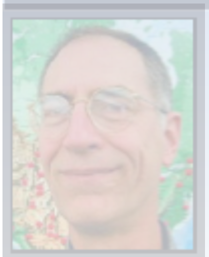
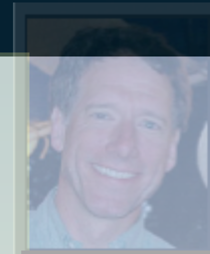
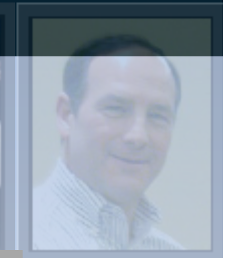
EarthScope is funded by the National Science Foundation and conducted in partnership with the US Geological Survey.

EarthScope is being constructed, operated, and maintained as a collaborative effort with UNAVCO, IRIS, and Stanford University, with contributions from NASA and several other national and international organizations.

Backups

TA Team



Management

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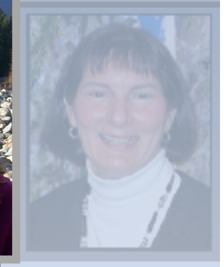
Katrin Hafner
Rob Woolley
Bob Woodward
Robin Morris
David Simpson
Perle Dorr
Cecelia Kelton

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Graylan Vincent
Joseph Goode
Patrick Hickey
Larry Jaksha

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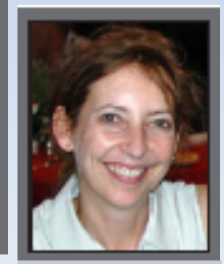
Rick Stout
Ron Kessenich
Mack Hardy
Steve Christman
Mike Flanagan

Installation
Bob Pierce
Ken Oliver
Jerry Hollinan
Elgin Hinson
Doug Ford

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Bruce Beaudoin
Elena Prusin
Mike Gorton
Derry Webb

ANF
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Geoff Davis
Brian Battistuz
Taimi Mulder

DMC
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Chad Trabant
Peggy Johnson
Gillian Sharer

Service
Howard Peavey
Doan Nguyen

Removal
Tom Mazon
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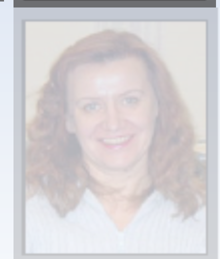
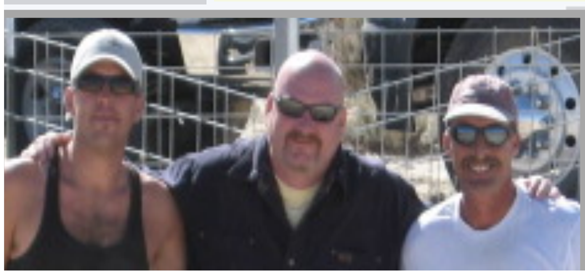
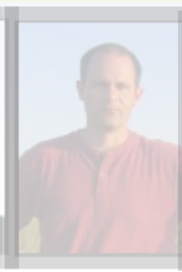
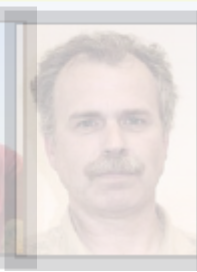
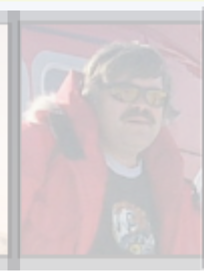
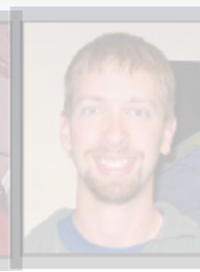
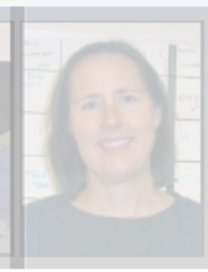
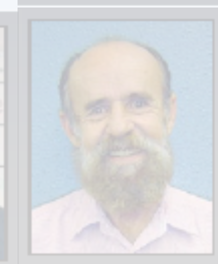



TA Management

EarthScope Management Team:

NSF project Director

A scientist and facility PI from;

