EarthScope's Transportable Array

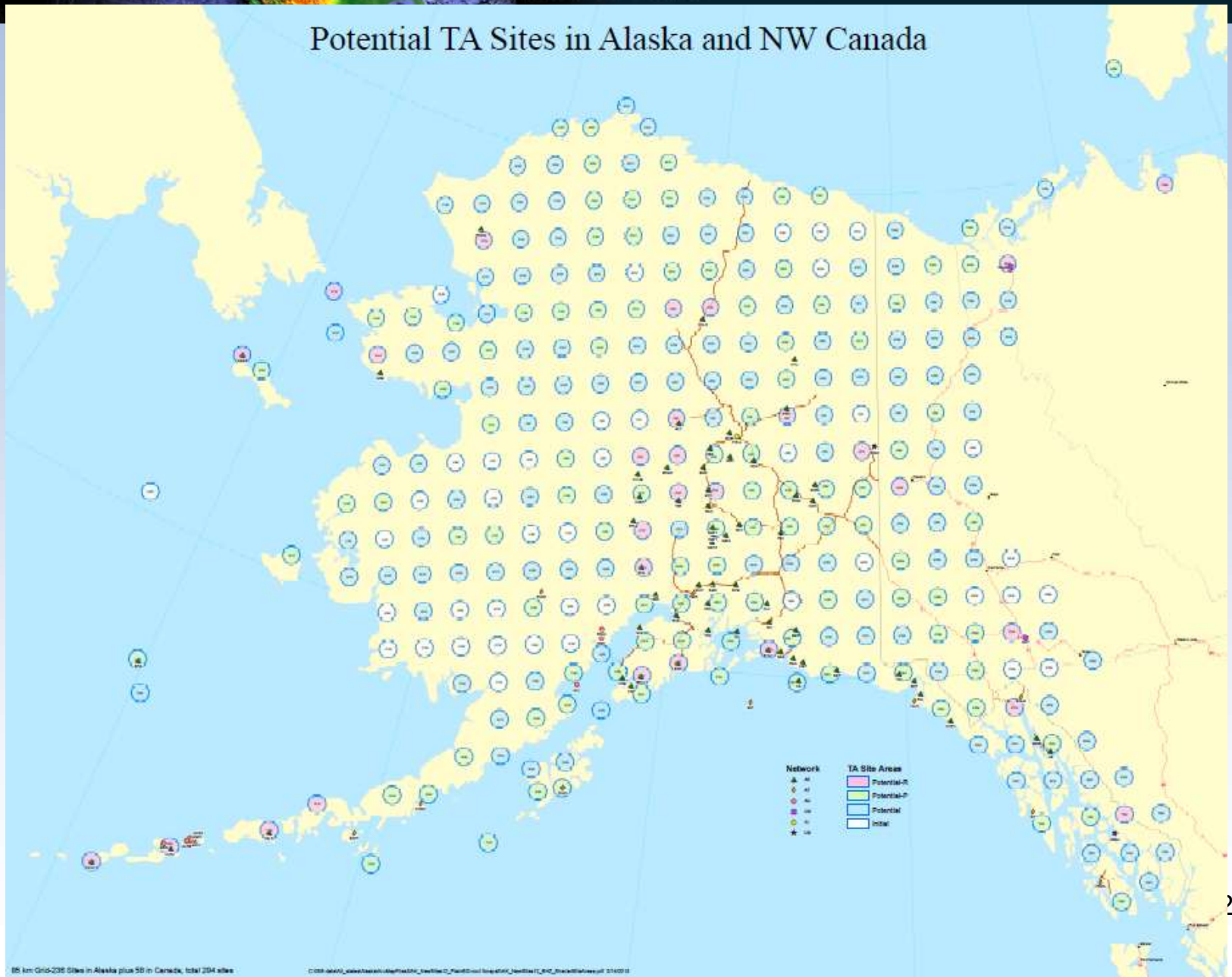
TA Engineering Team
Bob Busby
Allan Sauter
Patrick Bastien

Polar Technology Workshop
Naval Academy
Annapolis Md
2-4 Apr 2013

Proposed Project

296 sites

85 km grid



Outline

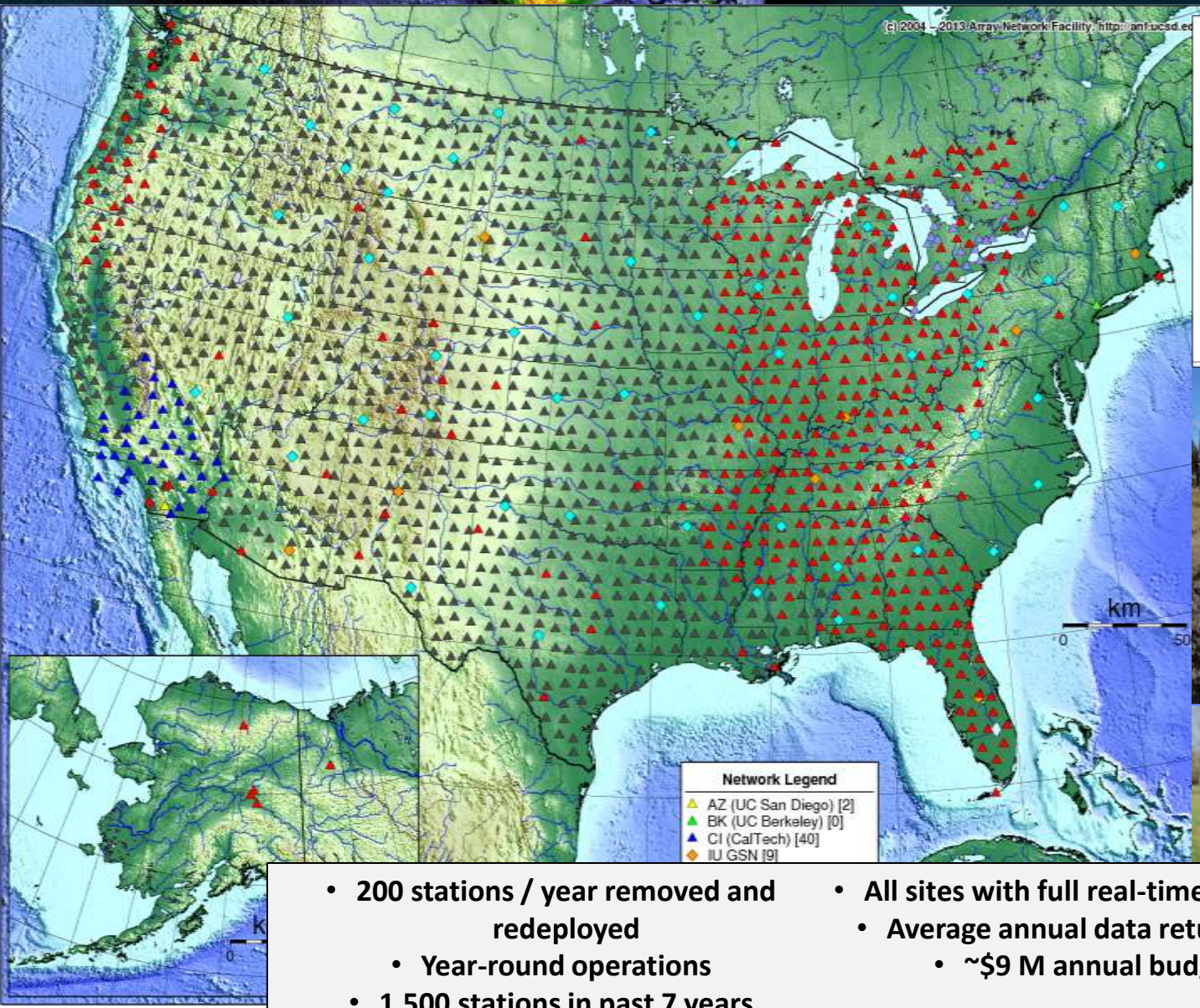
Introduction to EarthScope's Transportable Array (TA)

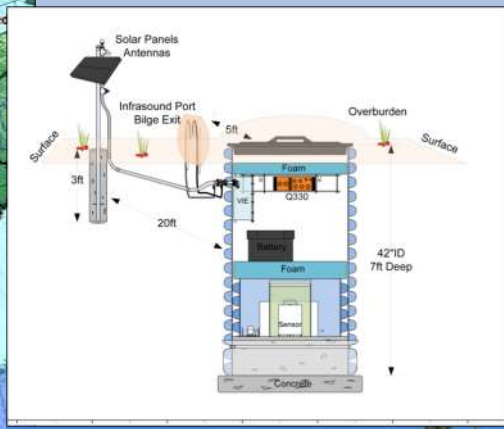
Describe the deployment plans for Alaska and Yukon

- Concept of Operations
- Seismic Station Design
  - Sensor Emplacement
  - Power and Enclosures
  - Data Communications

Opportunity for collaborative Science

Introduction to the TA





- 200 stations / year removed and redeployed
- Year-round operations
- 1,500 stations in past 7 years

- All sites with full real-time telemetry
- Average annual data return >98%
- ~$9 M annual budget

Station Design- tank vaults

http://www.passcal.nmt.edu/taweb

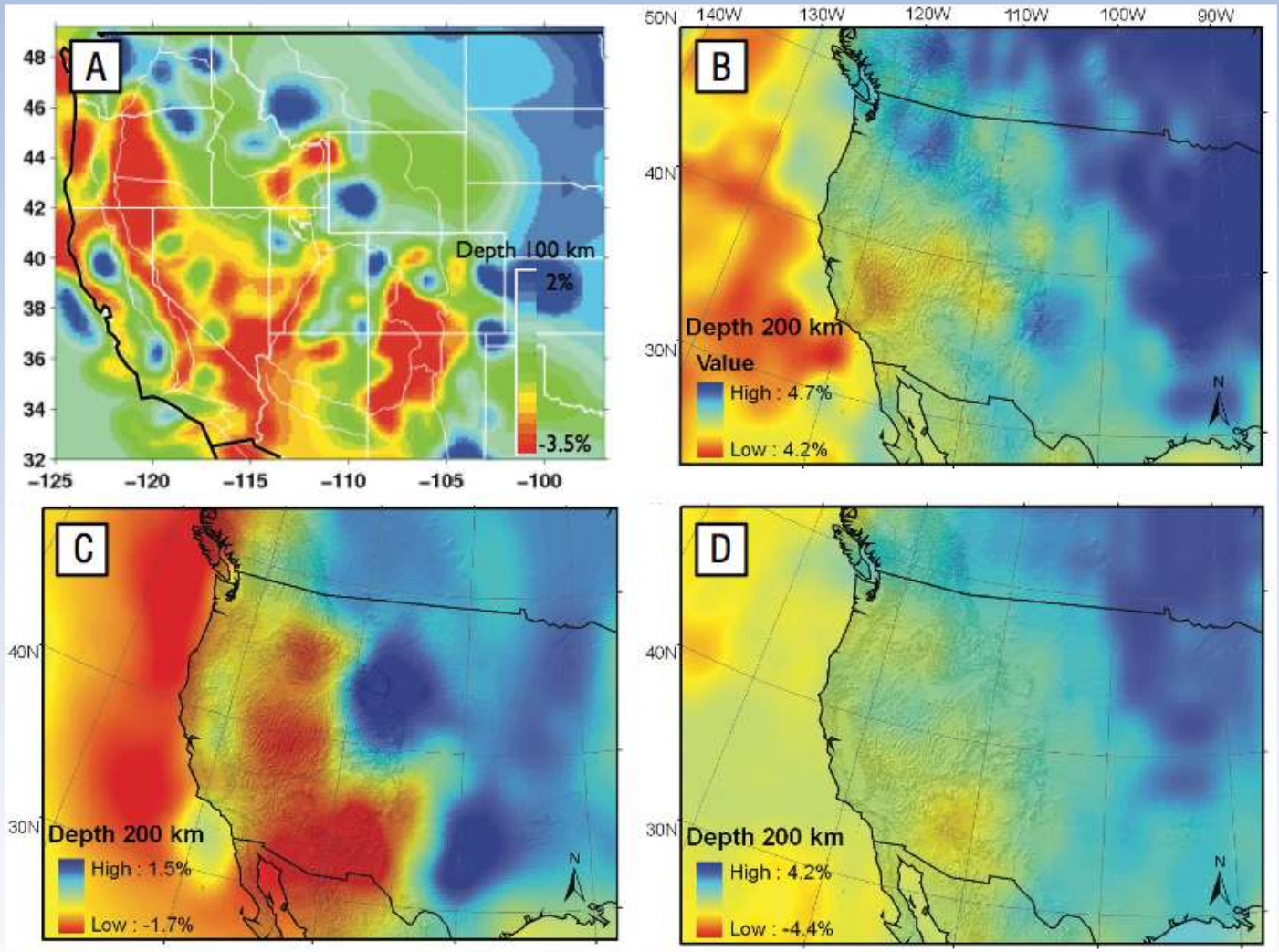
Freeman Engineered Products
HDPE custom rotomolded tank

