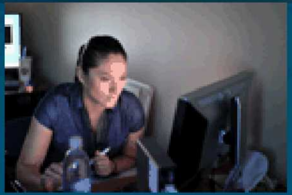
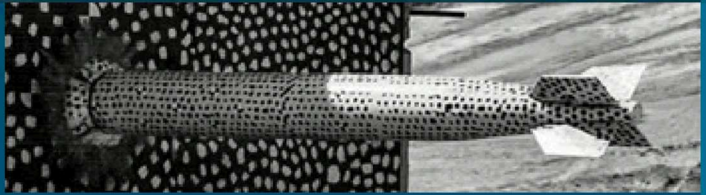
SAND2020-10290C

The Digitization, Calibration, and Recovery of Seismic Waveforms from Analog Tapes





PRESENTED BY

Brian Young // 8861 Geophysics

EIVR-58, October 5–8, 2020

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Legacy Data at the National Labs

>800 US UGTs

- 75% UGTs in the analog era

Data sits on physical tapes (analog), floppy disks, burnt CDs in boxes, cabinets, and bunkers

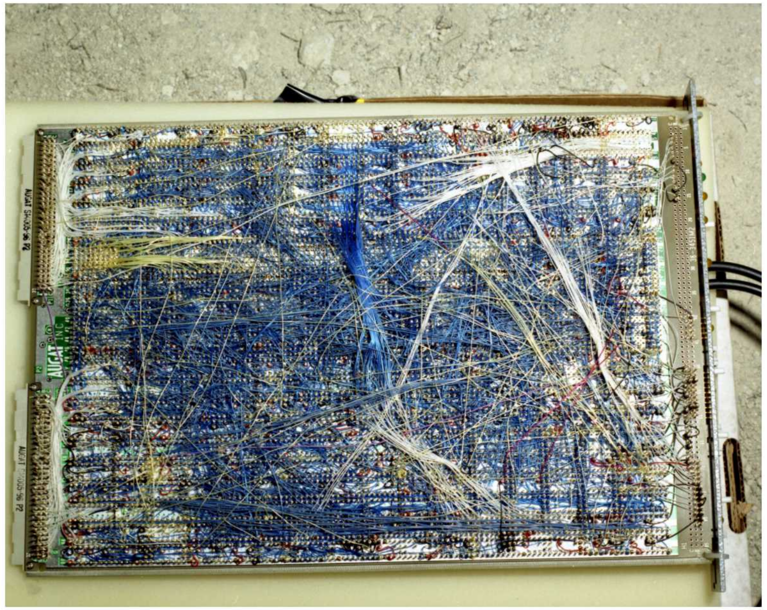
- Slowly decaying
- Tape data decays faster than paper records!

Discovery is a significant effort

- Orphaned data, reports
- Geologic samples

(left) Pallets of abandoned paper seismic records, tapes, and discs at NNSS
(right) LANL archive filled with legacy data in various states of organization

Sandia National Laboratories (1976). INTERIOR TRAILER 001, PROJECT X. National Archives ID: 75455977



Sandia National Laboratories (1976). DISTANT ZENITH-STARS SYSTEM, NEVADA TEST SITE. National Archives ID: 75491015

What can we do with more data?

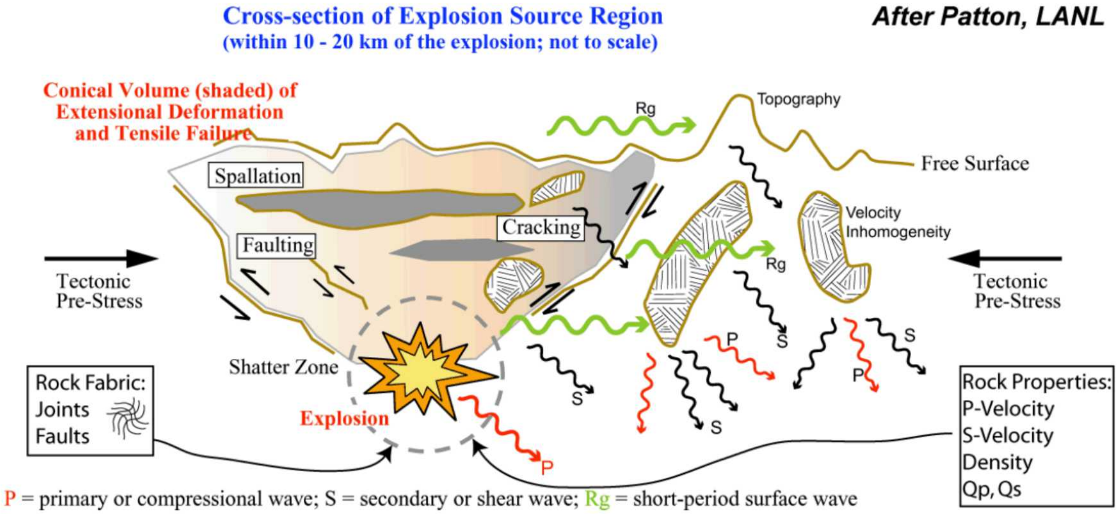
Opportunity cost—action vs. inaction

- What opportunities to learn will be lost if we never recover that data?
- What can we learn with thousands of new waveforms?

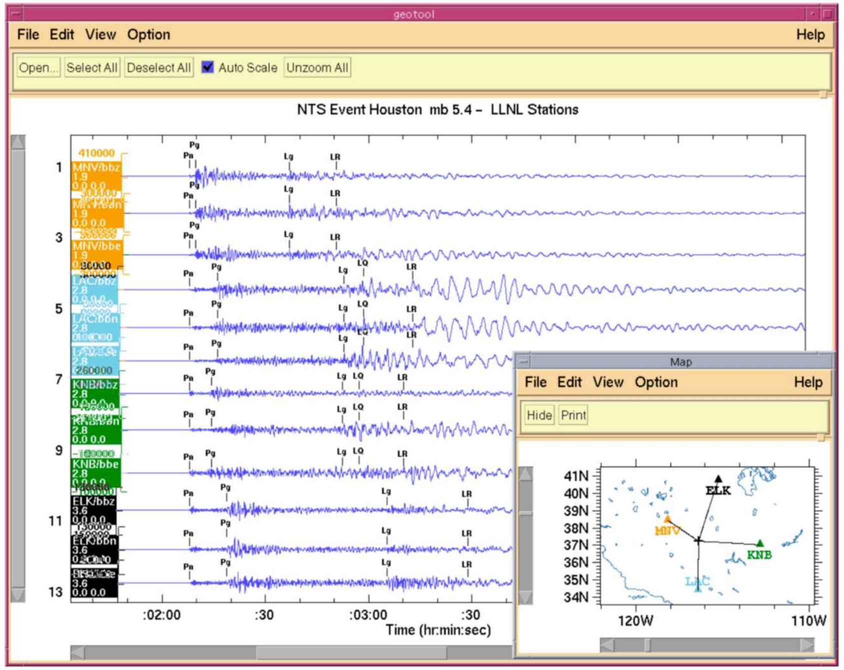
Each event is ground truth

More data means…

- More opportunities to say "*hmm, that's odd…*"
- Machine learning
- Bayesian/statistical analyses
- Uncertainty quantification