Plate Boundary Observatory

SAFOD

USArray

IRIS Management

David Simpson - President / Principal Investigator of USArray

Board of Directors,

Standing Committees of GSN, PASSCAL, DMS

USArray Management

Bob Woodward - Director

USAAC- Advisory Committee

Transportable Array — **Robert Busby, Manager**

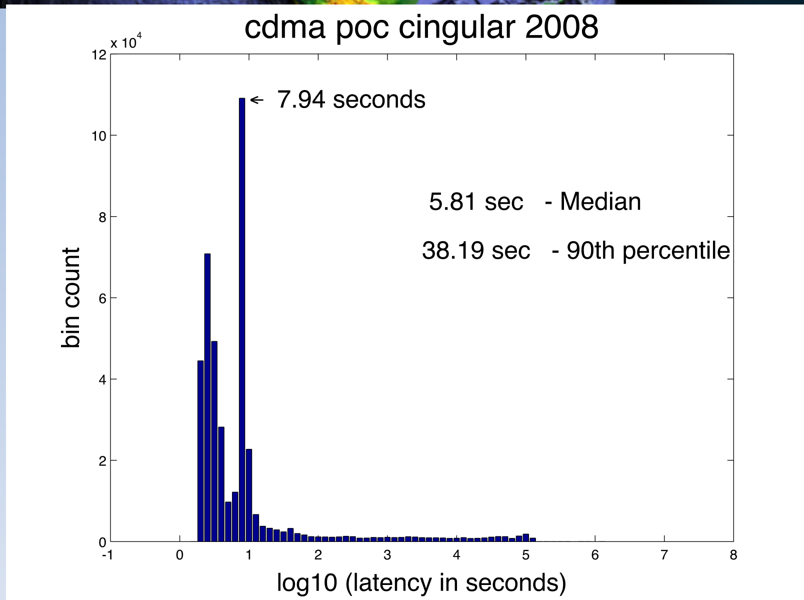
TA Working Group

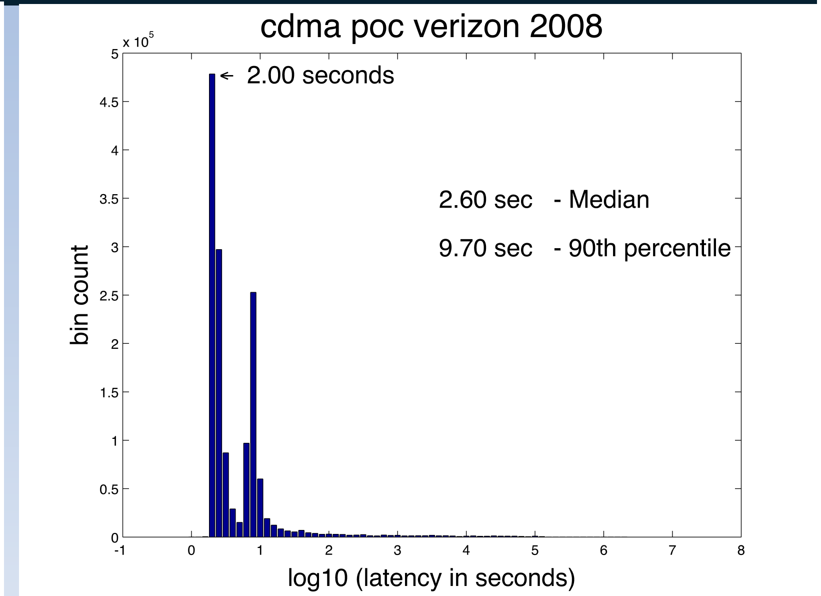
Flexible Array — Jim Fowler

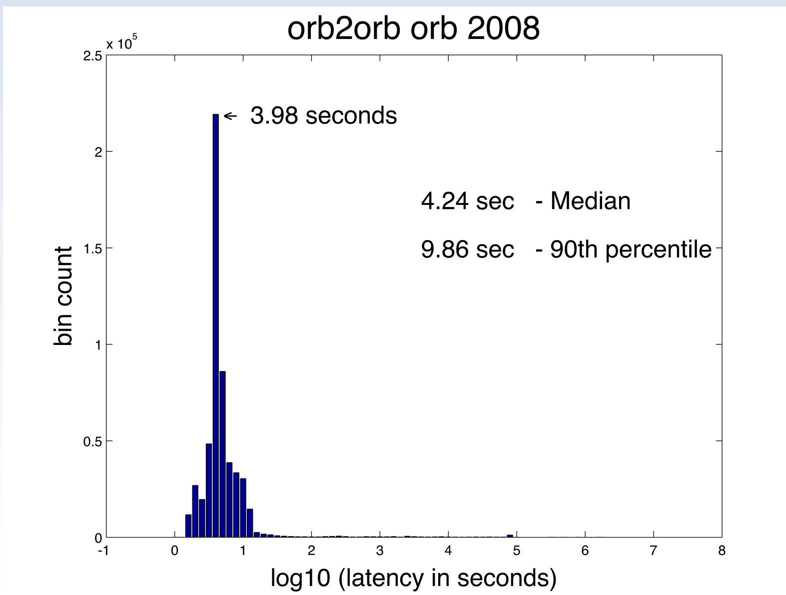