$1200

105 kg

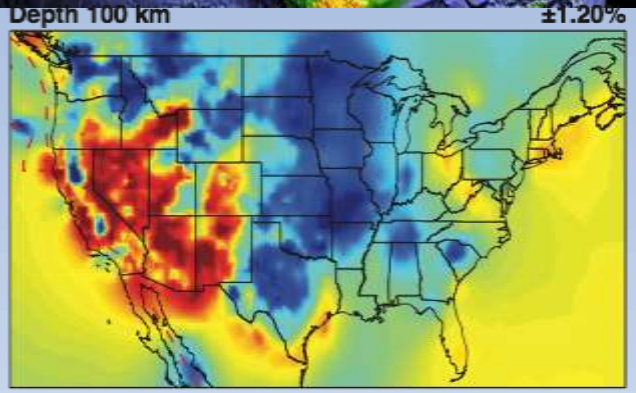
1.1m diameter
2.3m height

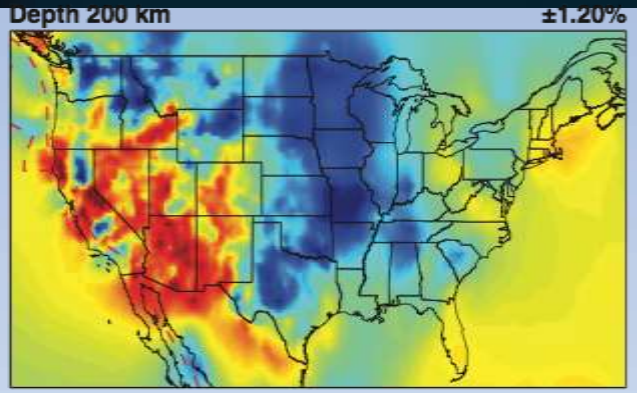
Tomography Before TA

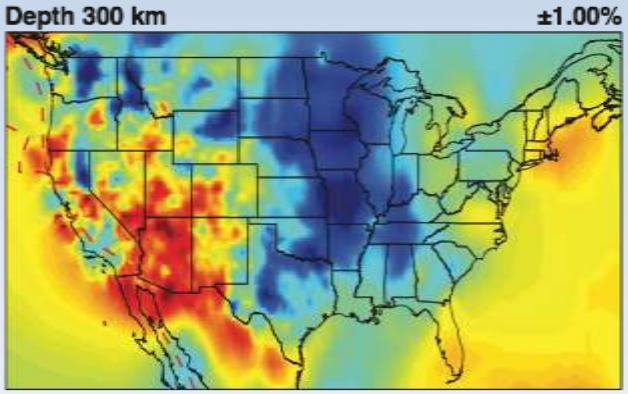


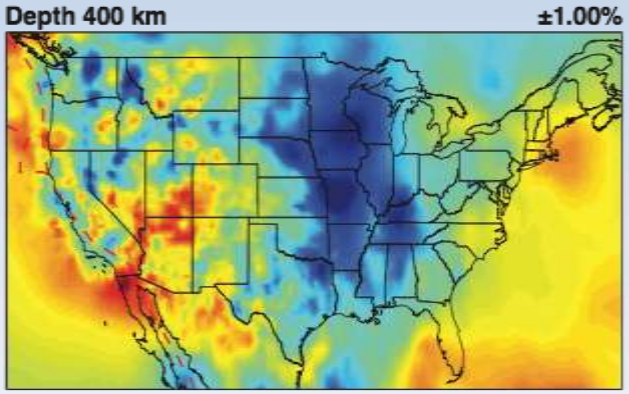
▲ **Figure 1.** (A) Model made by piecing together local tomography studies from Humphreys and Dueker (1994) and inverting with global data set (after Dueker *et al.* 2001). (B) Global *S*-wave model from surface wave diffraction (Ritzwoller *et al.* 2002). (C) Global *P*-wave model using finite frequency kernels (Montelli *et al.* 2004). (D) Global *S*-wave travel-time model (Grand 2002).