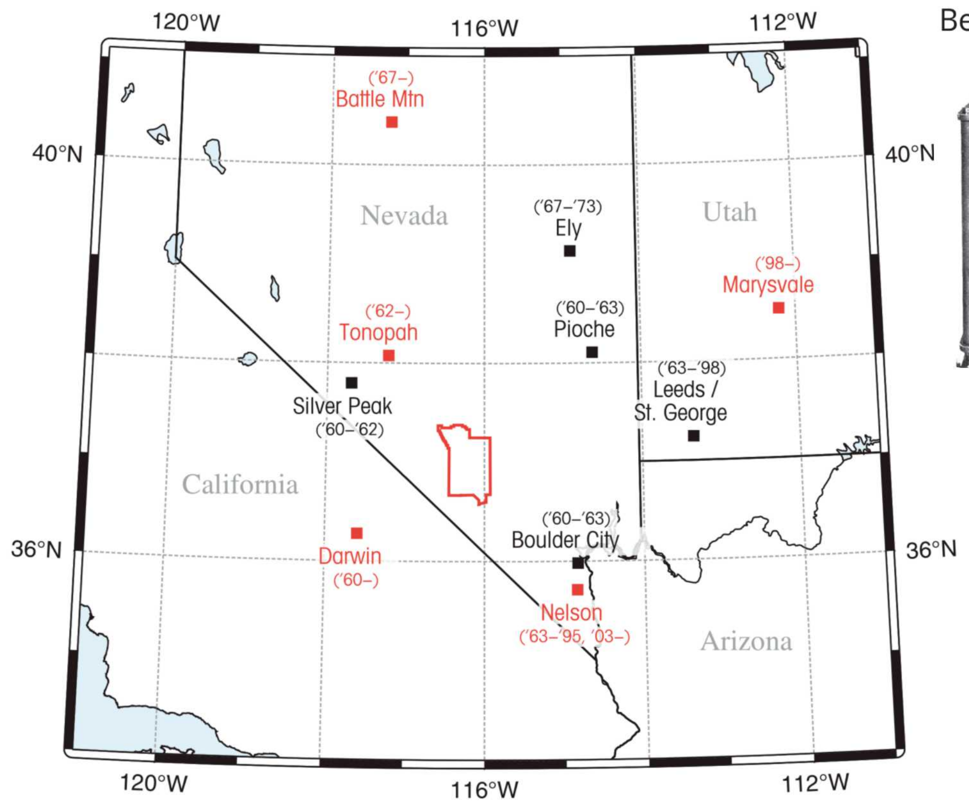


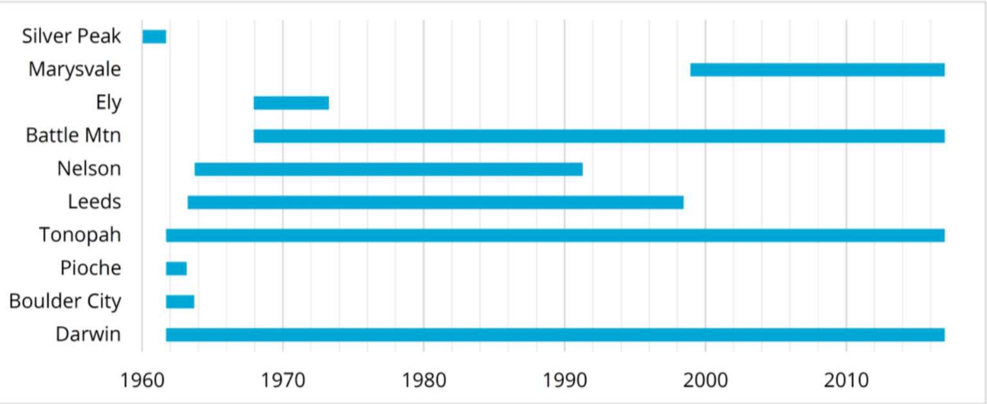
Mellors, R., C. Snelson, A. Pitarka, T. Chen, E. Matzel, W. Walter, and the SPE team (2016). A Large N Array at the Nevada National Securty Site. IRIS: USArray Short Course, Presentation. LLNL-PRES-694105.



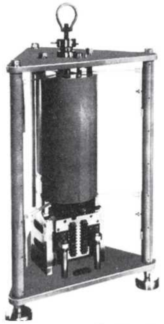
Walter, W. R., K. D. Smith, J. L. O'Boyle, T. F. Hauk, F. Ryall, S. D. Ruppert, S. C. Myers, R. E. Abbott, and D. A. Dodge (2006). An assembled Western United States dataset for regional seismic analysis, *Technical report*, Lawrence Livermore National Laboratory, 22 pp, UCRL-TR-206630. Available at https://ds.iris.edu/mda/18-001/

Leo Brady Seismic Network

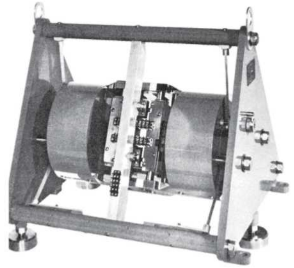




Benioff 1051



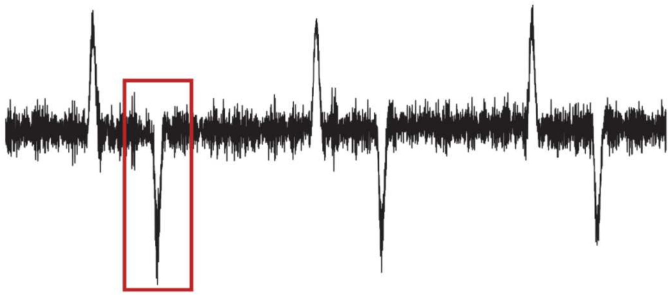
Benioff 1101



Crown CX822

Benioff seismometers at Nelson's Landing (June 1985)