Reference Network — Rhett Butler

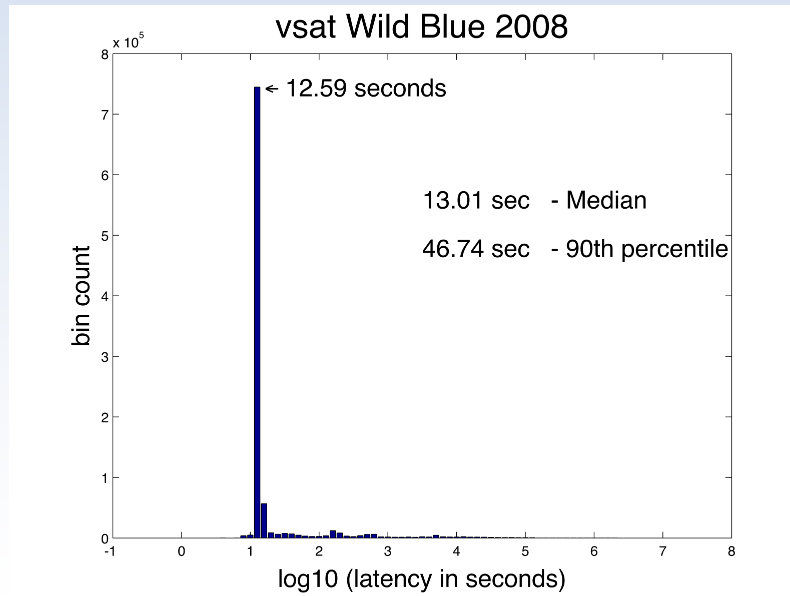
Magnetotelluric — Adam Schultz

Status: RT Latency



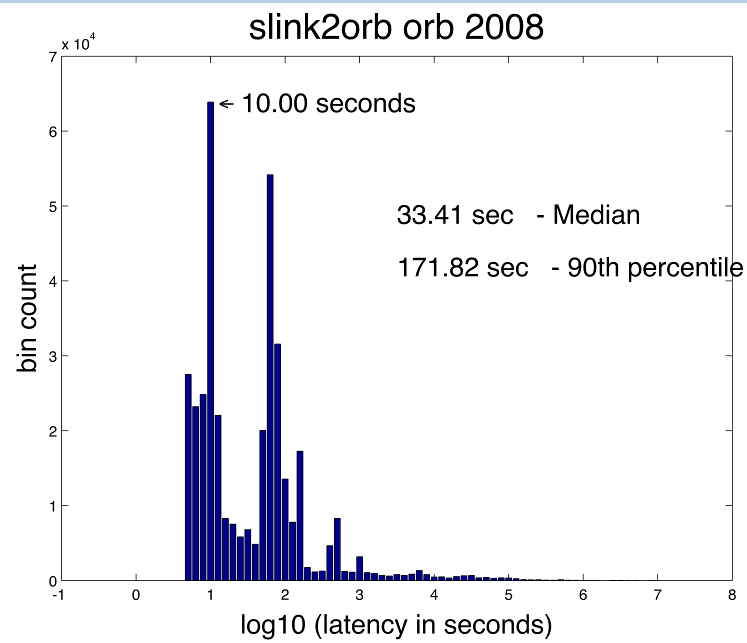


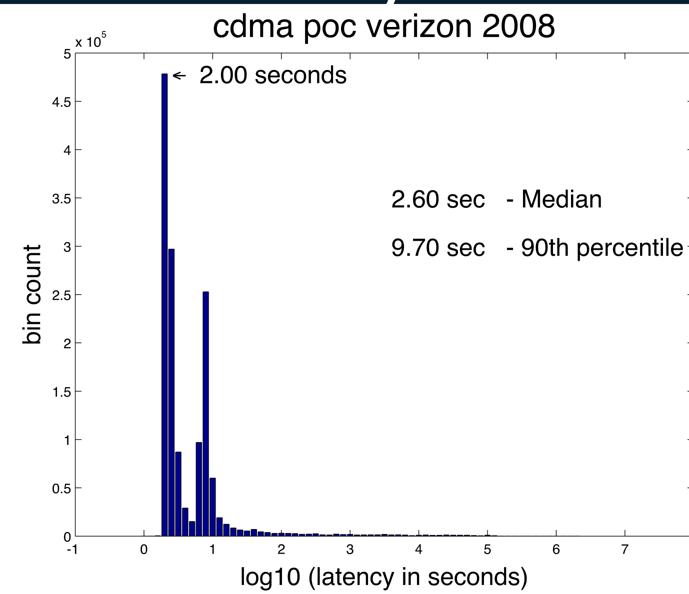


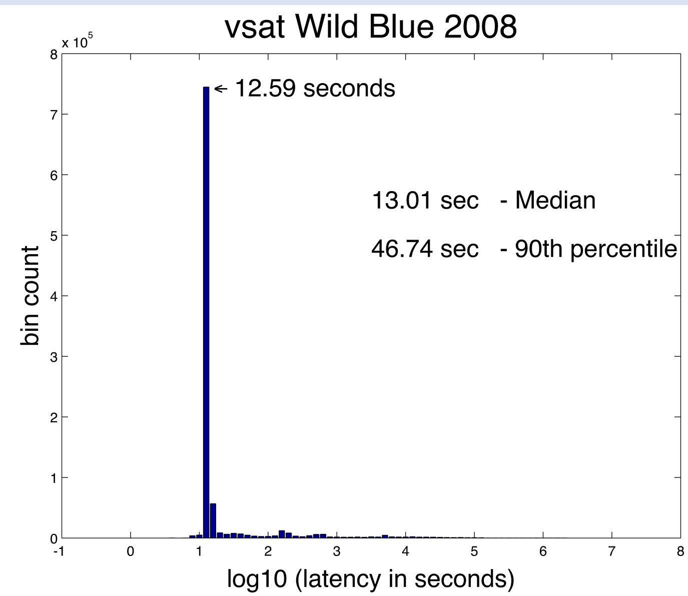


Status: Forwarding Latency

Typical of DMC feed to UW







Cell Modem Operation

Static IP

- Any application can reach modem
- Connection initiated either direction
- Reduces confusion between stations
- Costs $5/month
- Slightly harder to provision