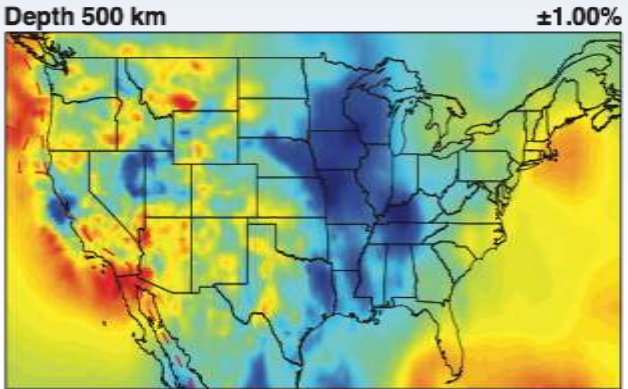
Tomography Burdick et al. 2012

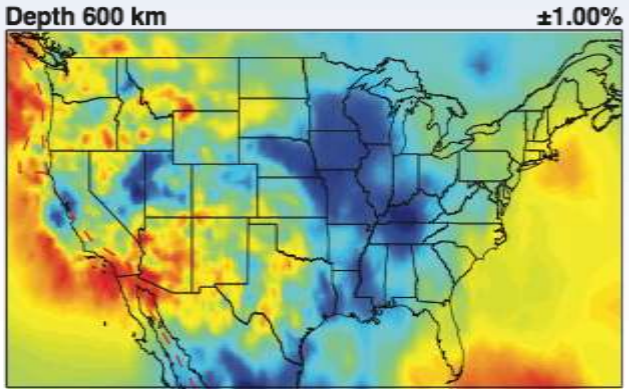




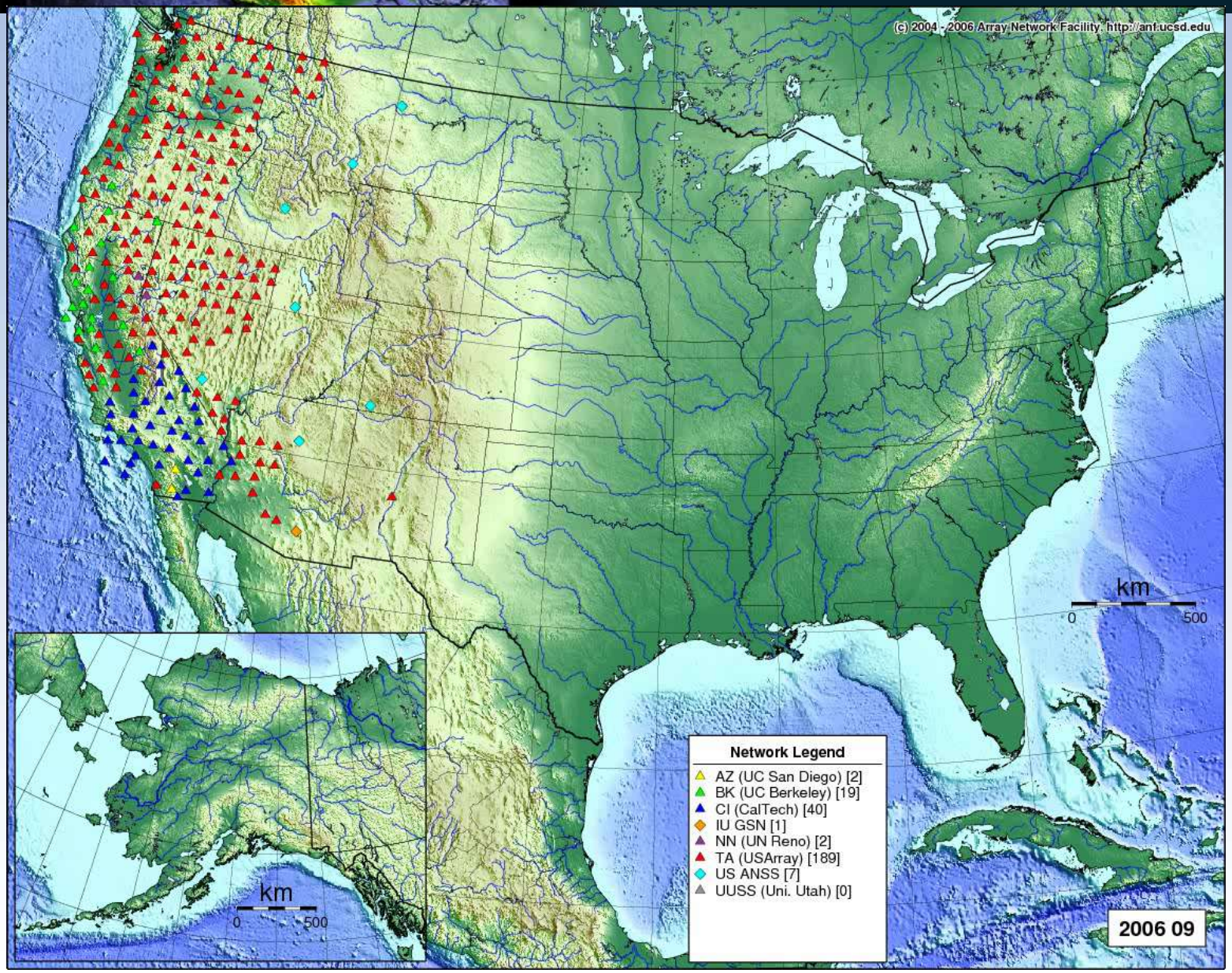




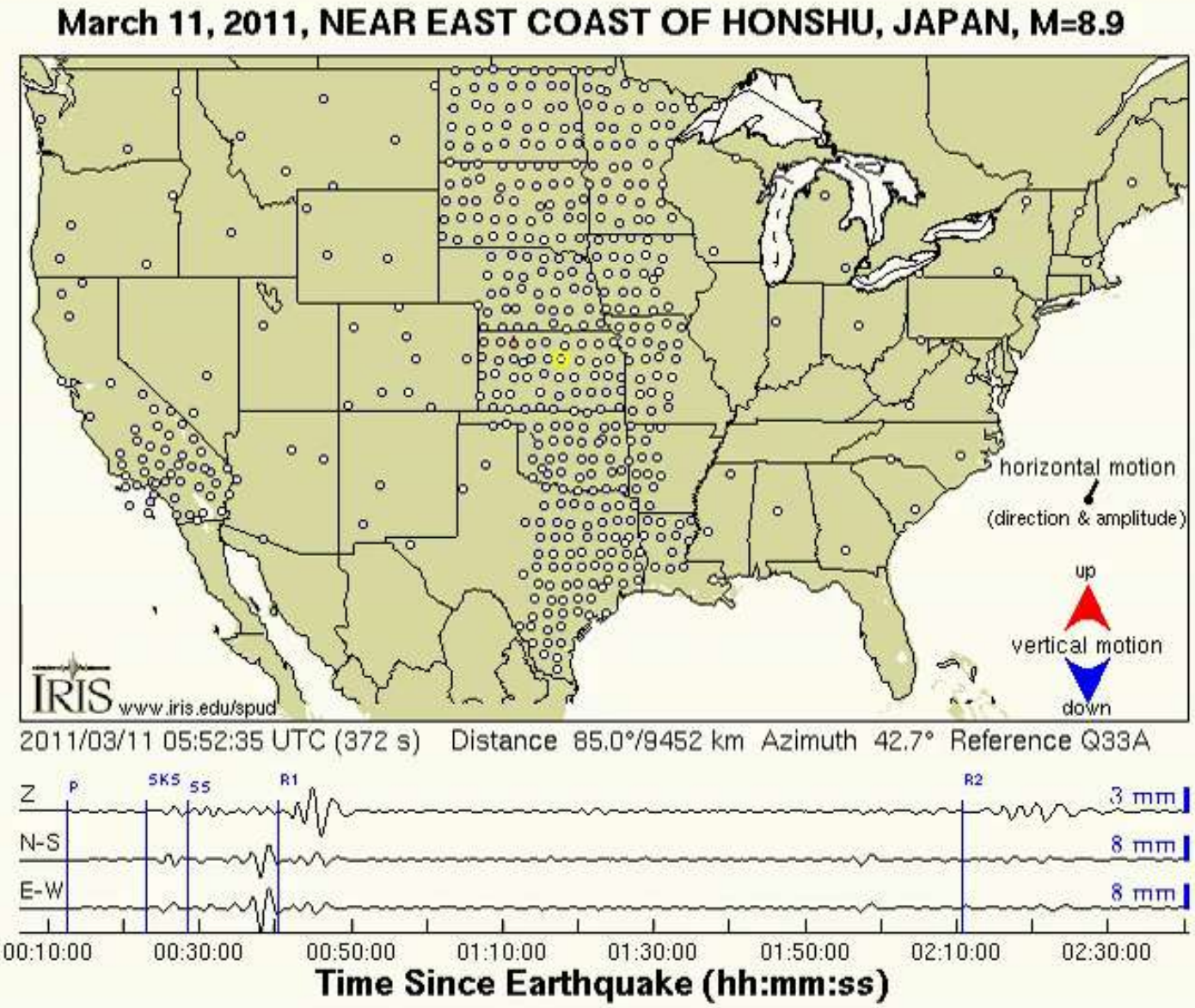




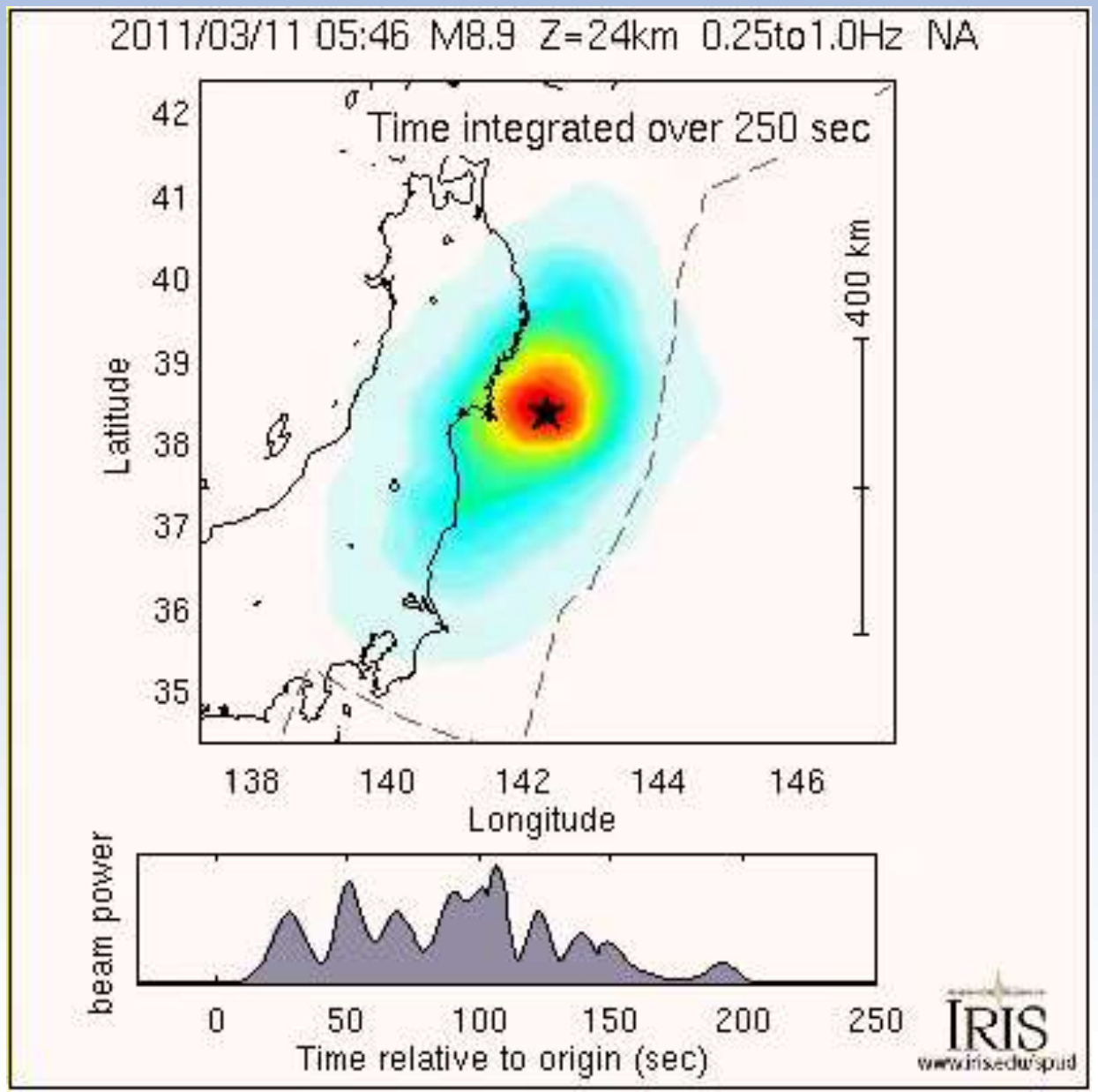
TA Rolling Deployment



Distributed real-time sensing array



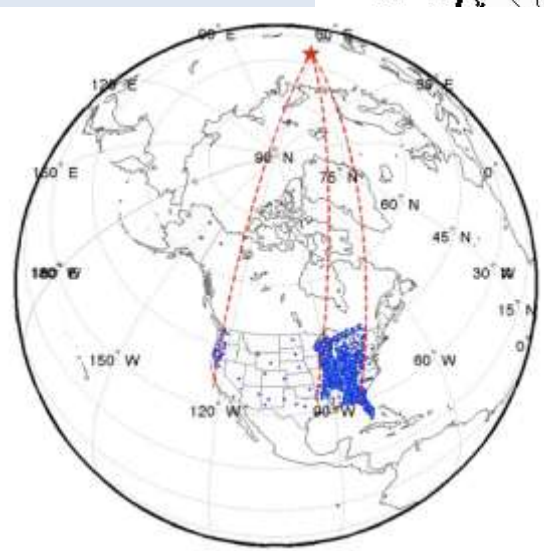
Distributed real-time sensing array
Beam Formed back projection

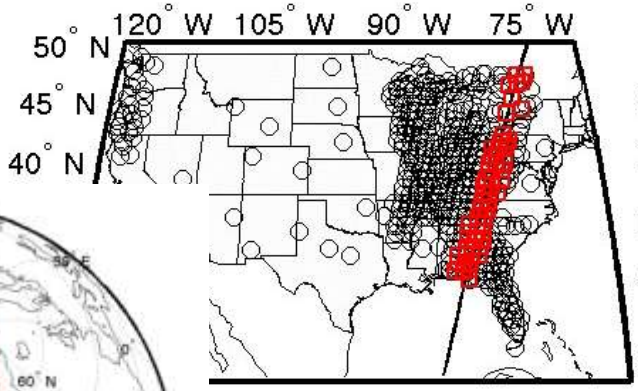


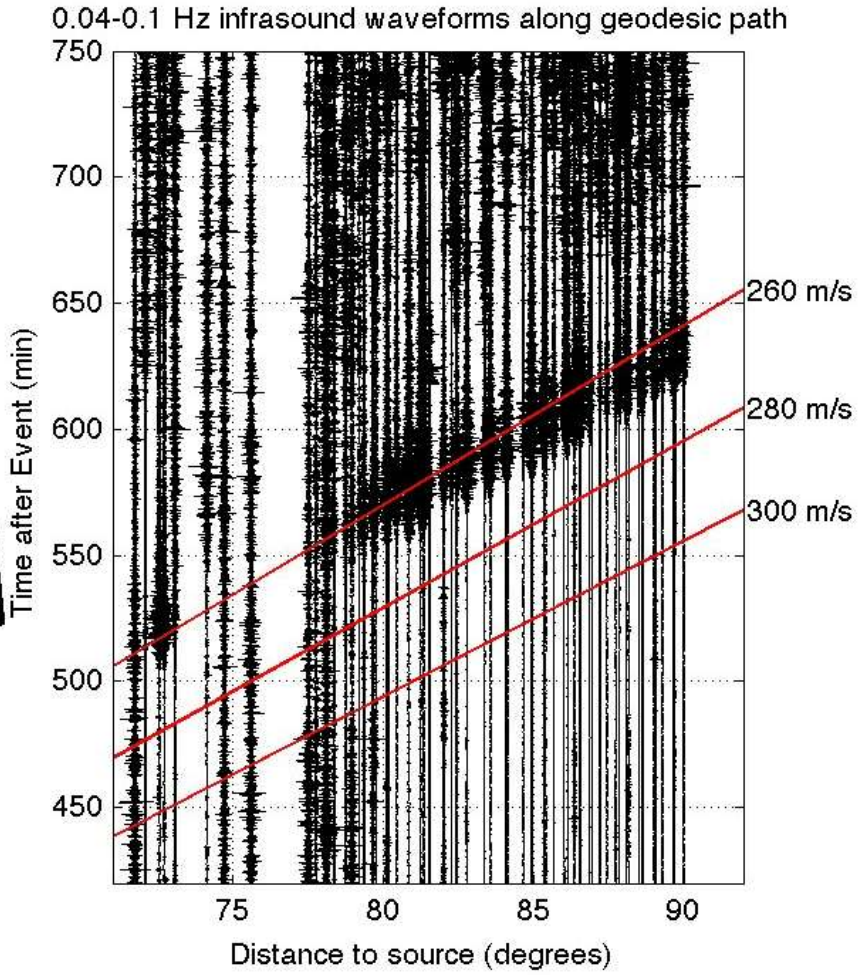
Atmospheric Acoustic Transportable Array

- Wide application of atmospheric data
  - Meso-scale atmosphere variation
  - Acoustic energy propagating in the atmosphere
- Acoustic – seismic coupling
- Noise induced on vertical and horizontal seismic channels

http://www.iris.edu/dms/nodes/dmc/specialevents/2013/02/19/chelyabinsk-russia-bolide-meteor/

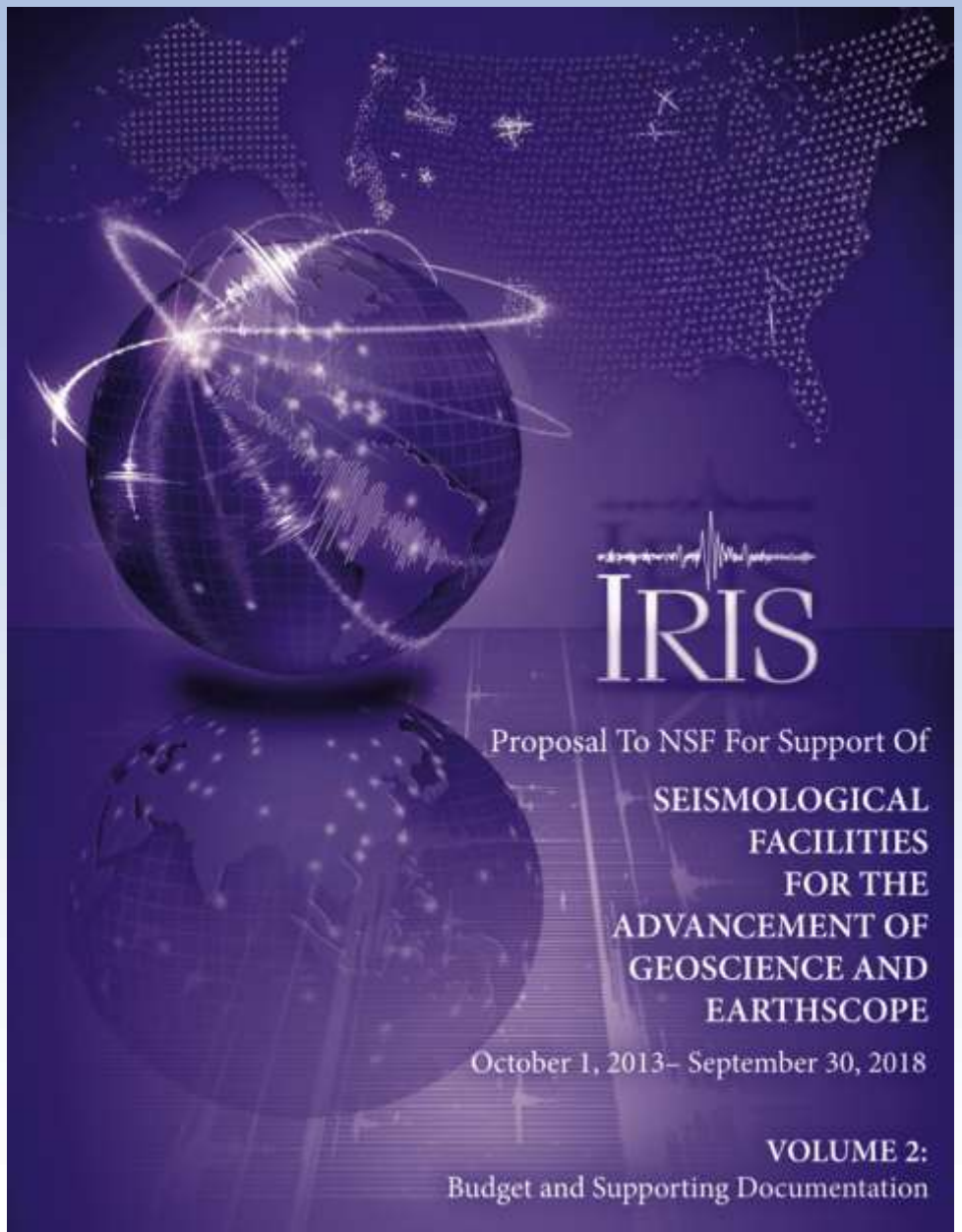






Project Proposal Status

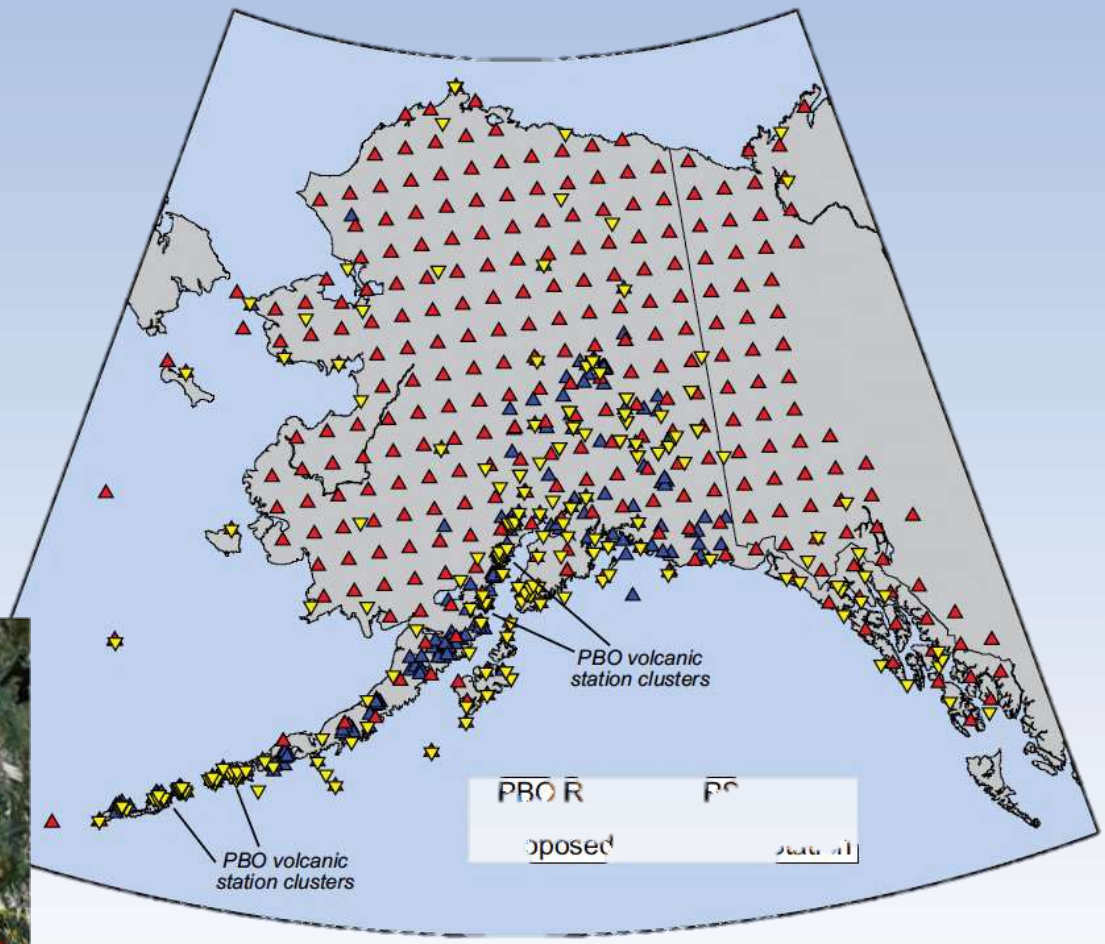
- EarthScope funded in 5 year increments
- Currently in Year 10
- Proposal submitted for 2013 – 2018 (for funding to start in October 2013)
- Engineering trials and design supported under current funding.