AMPEX tape players at Sandia National Laboratories



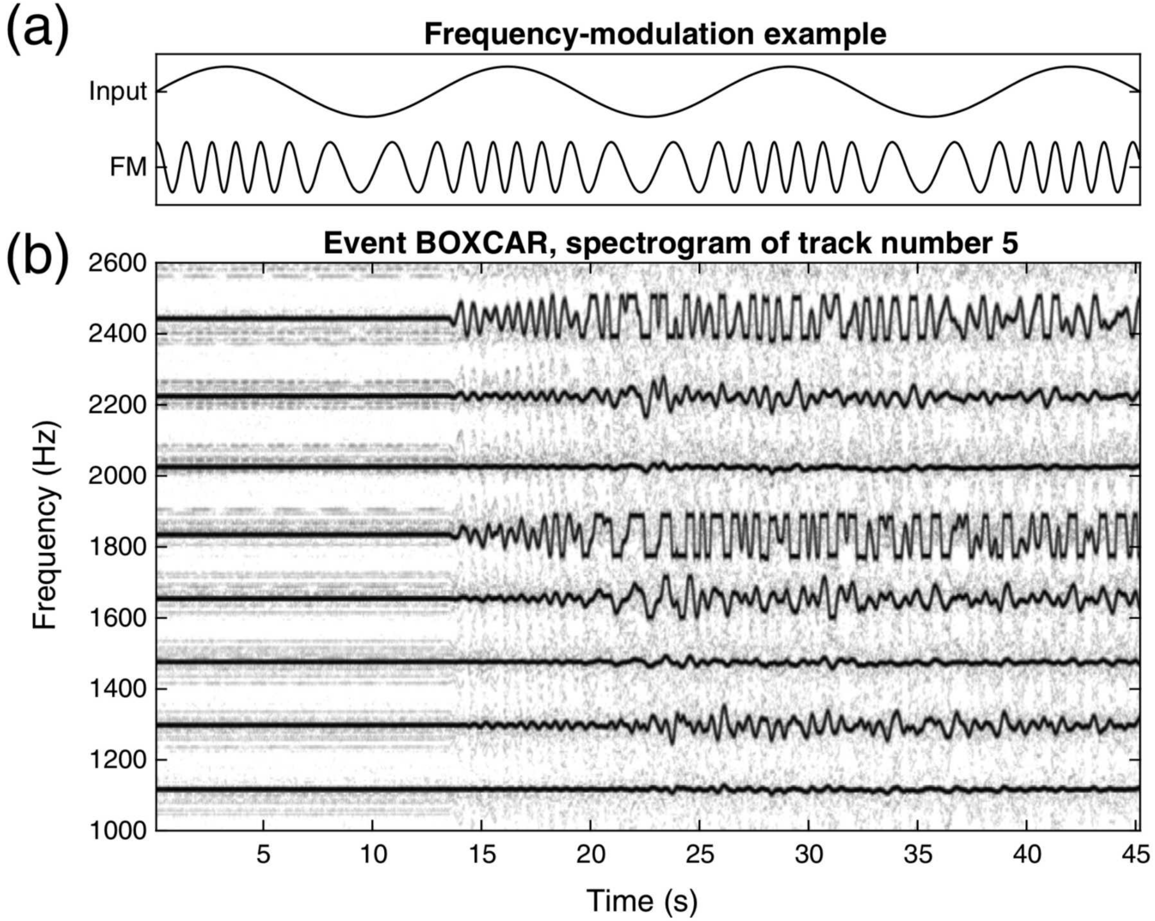
~75% UGTs were in analog era

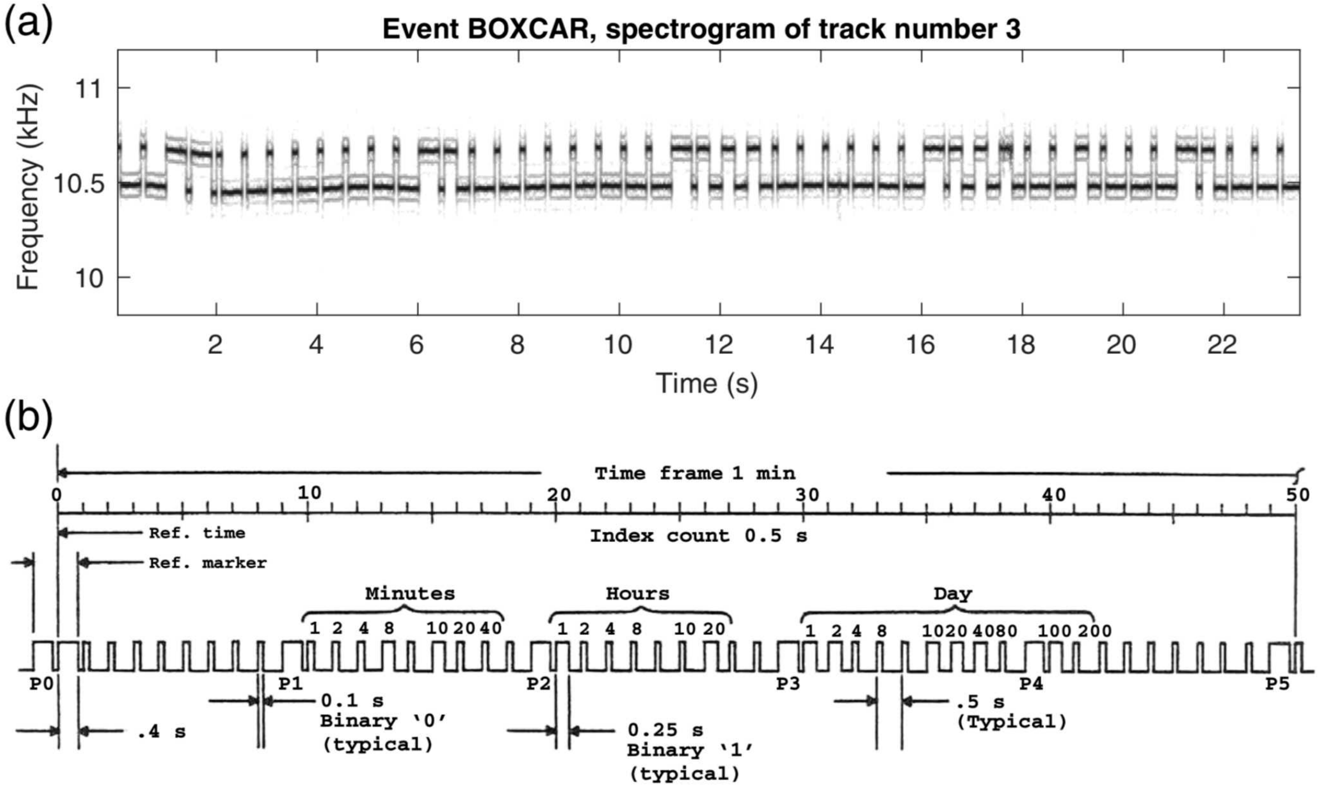
~600 UGTs, 1000+ tapes digitized

Digitizing tapes and recovering data

Analog tapes were hi-fi audio tapes (AMPEX)
- Used primarily for music, movie industries