Dynamic IP

- Need dynamic DNS host and/or Q330 POC receiver.
- Initial traffic must originate from station end
- Easy account setup, preferred by providors
- Difficult to troubleshoot
- Improved by Baler44 DHCP management

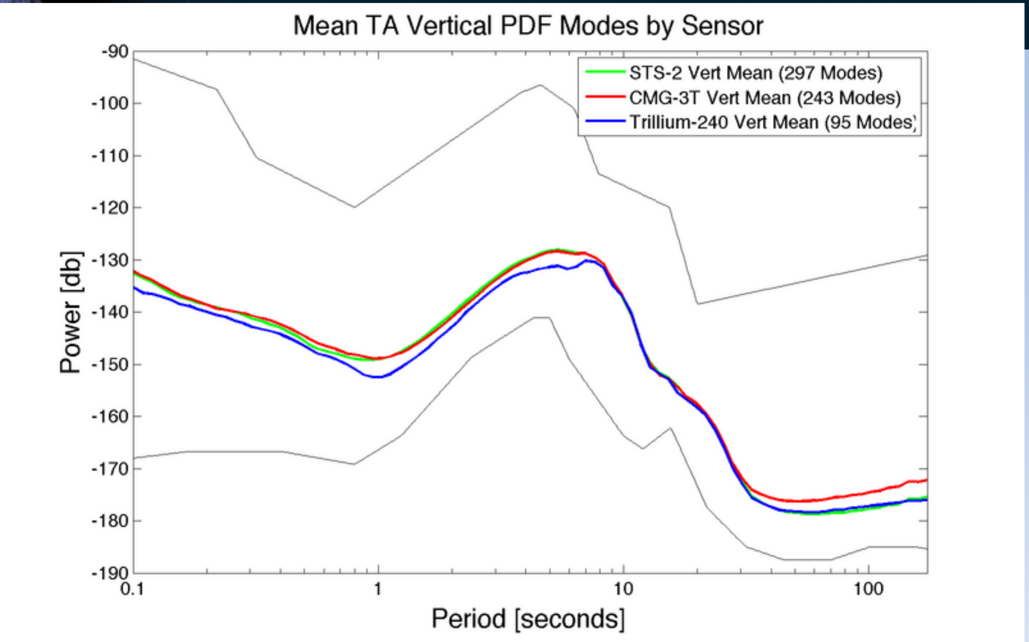
Quality Control Review

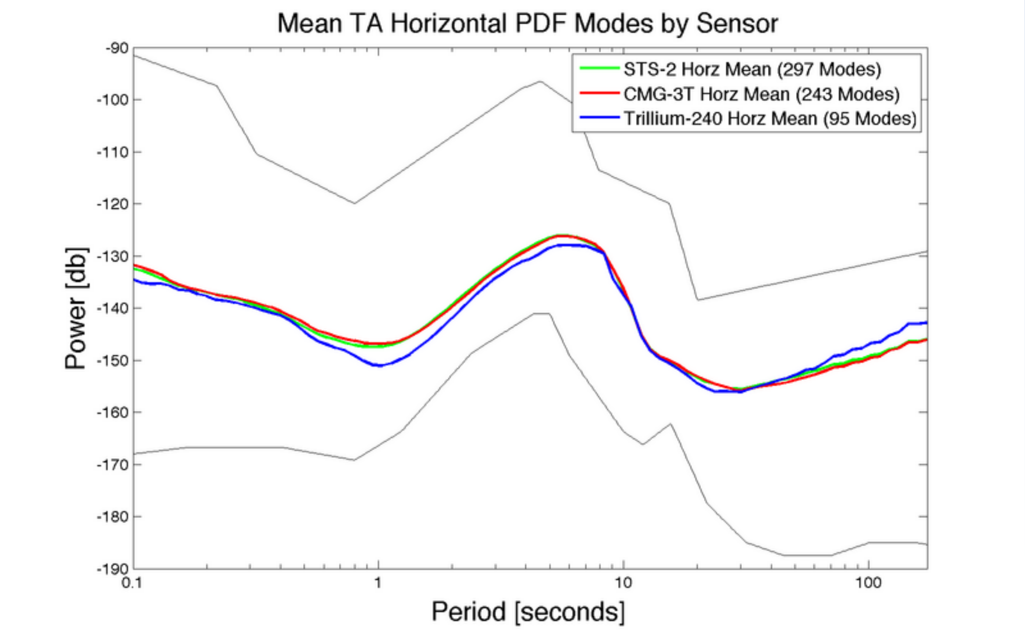
- Wide range of human and automated routine QC analysis

