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CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
HOFBURG PALACE - Vienna and Online
19 TO 23 JUNE

Recently digitized and calibrated historical seismic data of U.S. underground nuclear tests recorded on the Leo Brady Seismic Network in the 1960s and 1970s

Brian A. Young, Danielle Shields
Sandia National Laboratories

Sandia National Laboratories

INTRODUCTION

We recovered 1300 seismic waveforms from 20 historical U.S. underground nuclear tests recorded by the Leo Brady Seismic Network (LBSN).

These waveforms are available for download at *https://www.iris.edu/*

METHODS/DATA

We recover legacy analog waveforms by playing back magnetic tapes using old Ampex tape players and digitizing the output.

We calibrate short-period waveforms by modeling weight lift tests and inverting for the unique instrument constants.

START

RESULTS

20 historical events

1300 recovered waveforms

449 unique channels

151 calibrated short-period waveforms

71% success calibrating short-period waveforms

90% calibrating at least one unique waveform per event

CONCLUSION

We have a mature process for recovery and calibration of legacy seismic data for historical U.S. underground nuclear tests.

The majority of data are recoverable despite age.

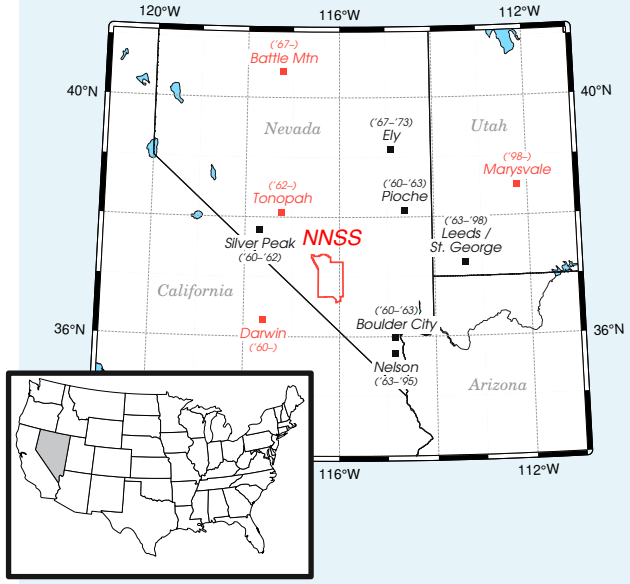
These data are publicly available on IRIS.

Please do not use this space, a QR code will be automatically overlayed

P2.5-500

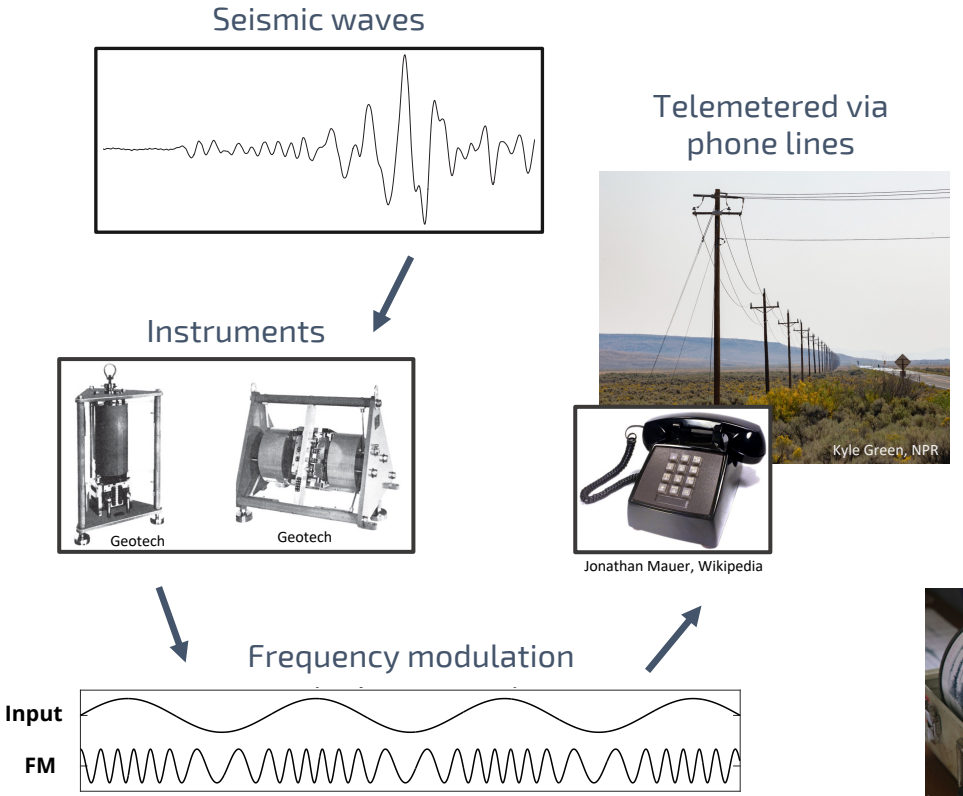
Introduction

Leo Brady Seismic Network



LBSN was deployed in ~1960 and recorded 90% of U.S. underground nuclear tests at the NNSS until the end of testing in 1992

Seismic data were recorded as frequency-modulated (FM) waveforms on analog tapes

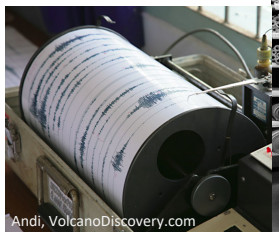


Analog tapes still exist, and we can recover data from them!