Time signals are bits encoded as square waves in frequency
- IRIG-C



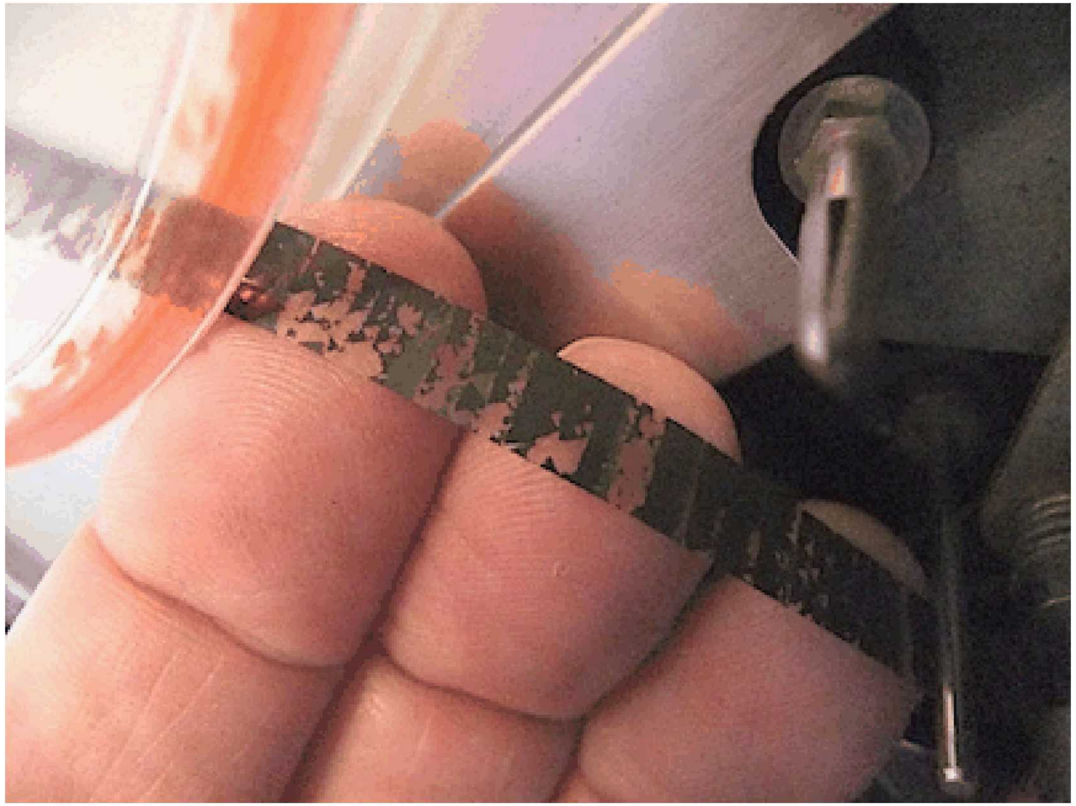


Digitizing tapes and recovering data

Analog tapes were hi-fi audio tapes (AMPEX)

- Used primarily for music, movie industries

Have to bake the tapes to avoid “sticky-shed syndrome”



Grimshaw, C. (2010). Creating this blog is a sticky business! *Imperial College Video Archive Blog*, Imperial College London. Accessed 2020-Sep-17 from: https://wwwf.imperial.ac.uk/blog/videoarchive/creating-this-blog-is-a-sticky-business/

Calibration

$$\sum F = 0 \qquad F = ma \qquad F = -kx$$

$$m\ddot{x} + c\dot{x} + kx = 0$$

$$V(t) = -G\frac{m_w g}{m\omega_d}e^{-\lambda\omega_0 t}\sin\omega_d t$$

$$\hat{T}_V(\omega) = \hat{T}_s(\omega)\cdot\hat{T}_g(\omega)\cdot\hat{T}_1(\omega)\cdot\hat{T}_2(\omega)$$

$$\hat{T}_s(\omega) = \frac{-\omega^2}{-\omega^2 + i2\lambda\omega\omega_0 + \omega_0^2}$$

$$\hat{T}_g(\omega) = \frac{\omega_g^2}{-\omega^2 + i2\lambda_g\omega\omega_g + \omega_g^2}$$

$$\hat{T}_1(\omega) = \frac{i\omega Q_{1a}\sqrt{2}}{i\omega + \omega_{1a}}\cdot\frac{\omega_{1b}^2}{-\omega^2 + i\omega\omega_{1b}Q_{1b}^{-1} + \omega_{1b}^2}$$

$$\hat{T}_2(\omega) = \frac{i\omega Q_{2a}\sqrt{2}}{i\omega + \omega_{2a}}\cdot\frac{\omega_{2b}^2}{-\omega^2 + i\omega\omega_{2b}Q_{2b}^{-1} + \omega_{2b}^2}$$

Coefficient	Value
z_0, z_1, z_2, z_3	0
p_0, p_1	$-\lambda\omega_0 \pm \omega_0\sqrt{\lambda^2 - 1}$
p_2, p_3	$-\lambda_g\omega_g \pm \omega_g\sqrt{\lambda_g^2 - 1}$
p_4	$-\omega_{1a}$
p_5, p_6	$-(2Q_{1b})^{-1}\omega_{1b} \pm \sqrt{(2Q_{1b})^{-2} - 1}$
p_7	$-\omega_{2a}$
p_8, p_9	$-(2Q_{2b})^{-1}\omega_{2b} \pm \sqrt{(2Q_{2b})^{-2} - 1}$
K	-1
K_g	ω_g^2
K_{1a}	$Q_{1a}\sqrt{2}$
K_{1b}	ω_{1b}^2
K_{2a}	$Q_{2a}\sqrt{2}$
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$$\hat{T}_V(s) = \hat{T}_s(s)\cdot\hat{T}_g(s)\cdot\hat{T}_1(s)\cdot\hat{T}_2(s)$$