Review	Auto or Manual	TA	RefNet
Automated SoH channel monitoring	M	✓	
Phase reading and bulletin production	M	✓	
Visual scanning review of 100% of raw LH? data in 1 day windows	M	✓	✓
Visual scanning of low pass data in 2 day windows	M		
Review of PDFs	M	✓	✓
Synthetics seismogram comparison, using waveform fits from R. Herrmann MT code	M	✓	✓
STA/LTA plots	A	✓	
Daily RMS	A	✓	
Daily percent data availability	A	✓	
Gaps and overlaps per day (including max values)	A	✓	
Review fits to Earth tides in one month windows	A	✓	✓

Sensors

- Summary noise results aggregated by sensor type
- Negligible differences between sensor types

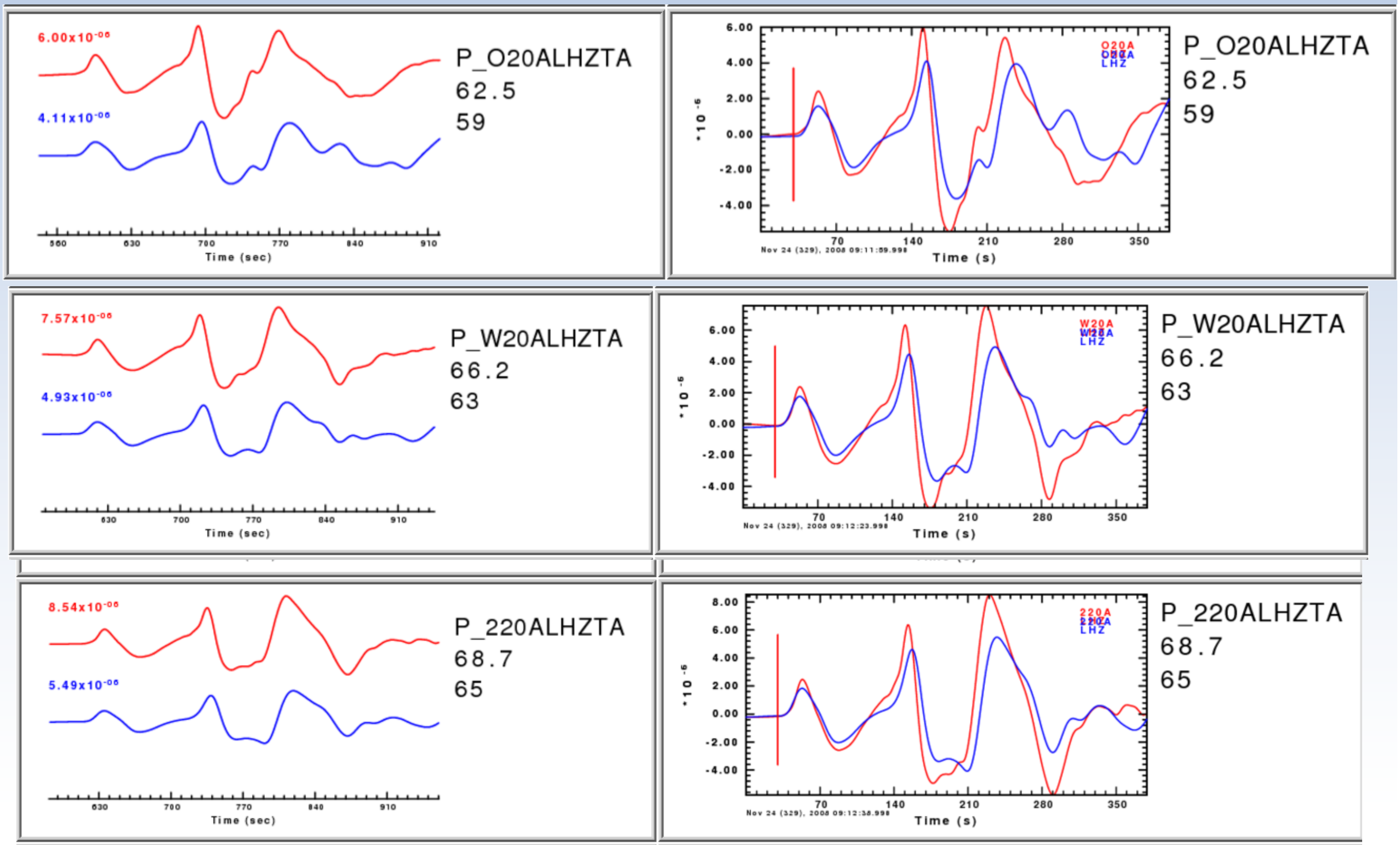




Event Synthetics

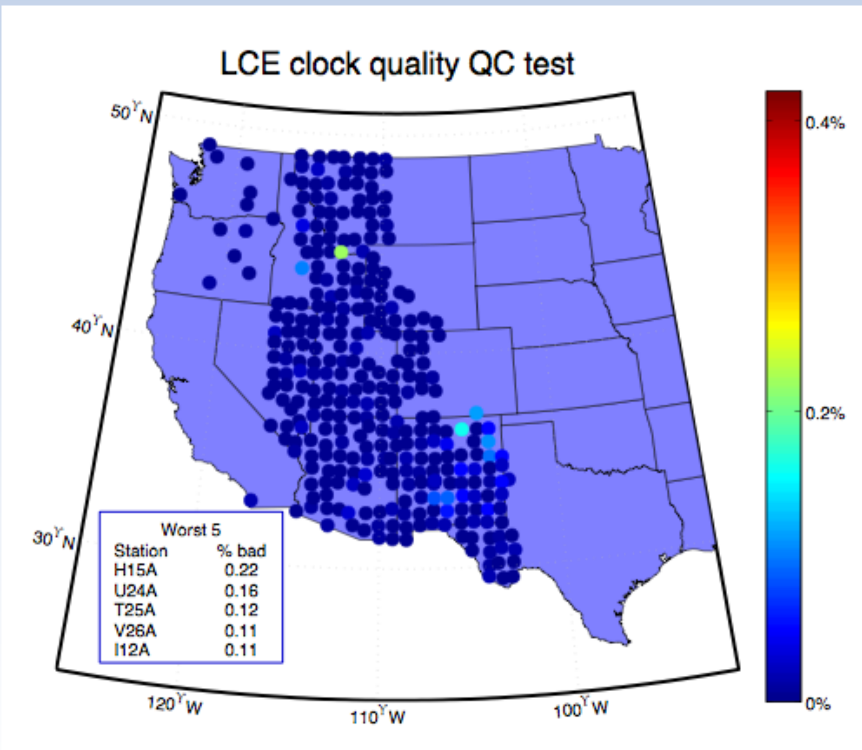
- Significant events are compared to synthetics generated by Hermann
- Polarity and amplitude issues are more apparent
- Method suffers when nodes occur within the array geometry

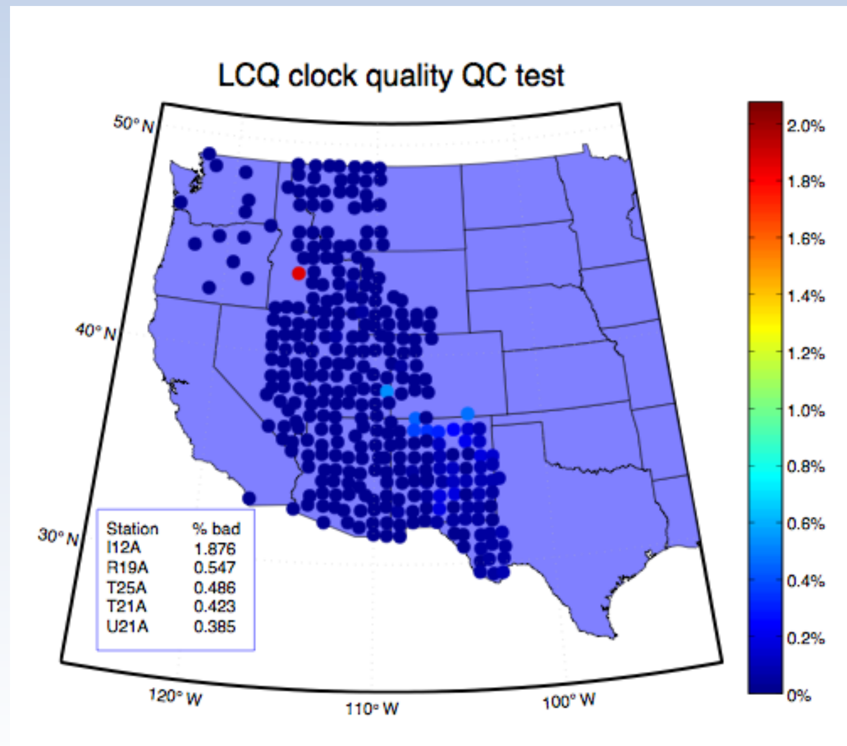
http://crunch.iris.washington.edu/synthetics/event/