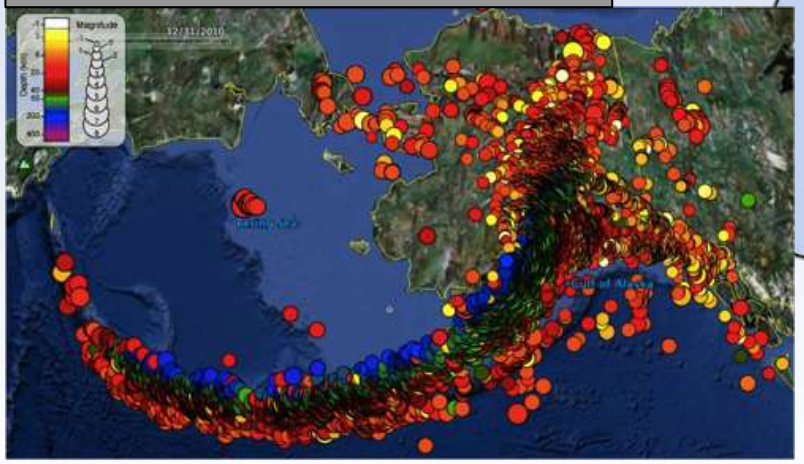
TA in Alaska / Yukon

- ~300 sites
- 85 km spacing
- Broadband Seismometers

  Infrasound, pressure
  - Some met packages
- Communications
- fully deployed 2017

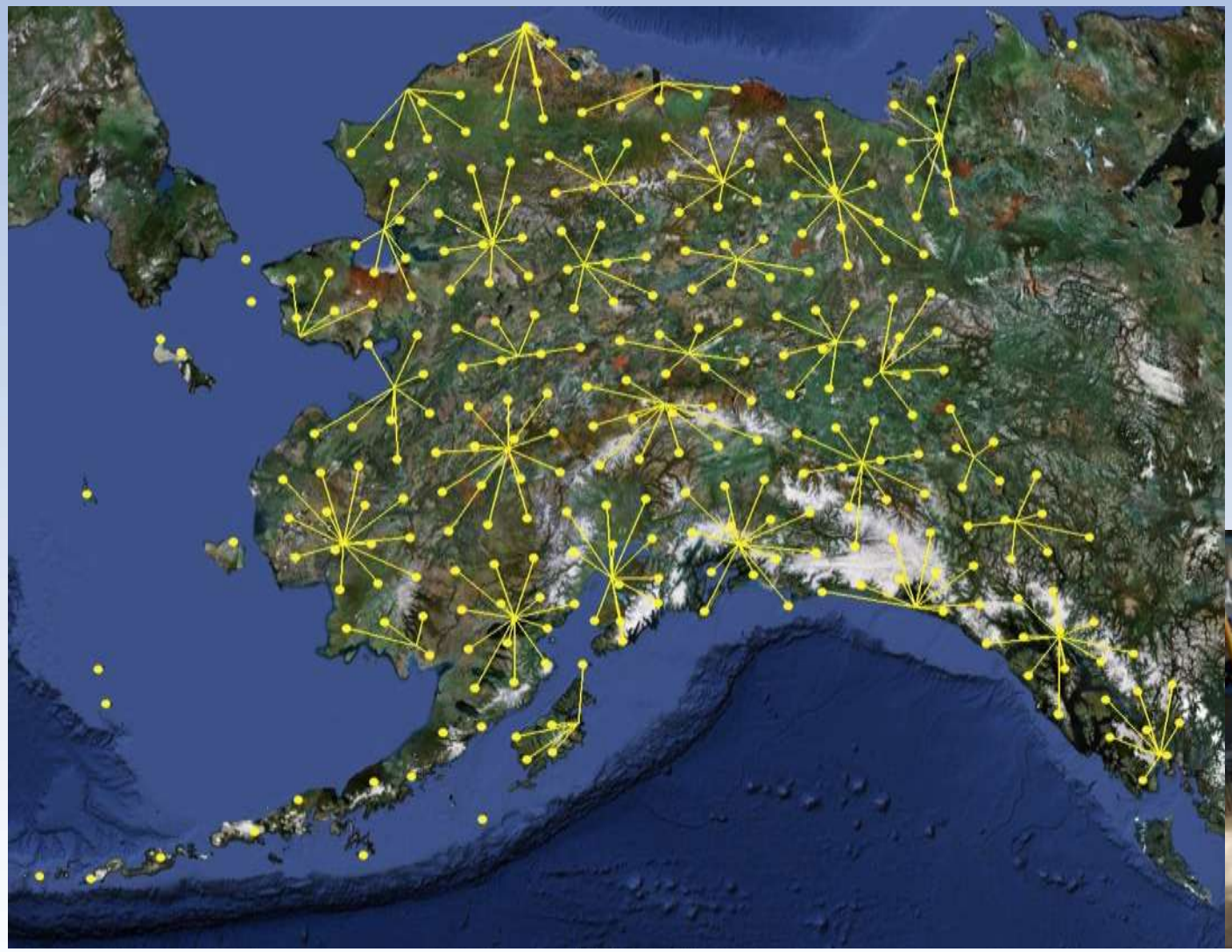


Seismicity in Alaska, 2010



www.usarray.org/alaska

Concept of Operations

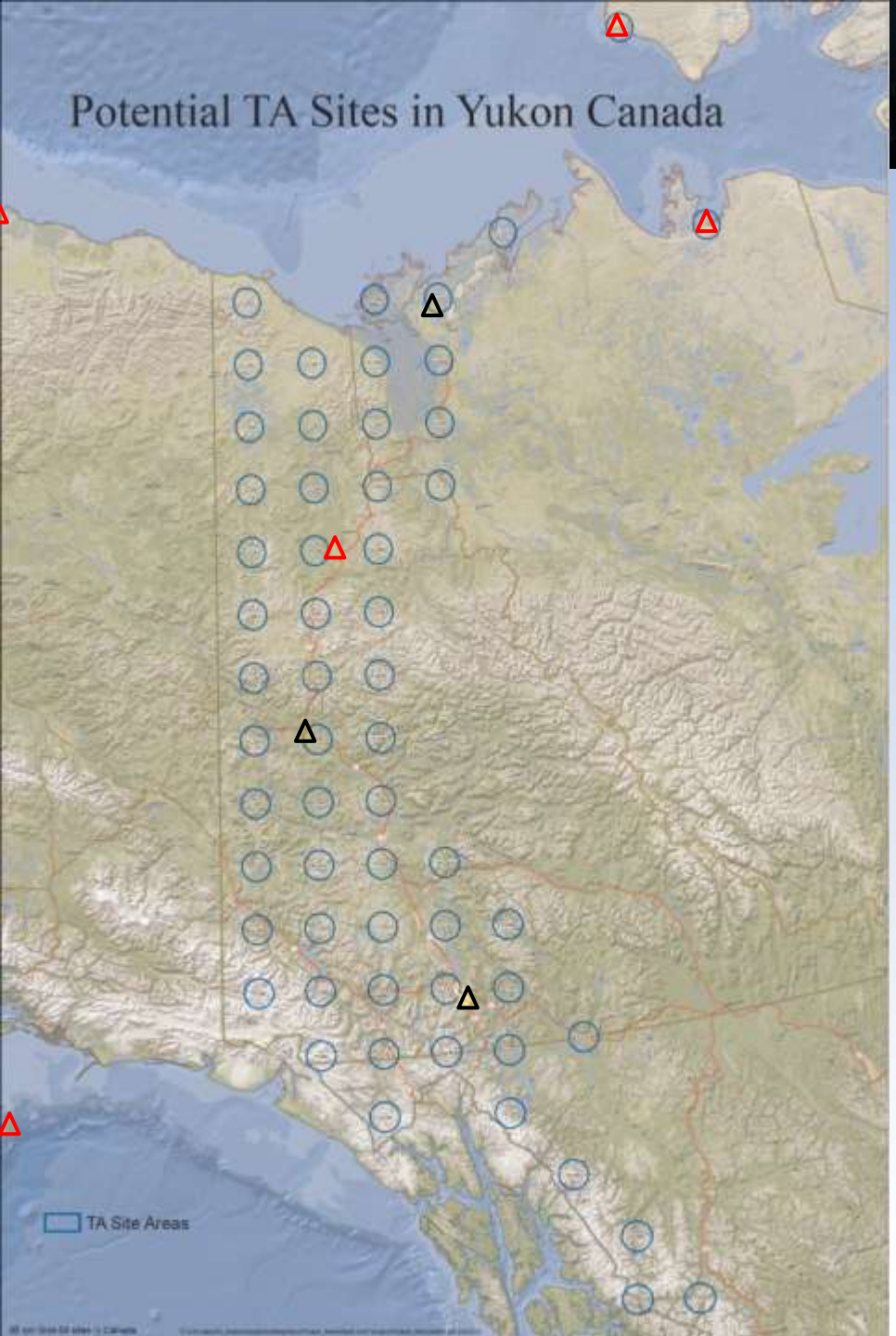


- Operations Base in Anchorage
- Spoke from village hubs
- Helicopter lift of drill rig

Hold cost/schedule contingency at the hub level

Initial Site Planning

2013 stations in Canada

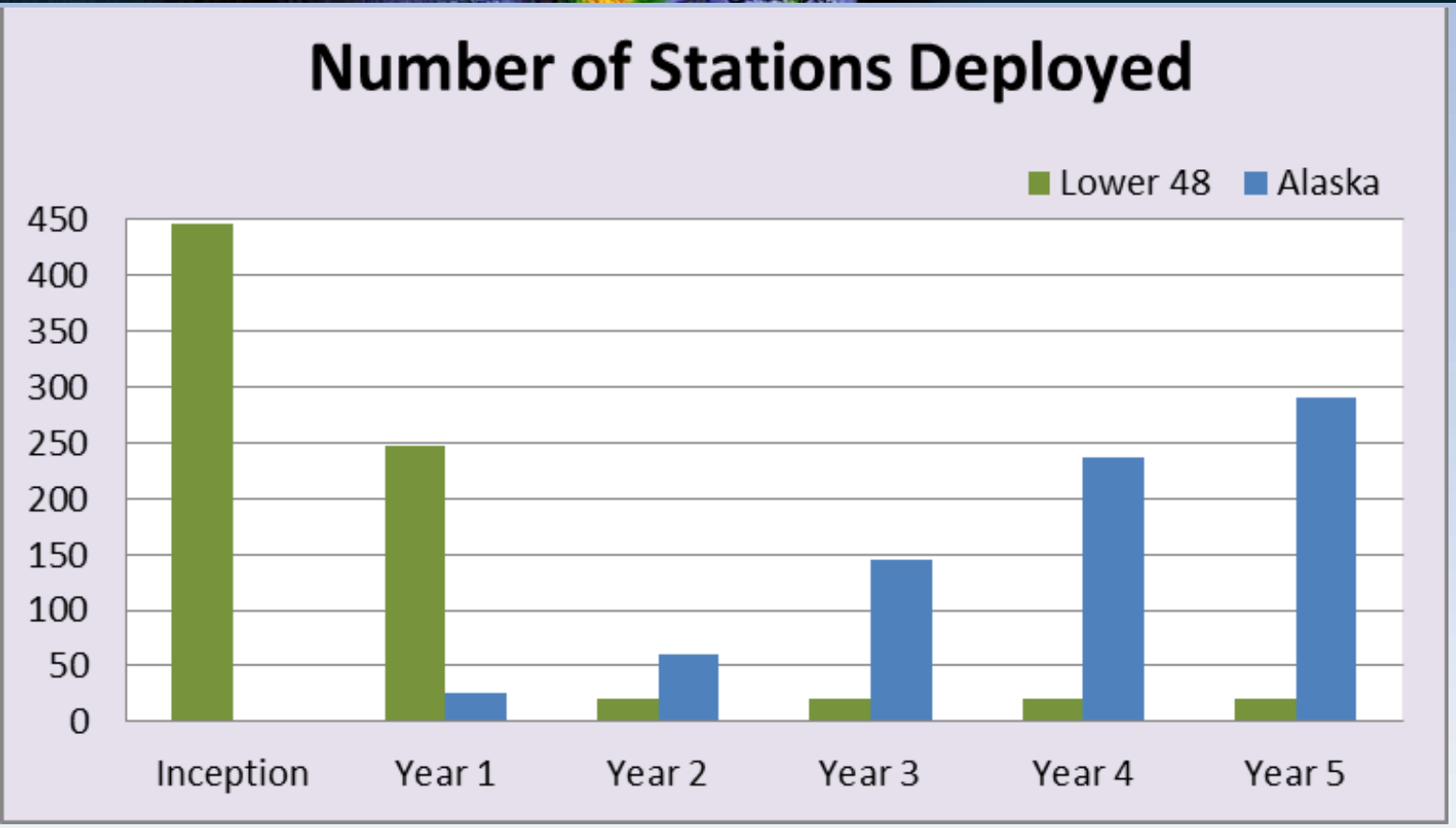


Planned 2013 stations
Existing Stations

Paulatuk
Sachs Harbor
Barrow AK
Middleton Island

Future Locations:
6 Sites in BC
9 Sites in NWT
43 Sites in Yukon

Project Schedule



- **Schedule balances roll-up in east with roll-out in Alaska**
- **Alaska field schedule is seasonally driven**
  - **Late spring – early fall**
- **Schedule provides longer operational window in AK**
  - **Additional time for FA experiments to get underway**
- **Additional time for Alaska organizations to assemble plans to make selected stations permanent or collaborative science.**