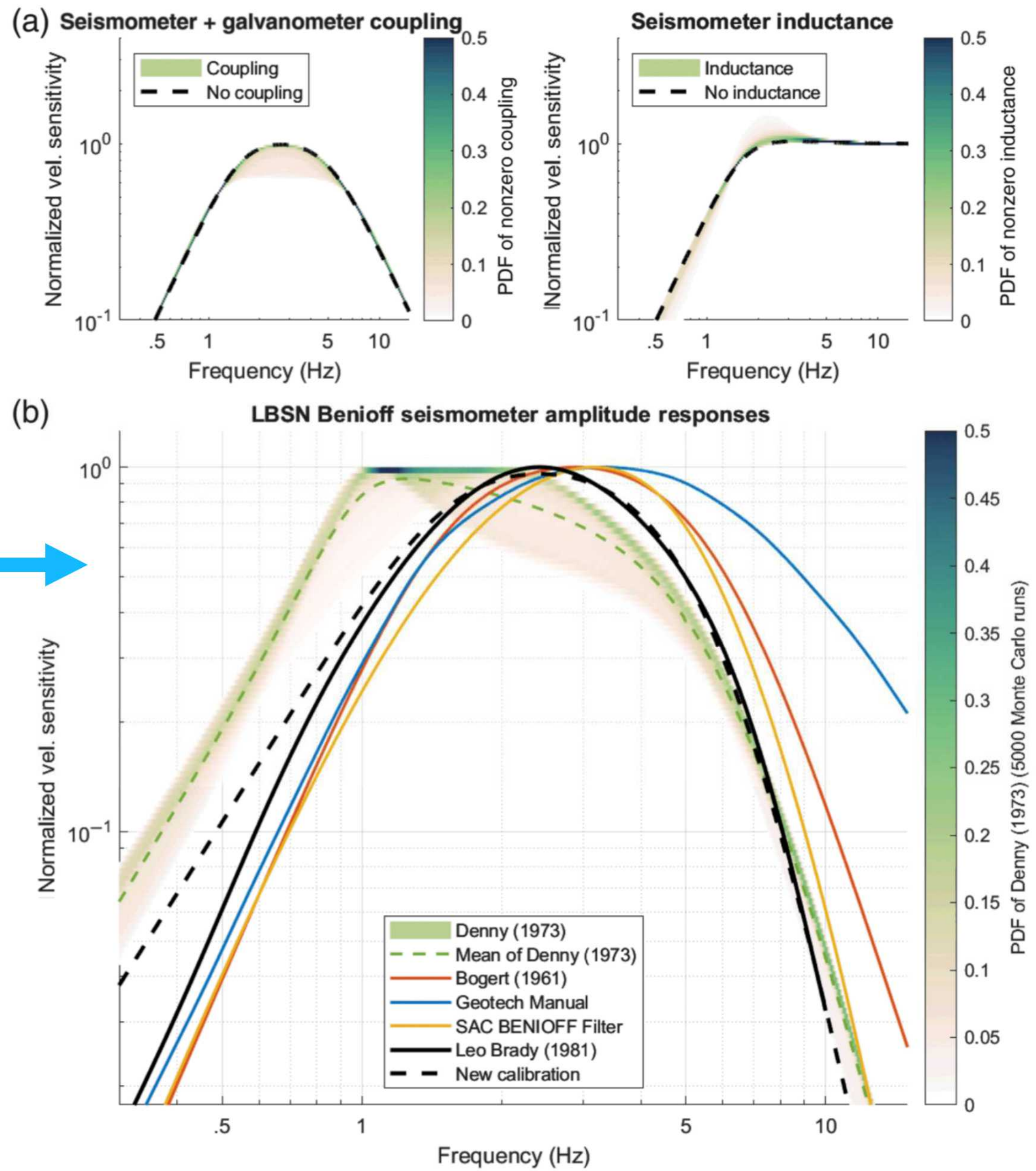
$$\hat{T}_s(s) = K\frac{(s-z_0)(s-z_1)}{(s-p_0)(s-p_1)}$$

$$\hat{T}_g(s) = K_g\frac{1}{(s-p_2)(s-p_3)}$$

$$\hat{T}_1(s) = K_{1a}\frac{(s-z_2)}{(s-p_4)}\cdot K_{1b}\frac{1}{(s-p_5)(s-p_6)}$$

$$\hat{T}_2(s) = K_{2a}\frac{(s-z_3)}{(s-p_7)}\cdot K_{2b}\frac{1}{(s-p_8)(s-p_9)}$$

Young, B. A. and R. E. Abbott (2020). Recovery and Calibration of Legacy Underground Nuclear Test Seismic Data from the Leo Brady Seismic Network. Seismol. Res. Lett., 91(3), 1488–1499. doi: 10.1785/0220190341



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$$\frac{}{(s-p_4)} \cdot \frac{}{(s-p_5)(s-p_6)}$$

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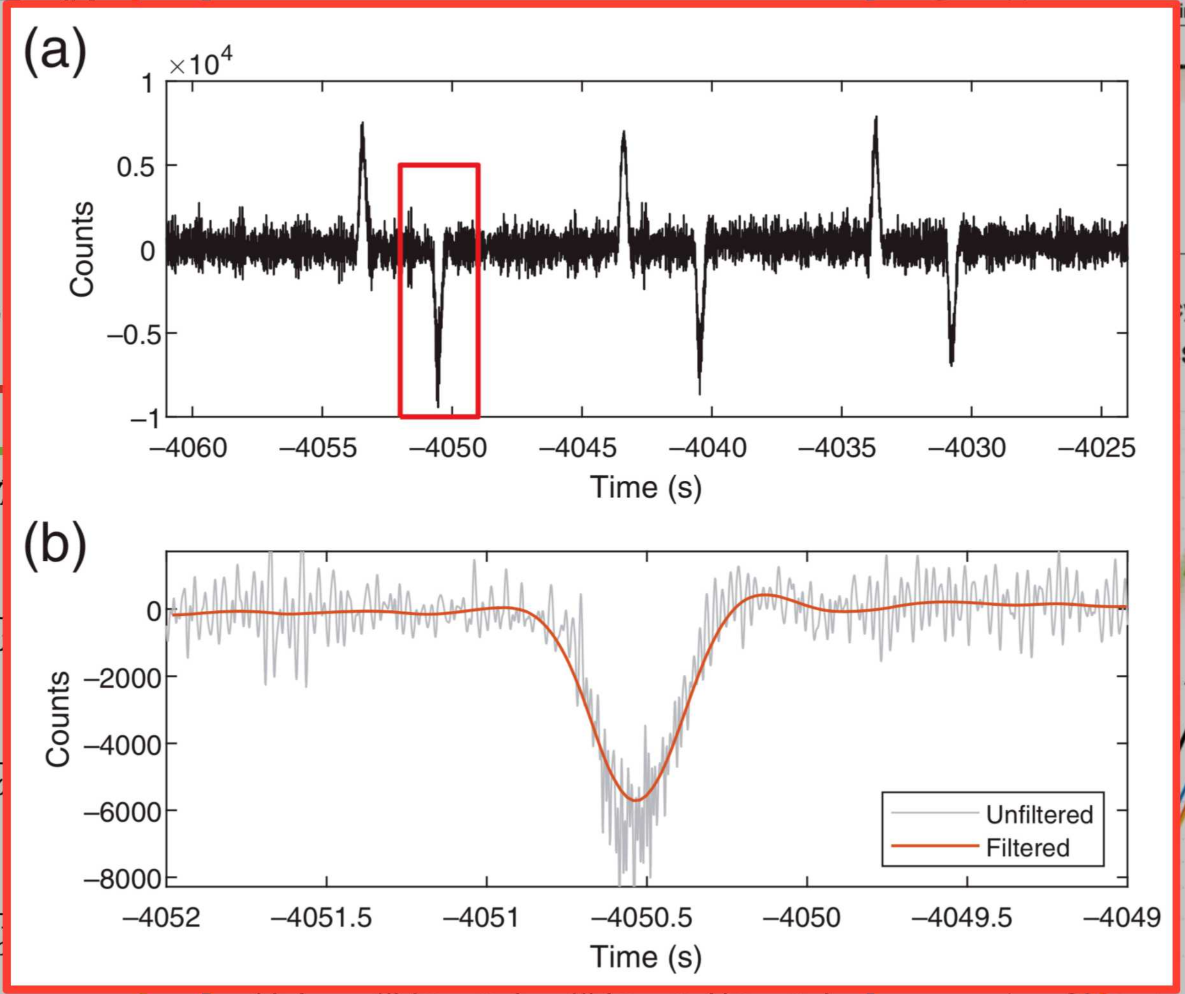