Clock Quality

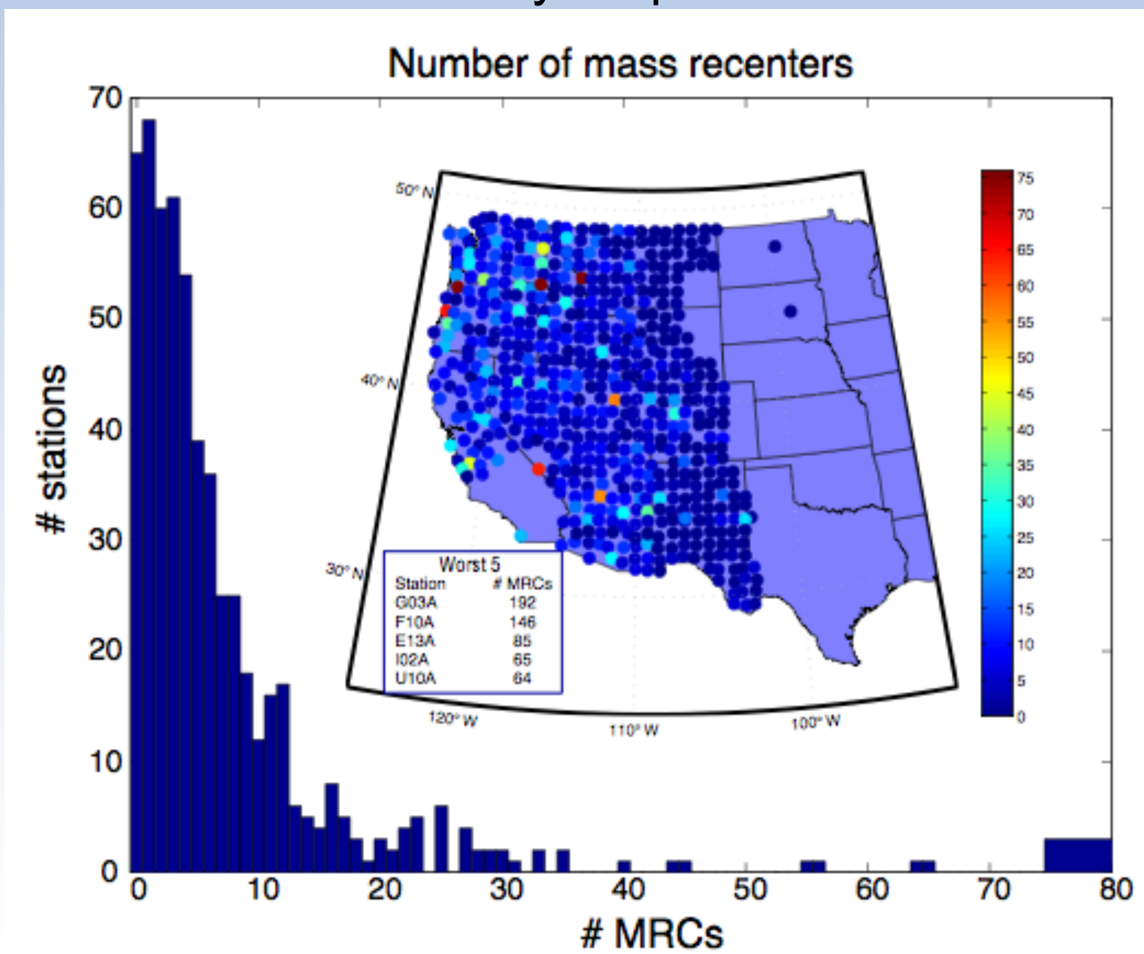
- Examination of clock quality channels for test interval (2007) indicates clock quality is excellent





Mass Position

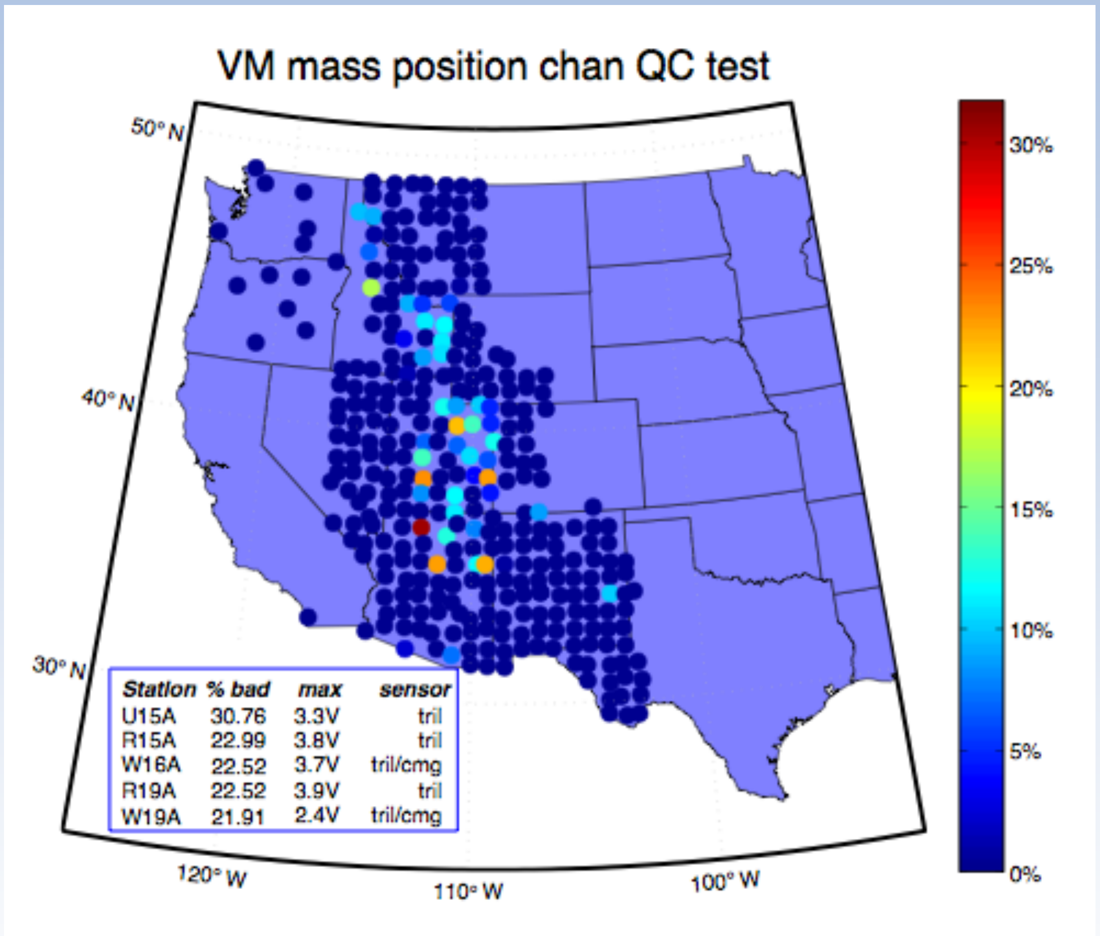
Sensor Mass Recenter operation affects data quality and broadly indicates the long-period quality of site. Most stations have 10 or fewer mass re-centers over a one year period