Station Design Aspects

- Sensor emplacement to achieve highest quality data
- Power strategies to balance weight, reliability, complexity
  - Solar panels, advanced chemistry batteries, fuel cells
- Communications scaled by volume and latency vs. cost

Post Hole Broadband Seismometers

Toolik Lake Field Station, North Slope Alaska

Sensor emplacement

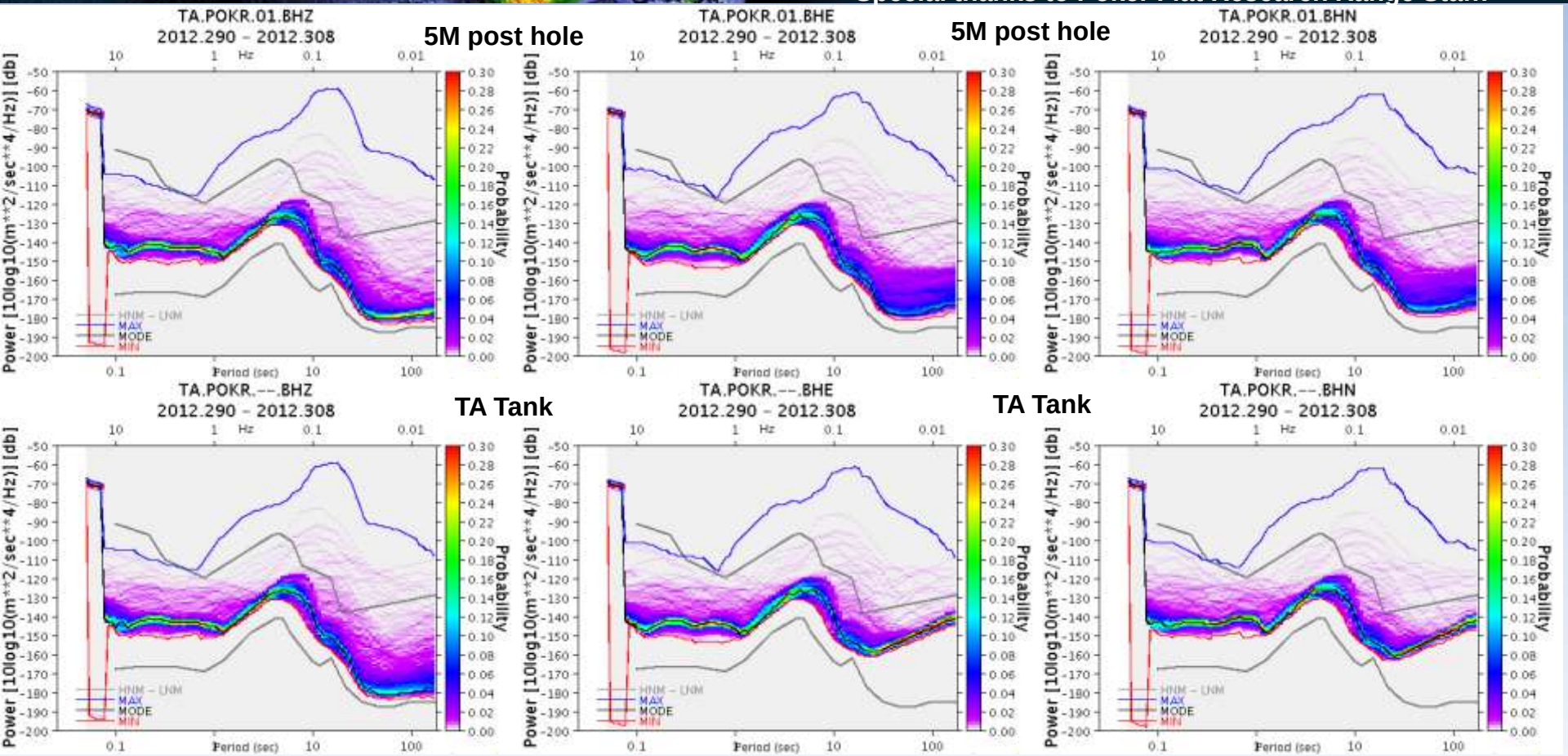
High quality long period Seismic data requires stable emplacement of the $20k 3 axis sensor (<1Watt)

In rock outcrops, a diamond coring machine can create 6” diameter holes to depths of 1.8m in an hour. In permafrost soil & silt, coring is also possible. Portable auger and air hammer drills are under test. Design goal is <500kg.

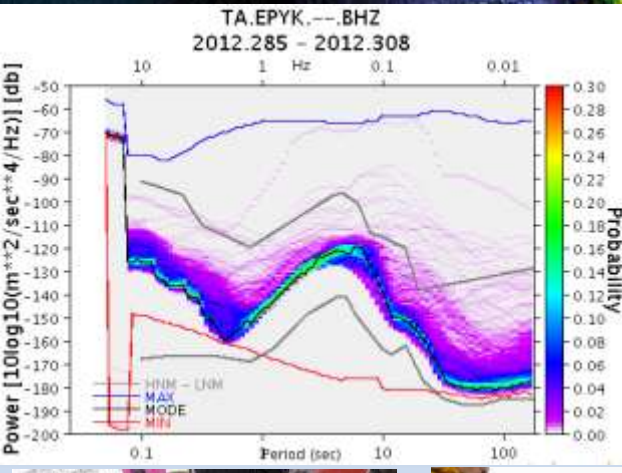
Motivation: Alaska, all equipment designed for transport in fixed wing aircraft or helicopter.

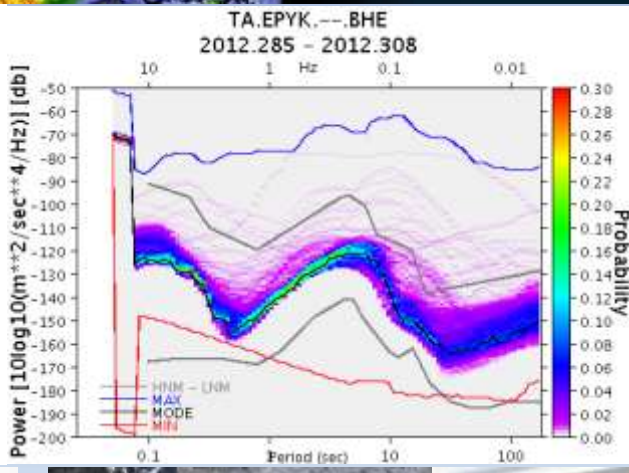
TA.POKR experiment

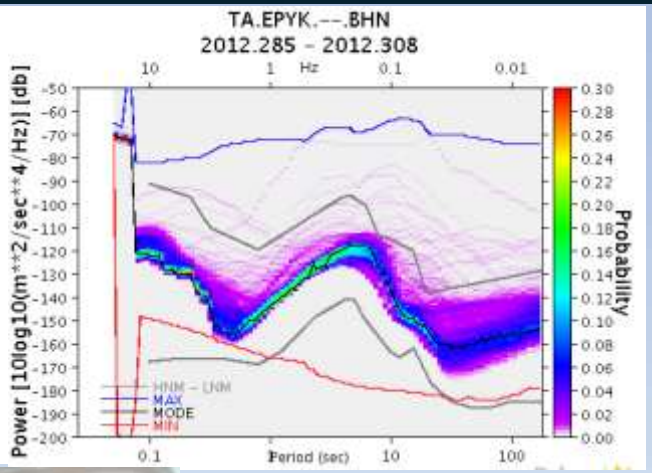
Special thanks to Poker Flat Research Range Staff!

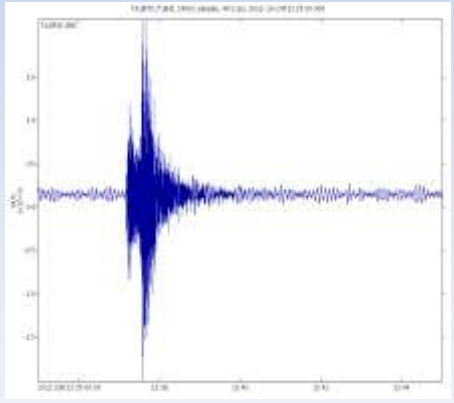


Eagle Plains Yukon









Oct 24, 2012 M4.5 Vertical

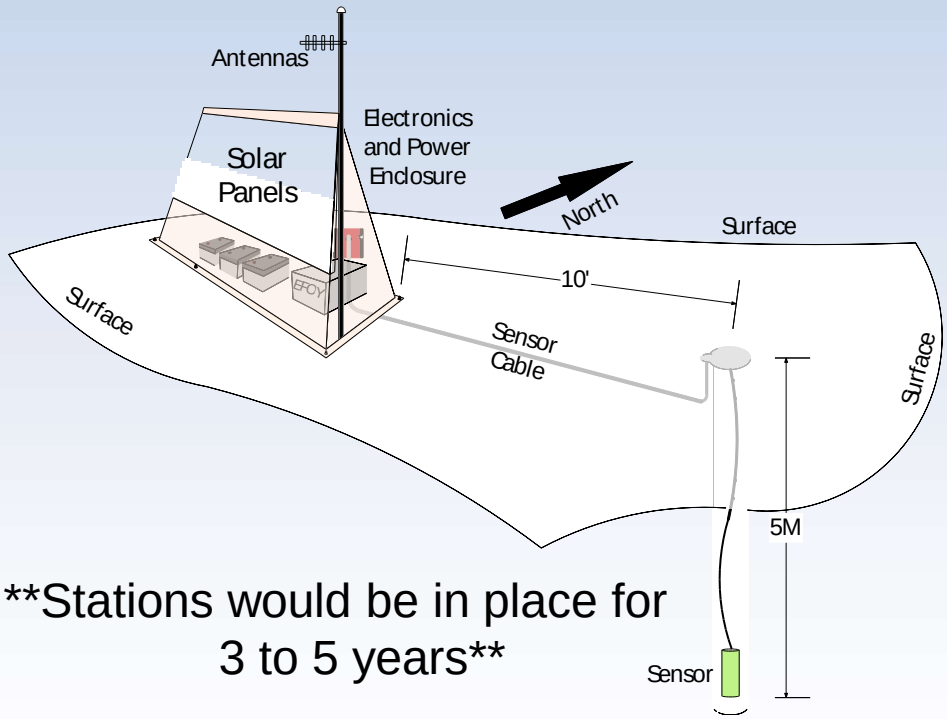
Stop Action Video of install

http://www.youtube.com/watch?v=JTTv6wqCqco

Oct 13, 2012 complete

Basic Description of Buried Sensor Design for AK

- Sensor: 3 component Broadband seismometer & auxiliary sensors
- Datalogger & local data storage
- Power & data telemetry