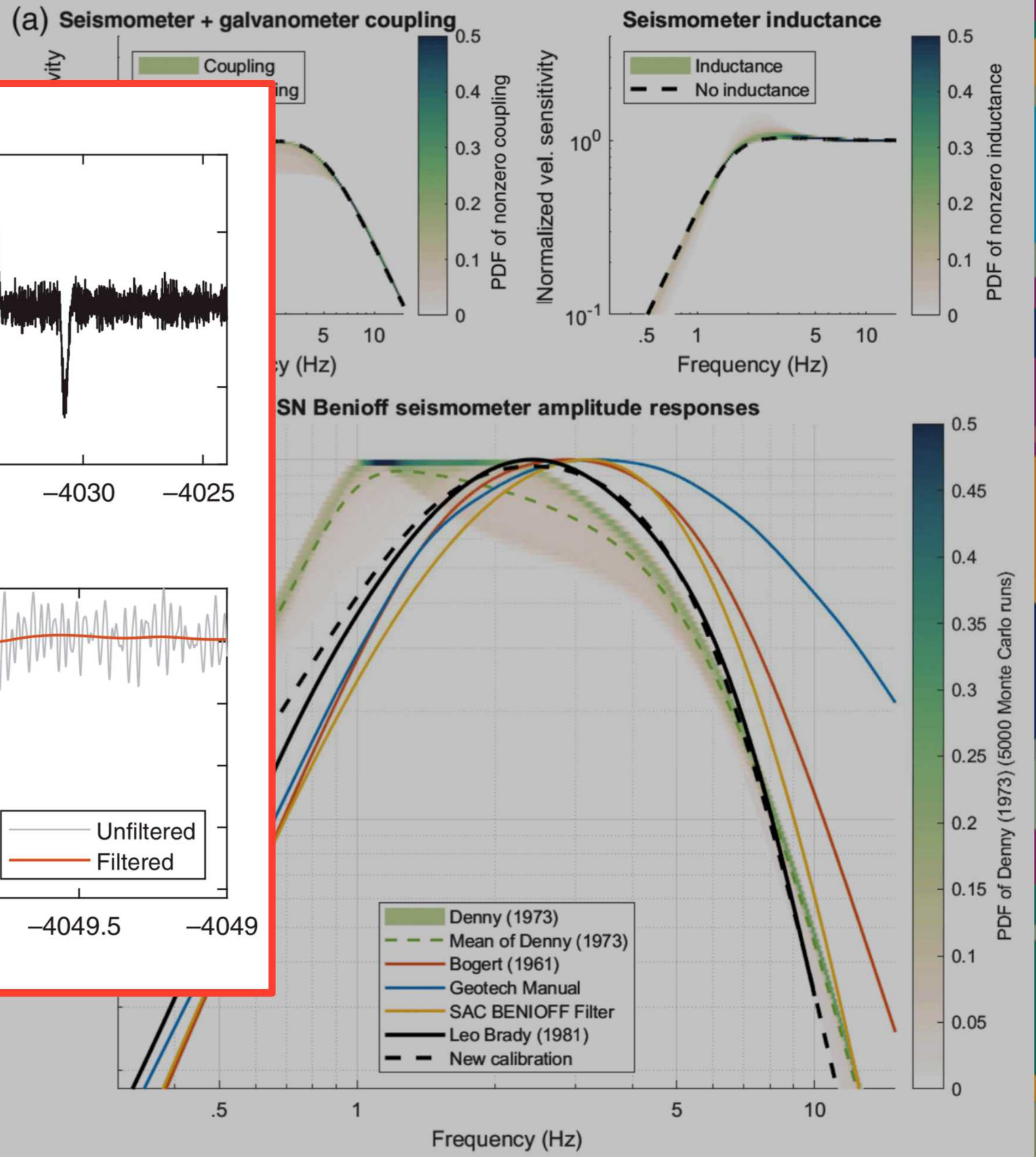

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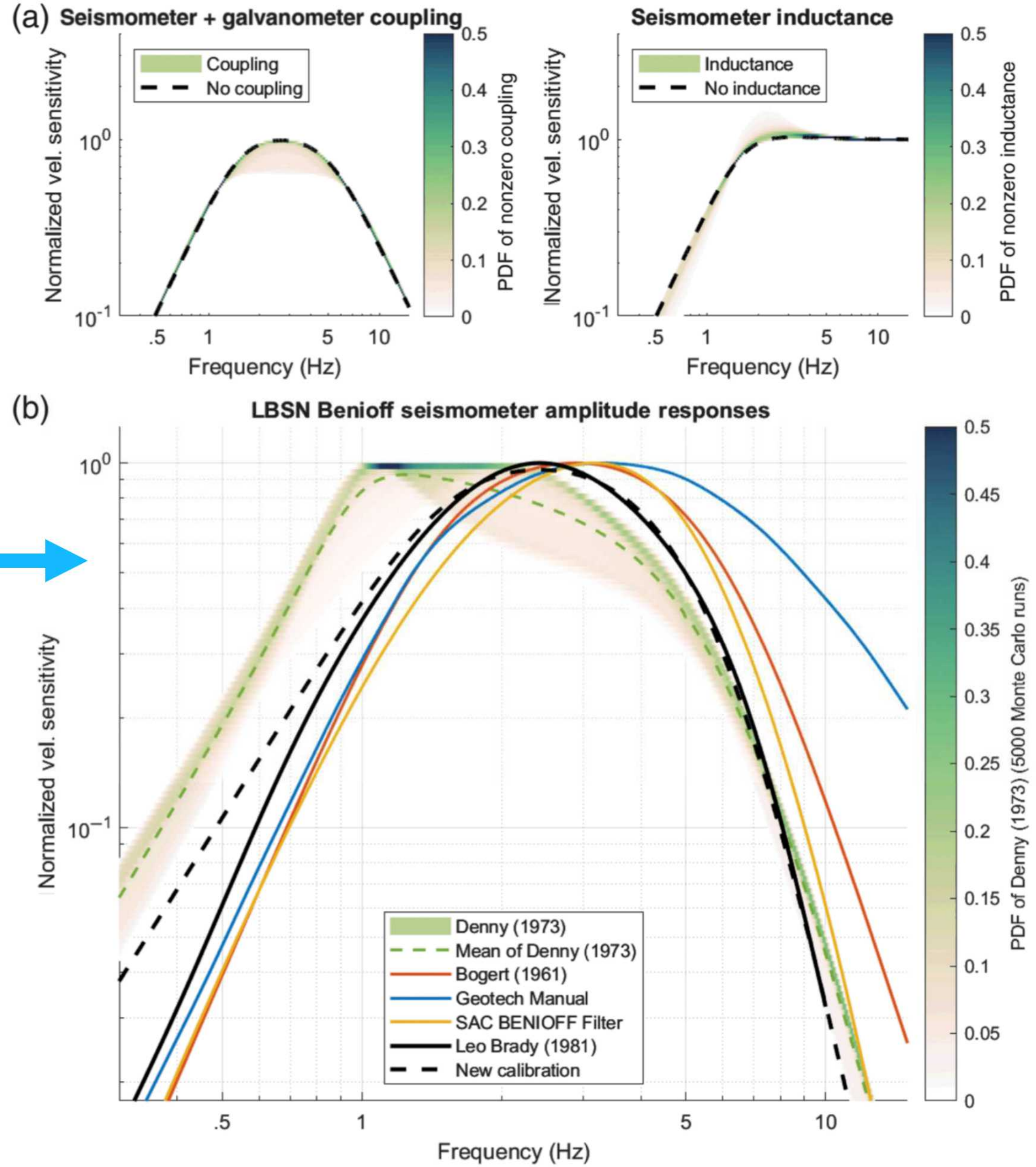
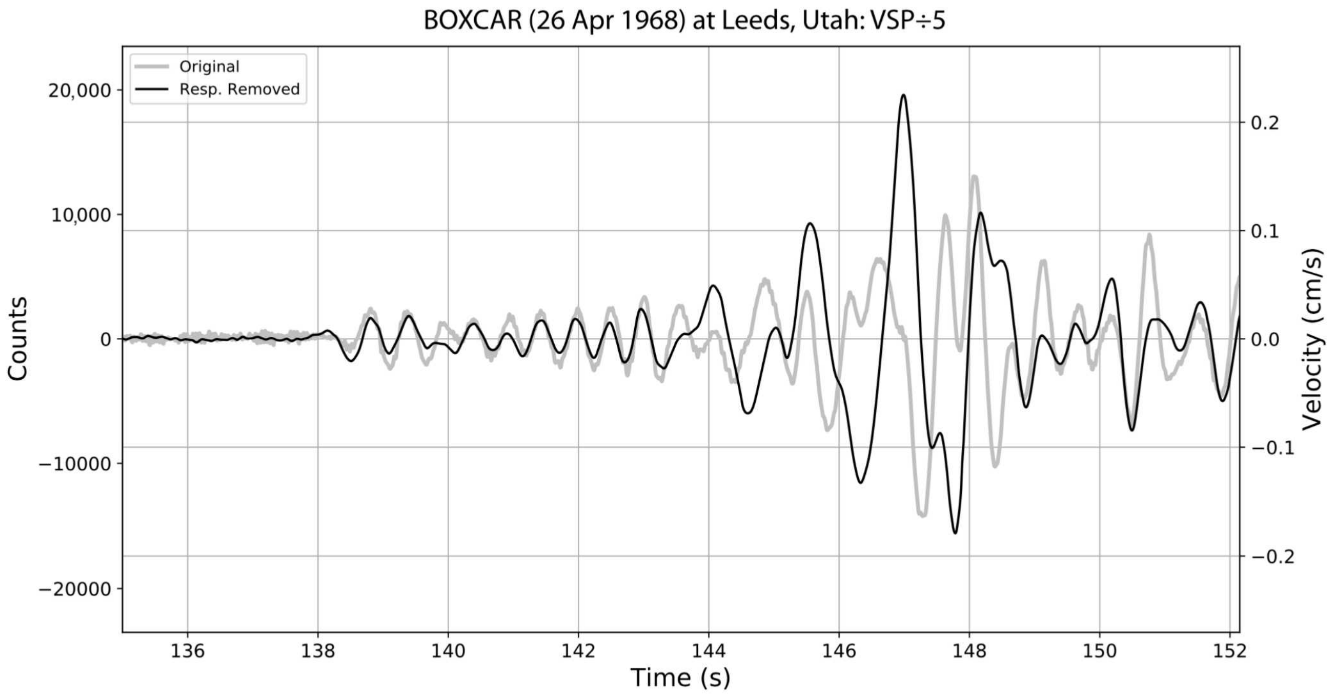