Mass Position

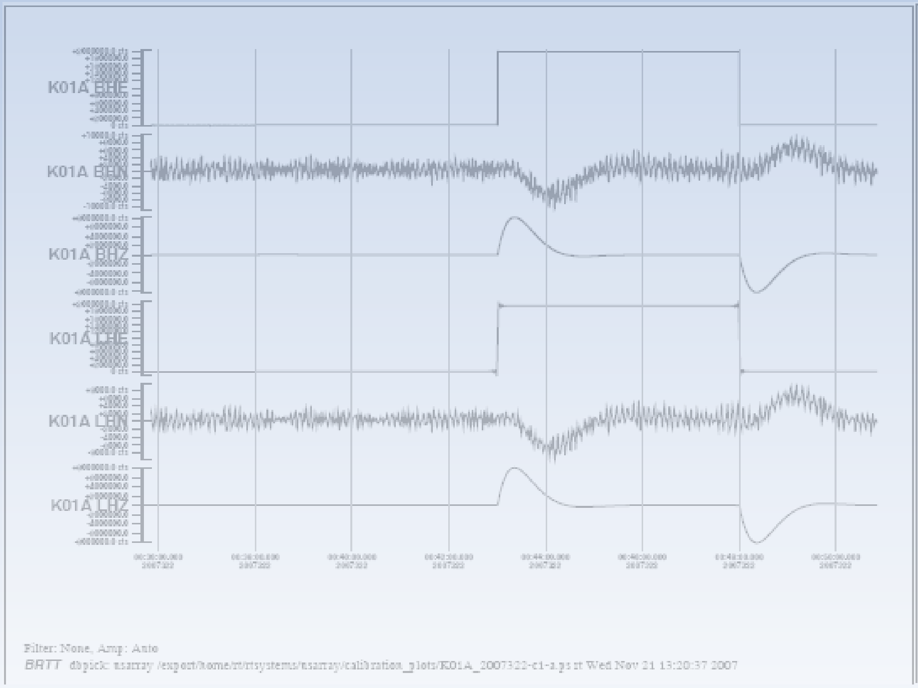
Modern BB sensors do not represent ground motion if ANY mass position channel is offscale. How often are these thresholds exceeded at any particular station?

The T240 sensor required closer tolerances and frequent monitoring.

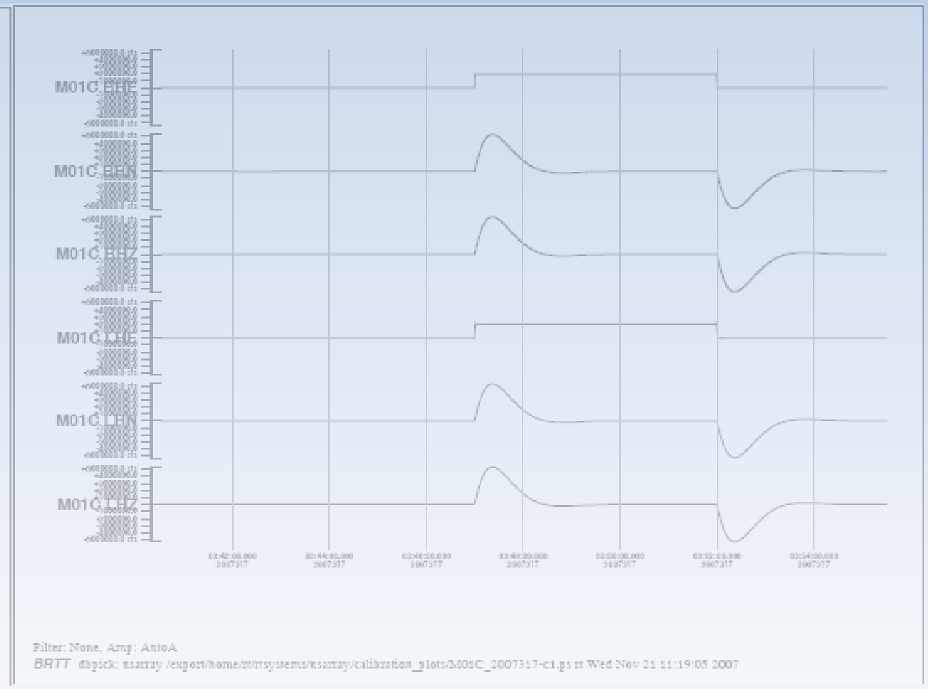


Additional Assessments

Calibration



STS-2



CMG-3T