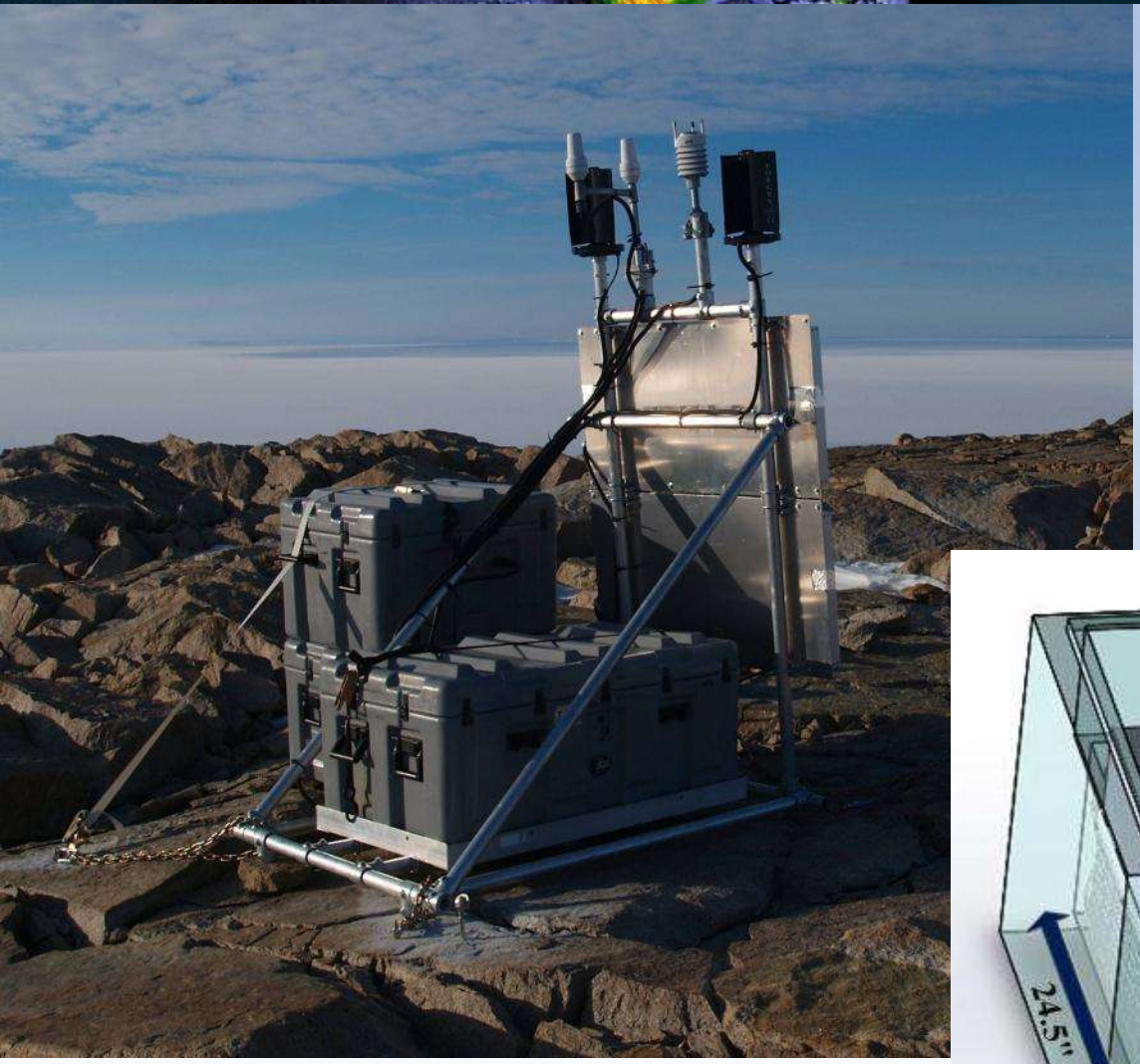


Stations would be in place for 3 to 5 years

TOLK Seismic Station

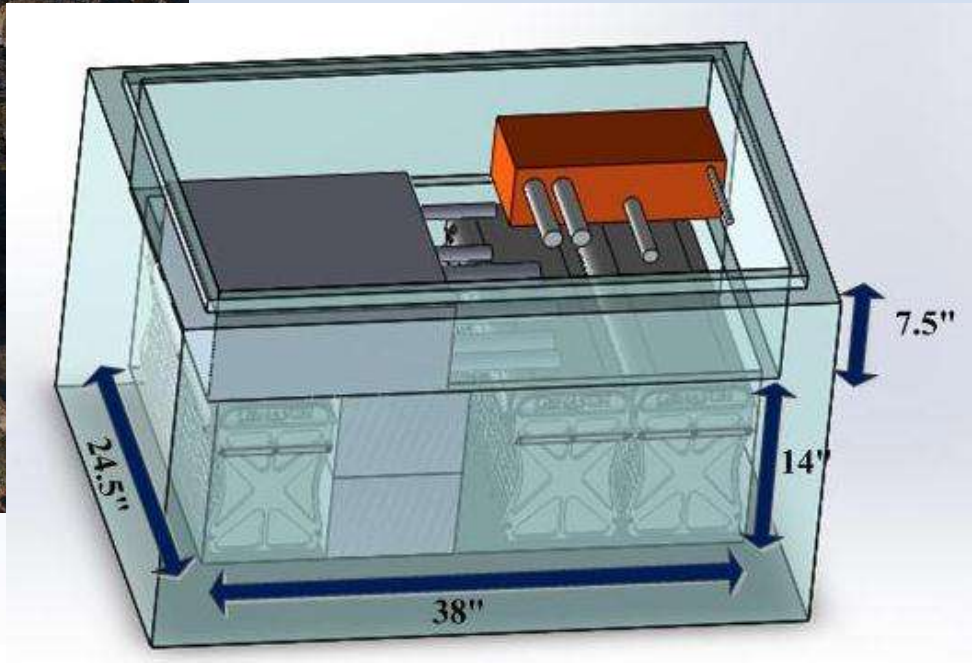
Footprint ~10 feet X 20 feet

Alternative Enclosure

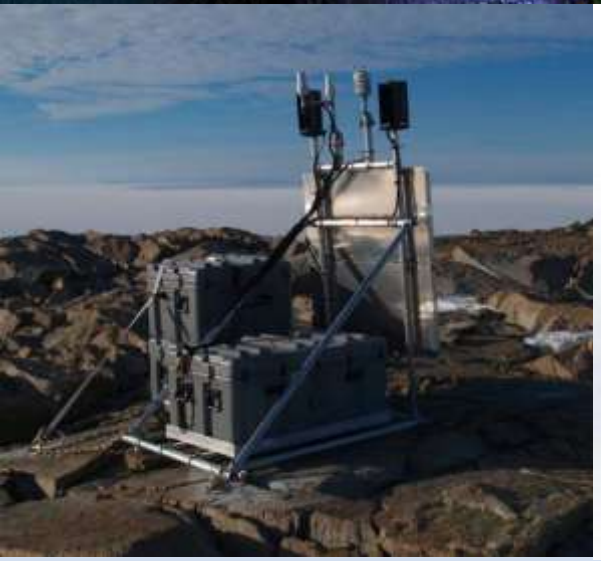


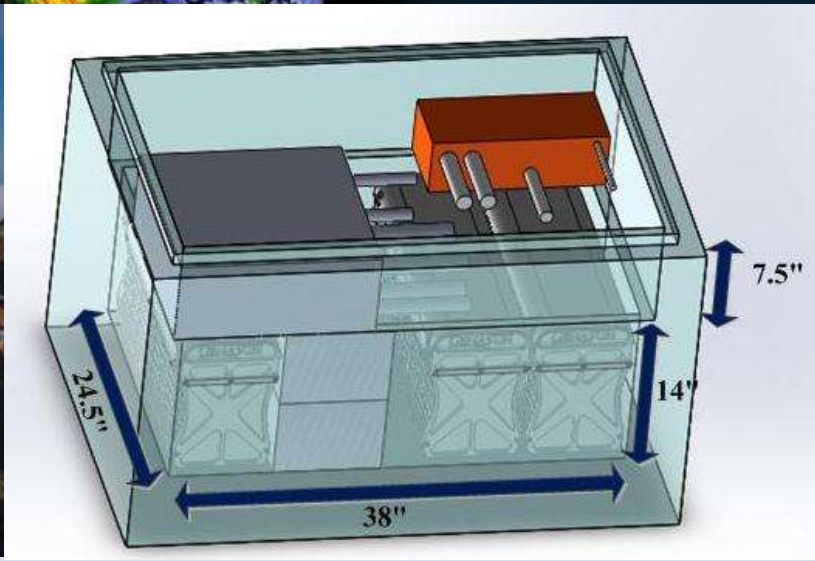
Contents:
(4) 100AH AGM Lead-Acid
(3) 360AH LiFePO4
Datalogger
Charge controller
local data storage
Comms terminal

410kg
30 x 44 x 28 inches



Comparing Enclosures





Comparing how many Lead Acid vs. LiFePO4 batteries you can wedge into two different types of enclosures, factor in the weight of the overall package and a transit cost of $25/kg round trip.

	#Pb batts	#LiFePO4	Cap cost	Weight	Transit Cost	Total Cost	KWH	cost/KWH
BOX1	3	2	$ 10,650	328	$ 8,200	**$ 18,850**	**12.2**	$ 1,545
BOX2	4	3	$ 15,100	411	$ 10,275	**$ 25,375**	**17.8**	$ 1,426
BOX2	16	0	$ 5,500	642	$ 16,050	**$ 21,550**	**19.2**	$ 1,122
HUT	24	0	$ 9,500	1025	$ 25,625	**$ 35,125**	**28.8**	$ 1,220
HUT	16	0	$ 7,500	769	$ 19,225	**$ 26,725**	**19.2**	$ 1,392

Power Details

Normal Operating mode 7.5 Watts

Low power mode (duty cycle storage, comms) 3.5 Watts

(3) 90 Watt PV panels, south facing

17-19 KWH batteries, two types of chemistry due to temperature

Nov 30-Jan 15 (1100 hours) @3.5W = 3.9 KWH,

@7.5W = 8.3 KWH

Nov 7-30, Jan 15-Feb 7 (1100 hours)

run in low power mode = 3.9 KWH

run in high power, with half PV gen = 4.2 KWH

Need a minimum of 8.3 KWH to coast through winter.

If solar power is not viable (Juneau, Aleutians), consider generators

Power Details

Objective:

Run continuously through the winter, in low power mode as necessary. But in high power when state of charge allows.

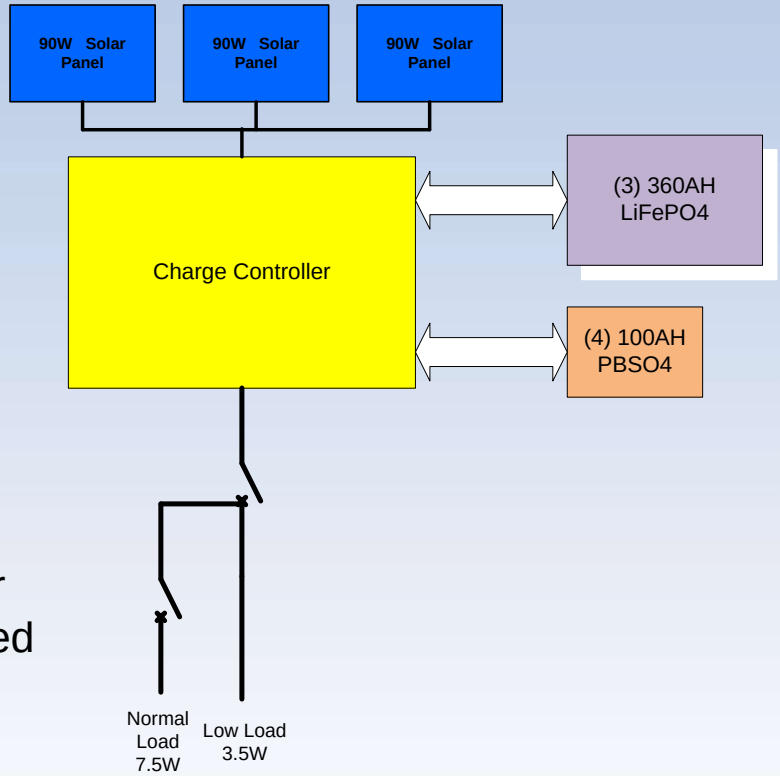
Complexities:

Charging LiFePO4 at < -10C is not advised

At cold temps charge Lead-Acid first, run system-wait to charge large battery banks until later in spring/summer when you have plenty of power. Use available power to heat enclosure before charging Lithiums??

Strategy:

Charge controller can charge either battery, switch either battery onto load and switch power mode of system based on state of charge.



Communications

Objective:

Deliver 40 Mbytes/day, with latencies under 4-6 hours. Need not be a continuous connection, but that is preferred when power and cost allow it. Must be under 2 Watts average daily power.

12 Gb/day compared with about 23 Gb/day today.

Complexities:

Can send data as file transfers or streaming packets or a combination to obtain highest compression.

Options:

Freewave and Cell where available

InMarSat M2M BGAN Hughes 9502 terminal $0.5/Mbyte

GlobalStar data network

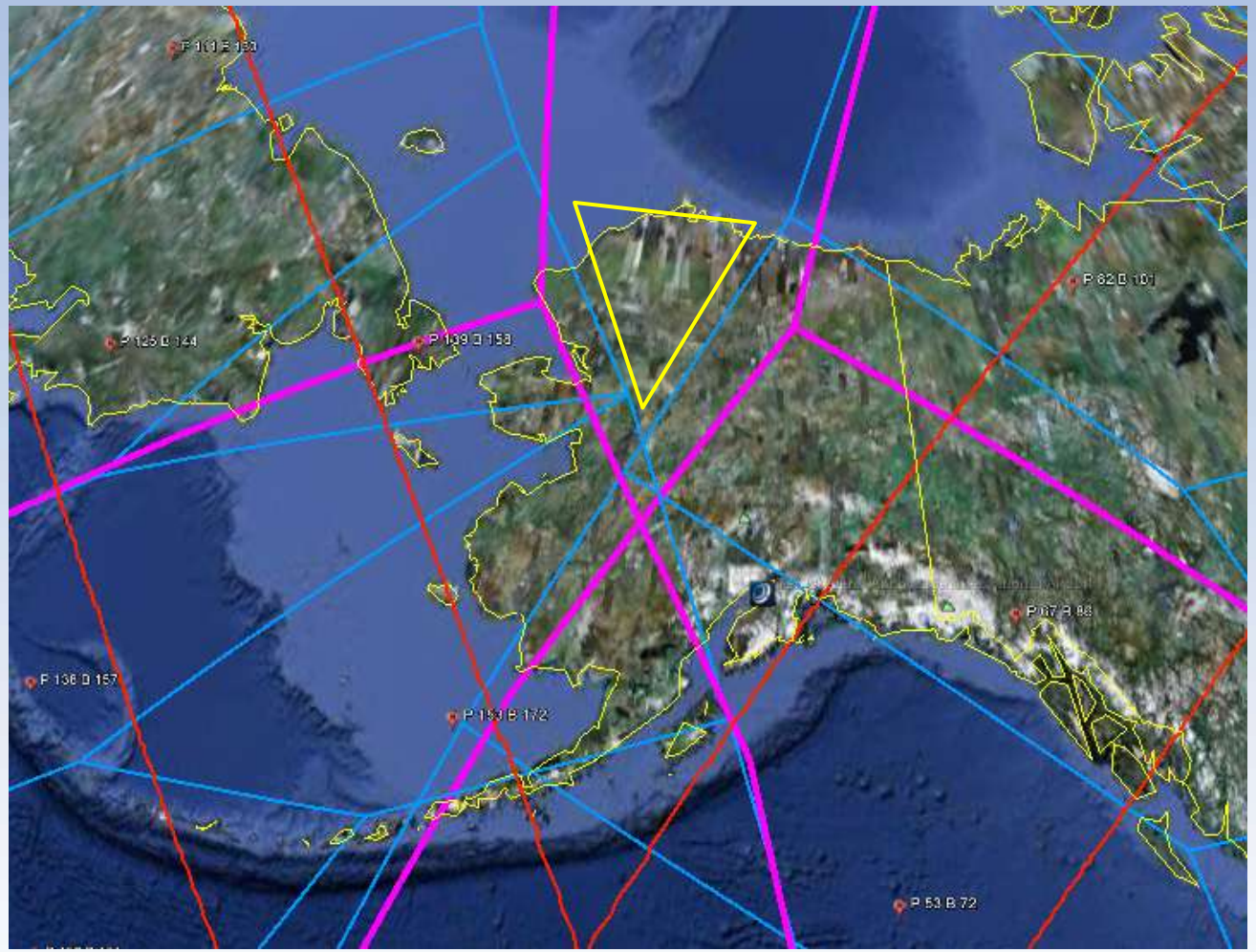
Iridium Open Port

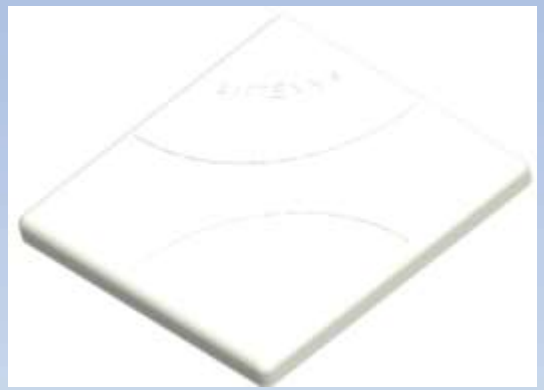
11-15W full transmit at 400kbps
1W standby, SMS wakeup
0.1W sleep
$1000

~ $850k annually

Hughes 9502 Inmarsat BGAN M2M Terminal

BGAN I4 EIRP Elevation





12 x 12 x 2 inch flat plate
20 degree requirement

Reported to work in Barrow.

RED Lines = 10 Degree elevation = minimum recommended for BGAN
PINK Lines = Regional Beams of APAC and AMER satellites = Should Work
BLUE Lines = Narrow Beams = Hard to reach

This map depicts Inmarsat's expectations of coverage, but does not represent a guarantee of service. The availability of service at the edge of coverage areas fluctuates depending on various conditions.

Potential Collaborations

Seismology Groups:

NRCan, Yukon Geological Survey
NOAA / Alaska Tsunami Warning Center,
UAF Alaska Earthquake Information Center and GPS,
USGS Alaska Volcano Observatory

PI led;

Audet – Yukon and NWT
Dallimore – Beaufort Sea
…

Other Disciplines:

Soil Temperature

Romanovsky UAF
Dallimore PGC

Meteorlogical

NOAA Weather Service
BLM – Fairbanks, National Petroleum Reserve

Paleoclimate, organic core samples

LDEO - Pateet

For More Information

On the Web

- EarthScope
  www.earthscope.org
- USArray
  www.usarray.org
- PBO
  pboweb.unavco.org
- National Science Foundation
  www.nsf.gov

EarthScope is funded by the National Science Foundation.

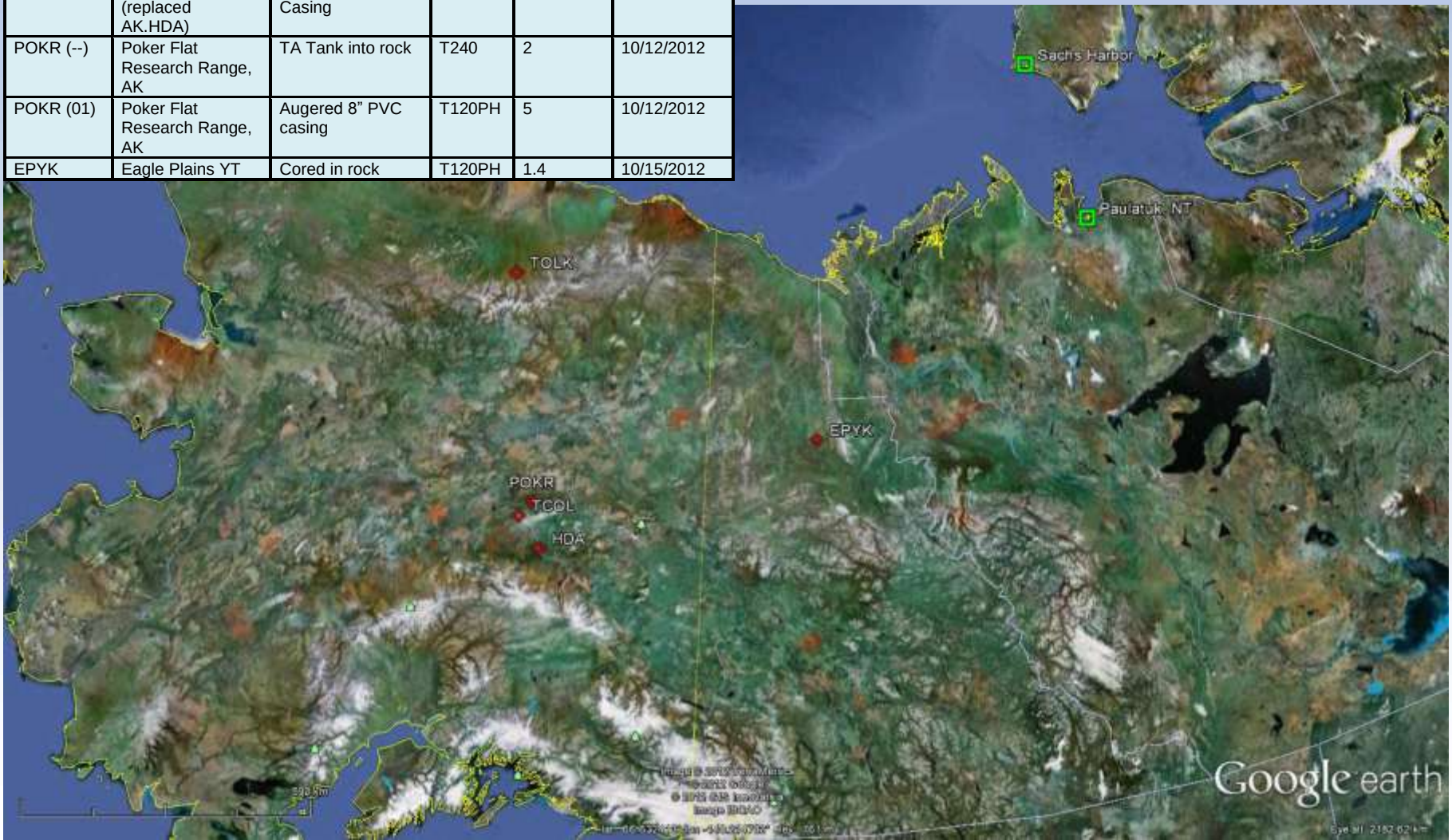
EarthScope is being constructed, operated, and maintained as a collaborative effort with UNAVCO, IRIS, and Stanford University, with contributions from the US Geological Survey, NASA and several other national and international organizations.

Summary

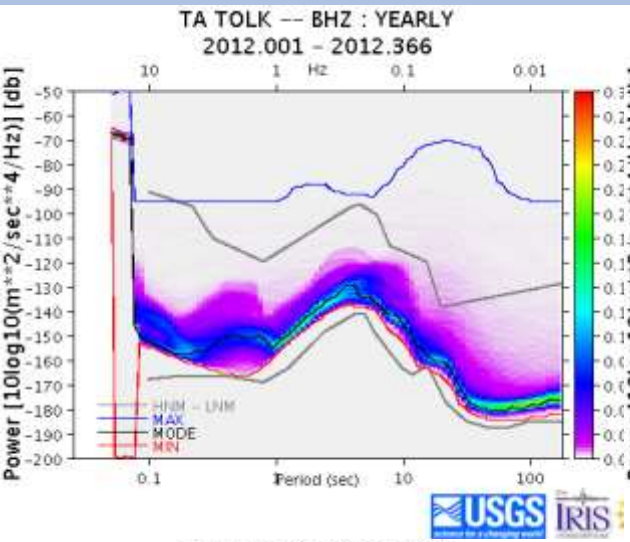
- Current TA operation is fully staffed and operating at high levels of proficiency
  - Some staffing changes are required but the overall subaward structure is well suited to new tasks.
  - An experienced team is in place.
- Proposed schedule balances a rollout in Lower48 and ramp-up in AK, giving some time for techniques and equipment to be adapted to experience
- Development of reliable station deployment in harsh conditions is underway. Logistics planning and permitting are immense challenges.
- The TA in Alaska is poised for success
  - We are working on the ground in Alaska
  - Actively communicating with stakeholder communities
- IRIS Governance has proven to be an excellent model to shepherd community interests and to manage a $50M field effort to collect relevant data, openly available to all.

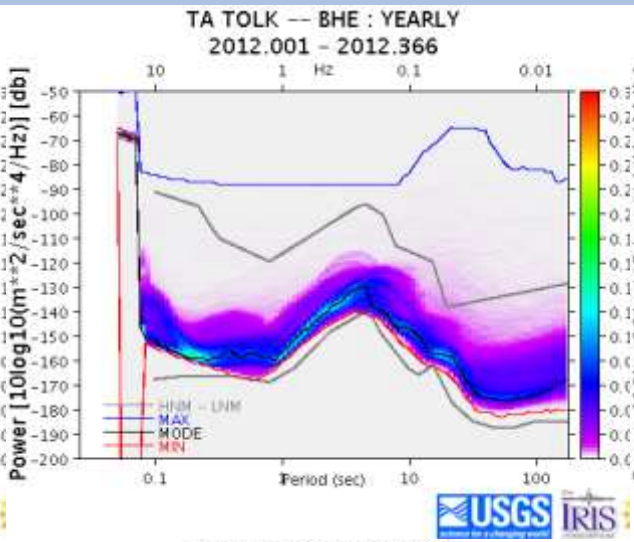
Alaska Test Stations

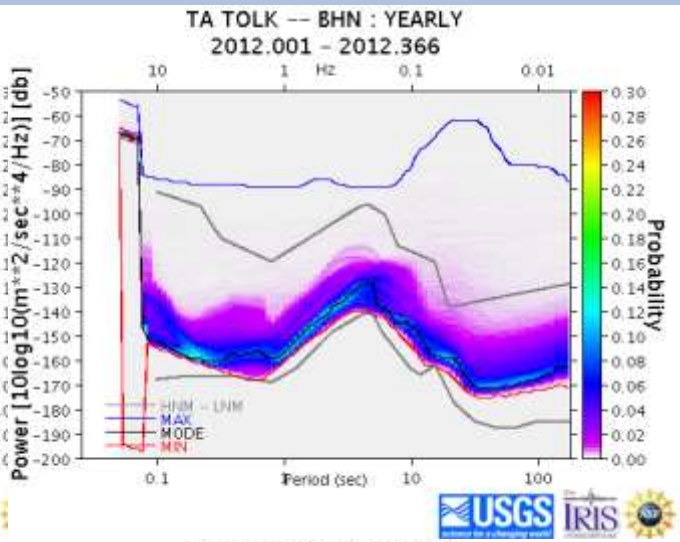
Station	Location	Hole Type	Sensor	Depth (m)	Started
TCOL (--)	CIGO, Fairbanks, AK (adjacent to COLA)	Augered 8” PVC casing	STS-4B	10	10/9/2012
TCOL (01)	CIGO, Fairbanks, AK (adjacent to COLA)	Augered 8” PVC casing	STS-4B	5	10/9/2012
HDA	Harding Lake AK (replaced AK.HDA)	Augered 8” PVC Casing	T120PH	5	10/4/2012
POKR (--)	Poker Flat Research Range, AK	TA Tank into rock	T240	2	10/12/2012
POKR (01)	Poker Flat Research Range, AK	Augered 8” PVC casing	T120PH	5	10/12/2012
EPYK	Eagle Plains YT	Cored in rock	T120PH	1.4	10/15/2012