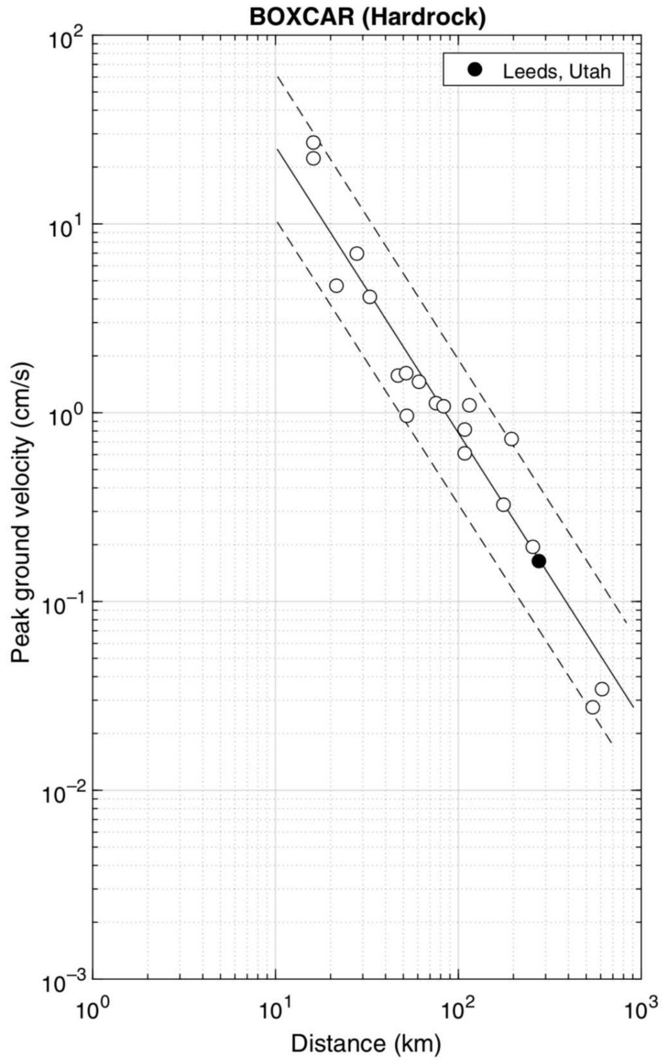
Calibration

Pre-1992 method:
0.1472 cm/s
(assumes constant nominal deflection, natural period)