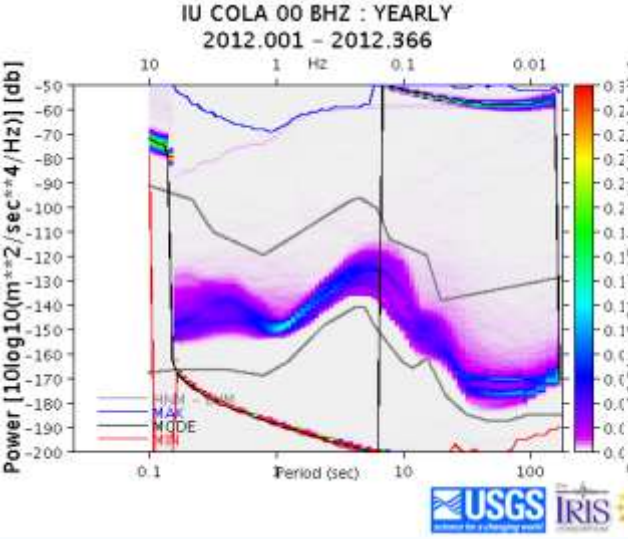


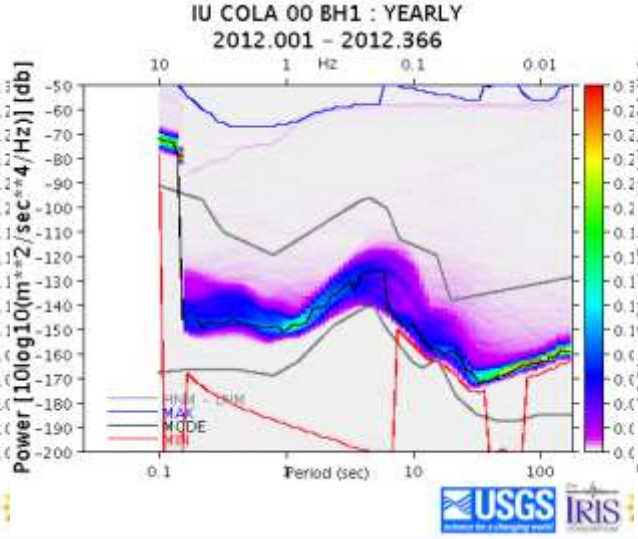
Alaska Stations

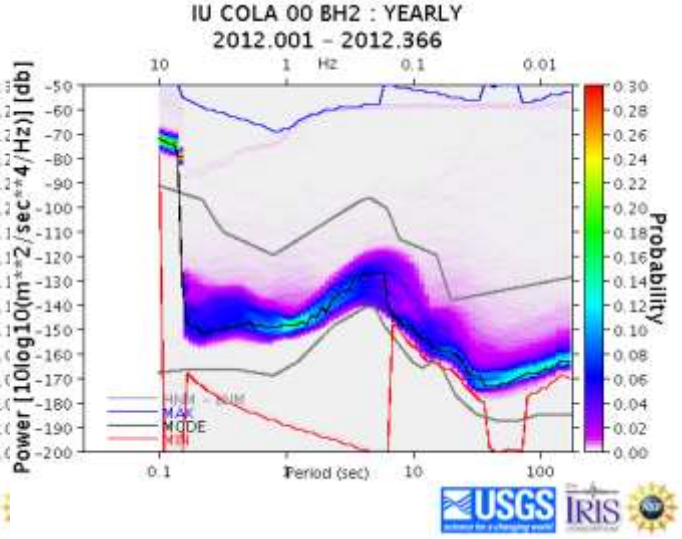






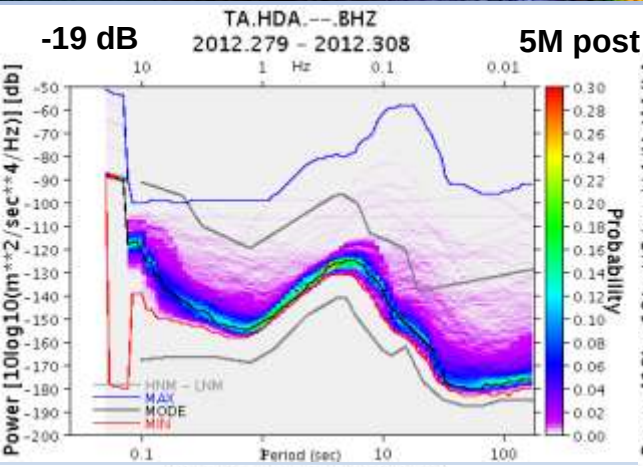




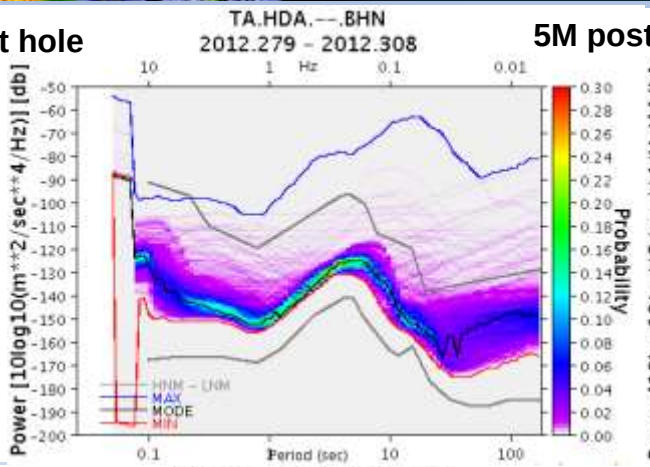


TA.HDA Harding Lake

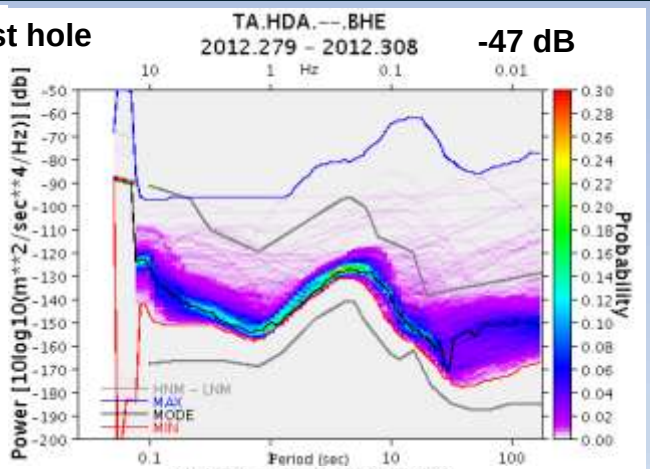
-19 dB



5M post hole

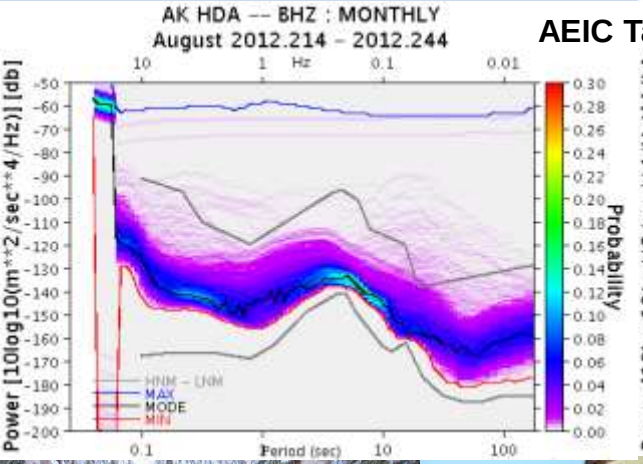


5M post hole

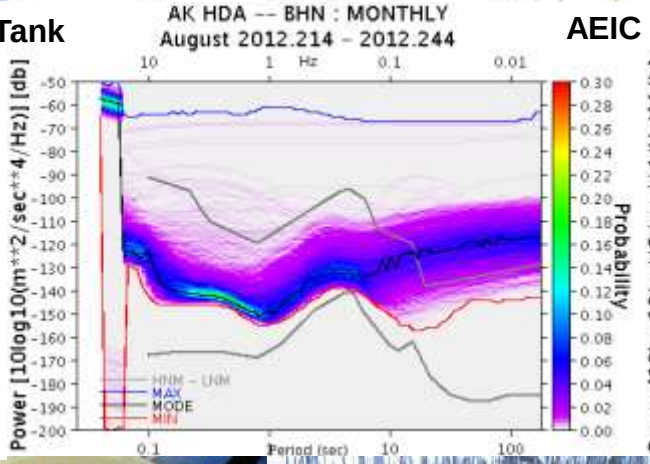


-47 dB

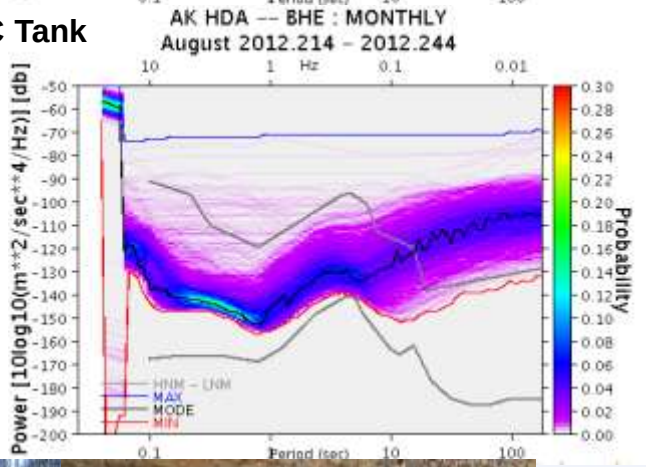
AEIC Tank



AEIC Tank



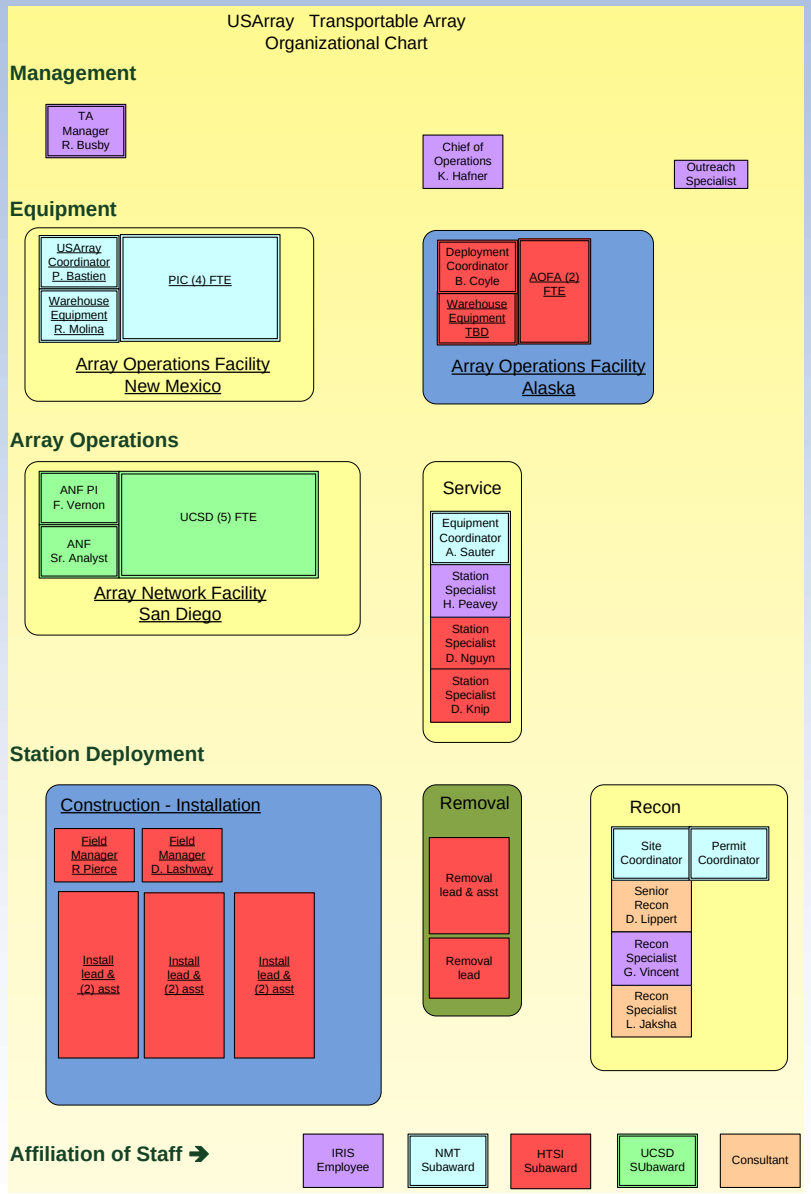
AEIC Tank



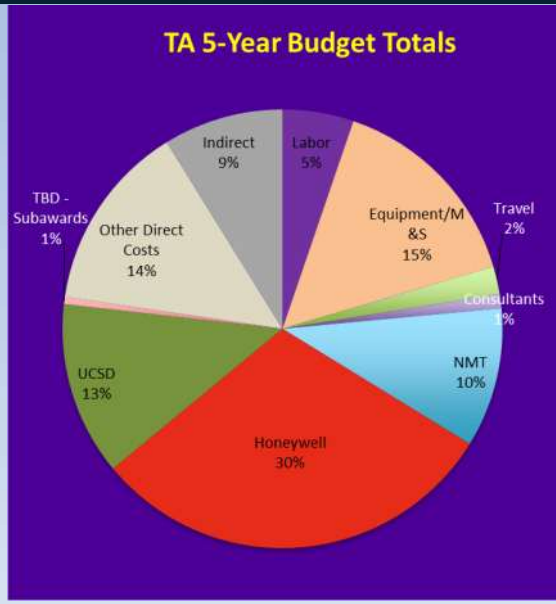
AEIC Tank

5M post hole

Staffing Concept



Small blocks represent FTEs listed in WBS elements and grouped by (colored) functional task blocks. Affiliation of FTE with contract shown at bottom.



Changes in staffing are:

Honeywell Services

New Array Operations in Alaska

Consolidation of construction and Installation teams

Reductions in AOF New Mexico as Alaska ramps up.

Increased Permitting, then transition to install

Add a subaward to UAF to facilitate integration with regional network.