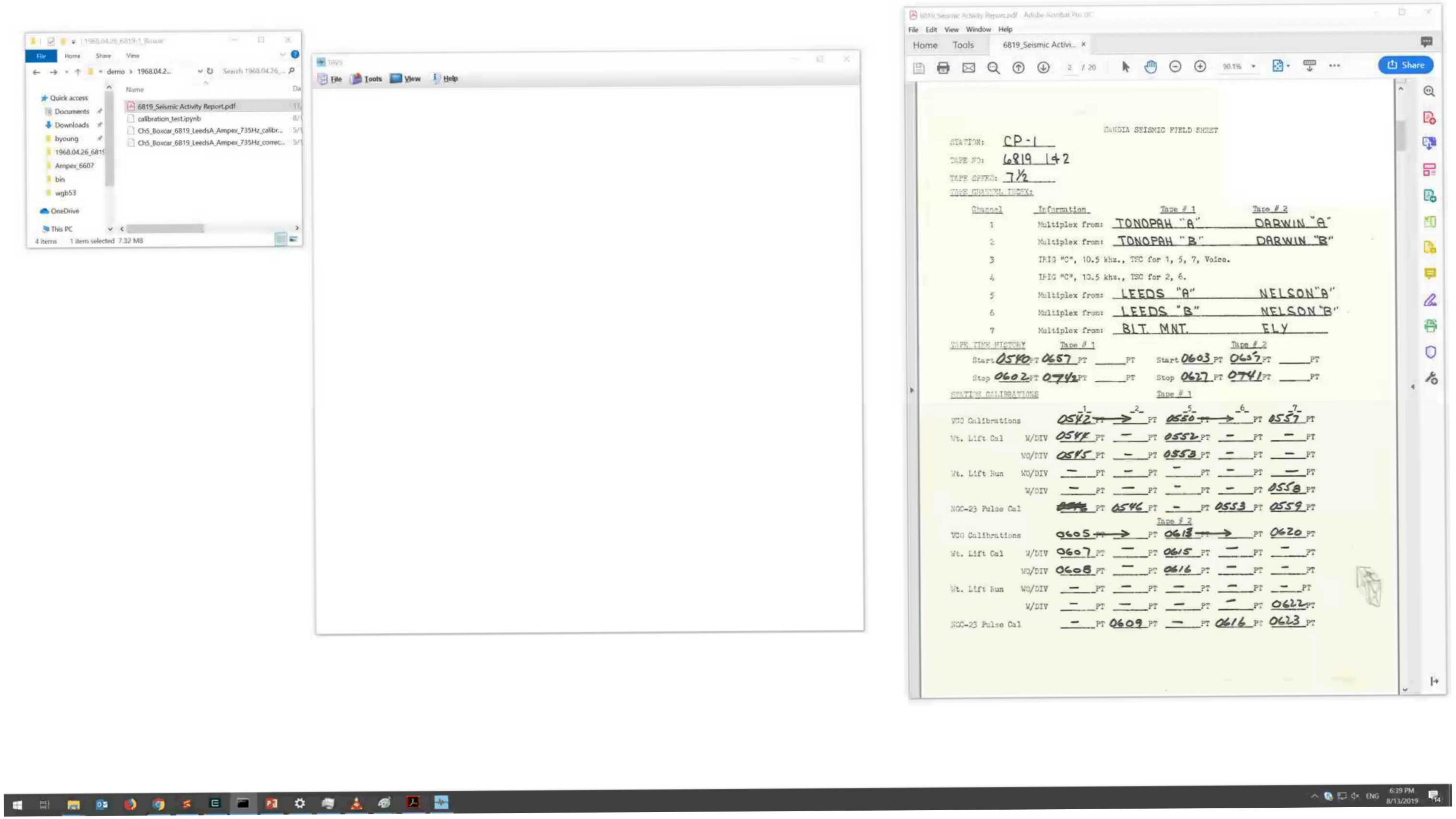
New method:
0.1637 cm/s
(Recalculate instrument constants from recorded calibration pulses)

Murphy & Lahoud (BSSA, 1969):
0.1620 cm/s
(empirical)





Telemetry Analysis & Visualization Suite

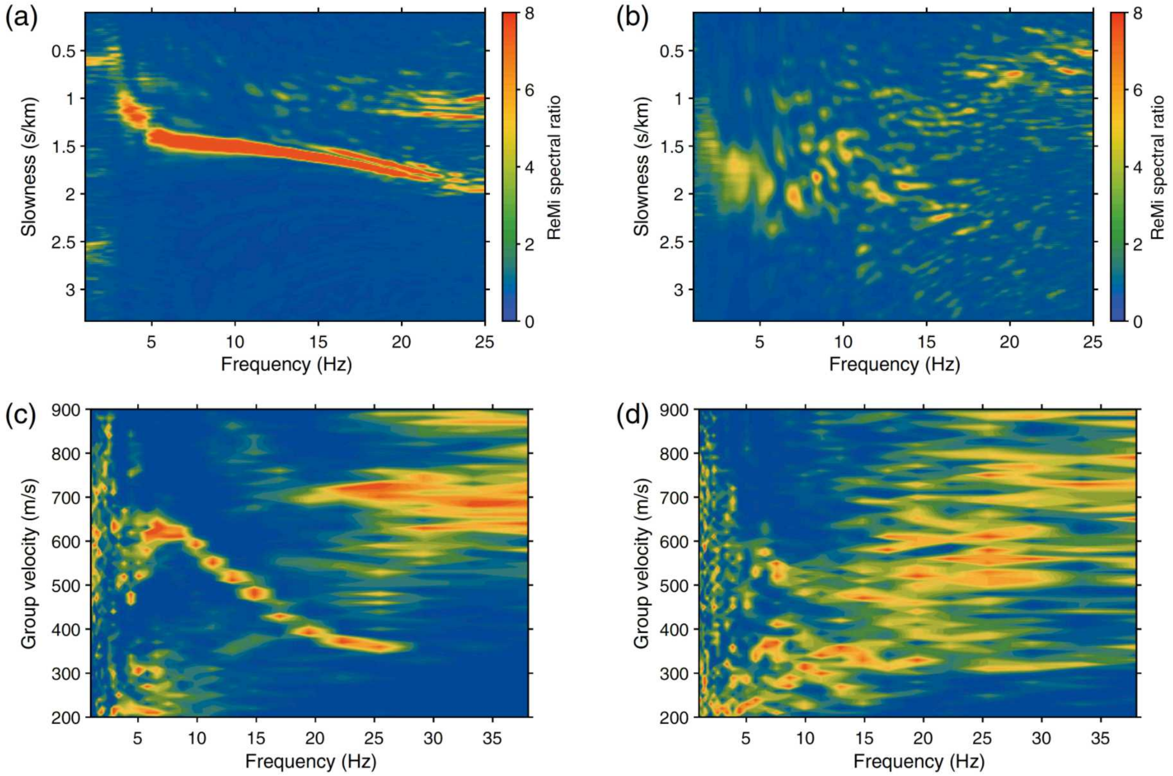


Future work


EG&G/LOS ALAMOS DATA TAPE
DO NOT ERASE
AMPEX


LNN 1990 (continued)
Unclassified Use Only

Future work



Toney, L. D., R. E. Abbott, L. A. Preston, D. G. Tang, T. Finlay, and K. Phillips-Alonge (2019). Joint Body- and Surface-Wave Tomography of Yucca Flat, Nevada, Using a Novel Seismic Source. *Bull. Seismol. Soc. Am.*, doi: 10.1785/0120180322