Sameer Verma, Flickr

Sandia National Laboratories

Split between tape, paper



Andi, VolcanoDiscovery.com

Dorris Tendall, SNL

Paper records no longer exist

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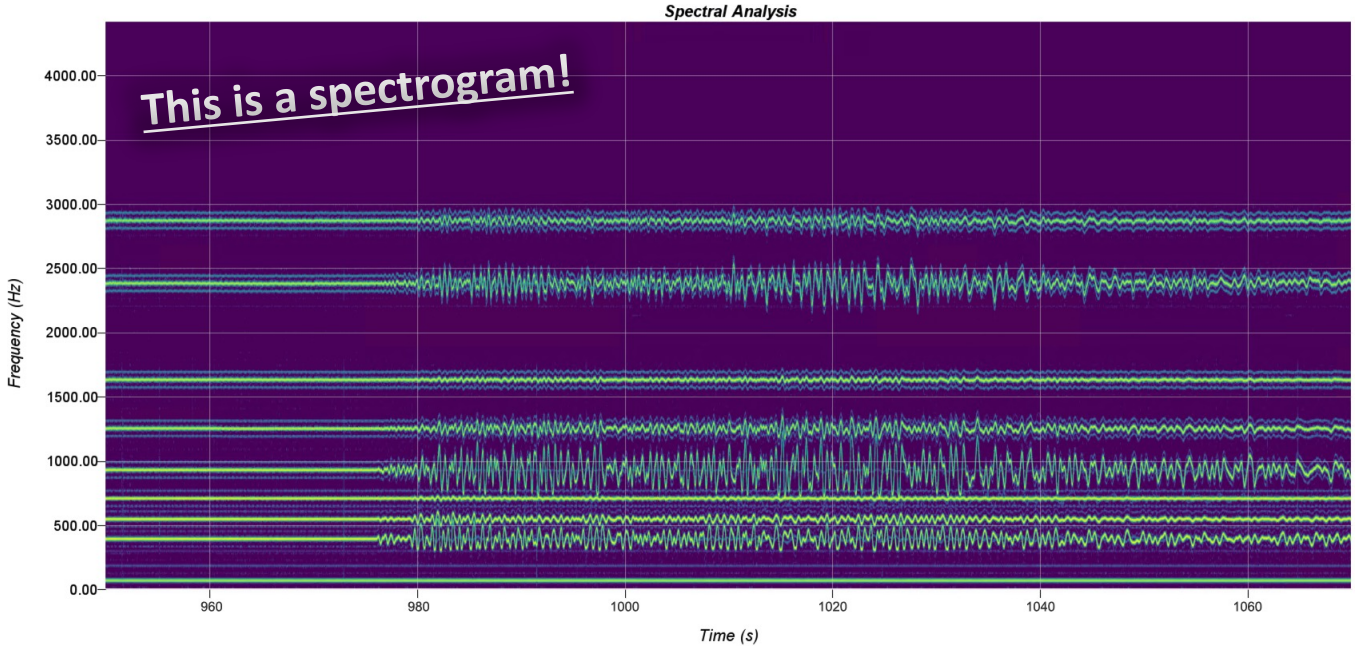
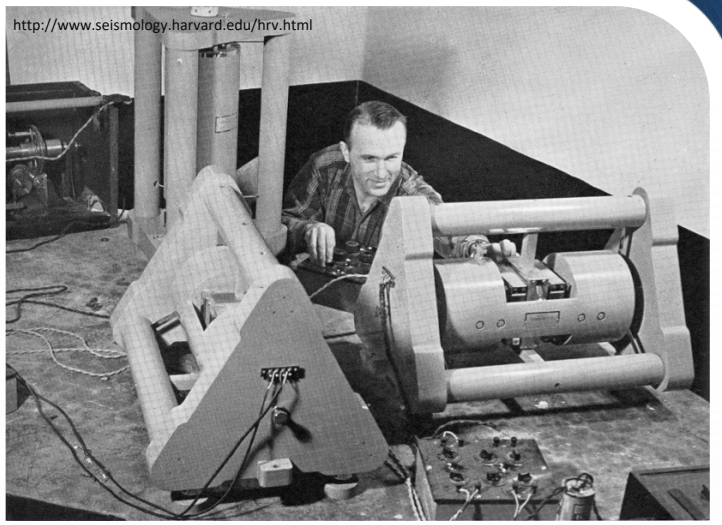
Objectives

1. Digitize analog data
2. Recover waveforms
3. Determine instrument response
4. Calibrate the waveforms

Analog tape



Frequency-modulated data



Benioff Short-Period Seismometers

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Methods / Data

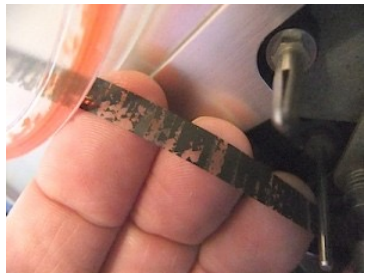
How do we recover the data?

They're "audio" tapes.

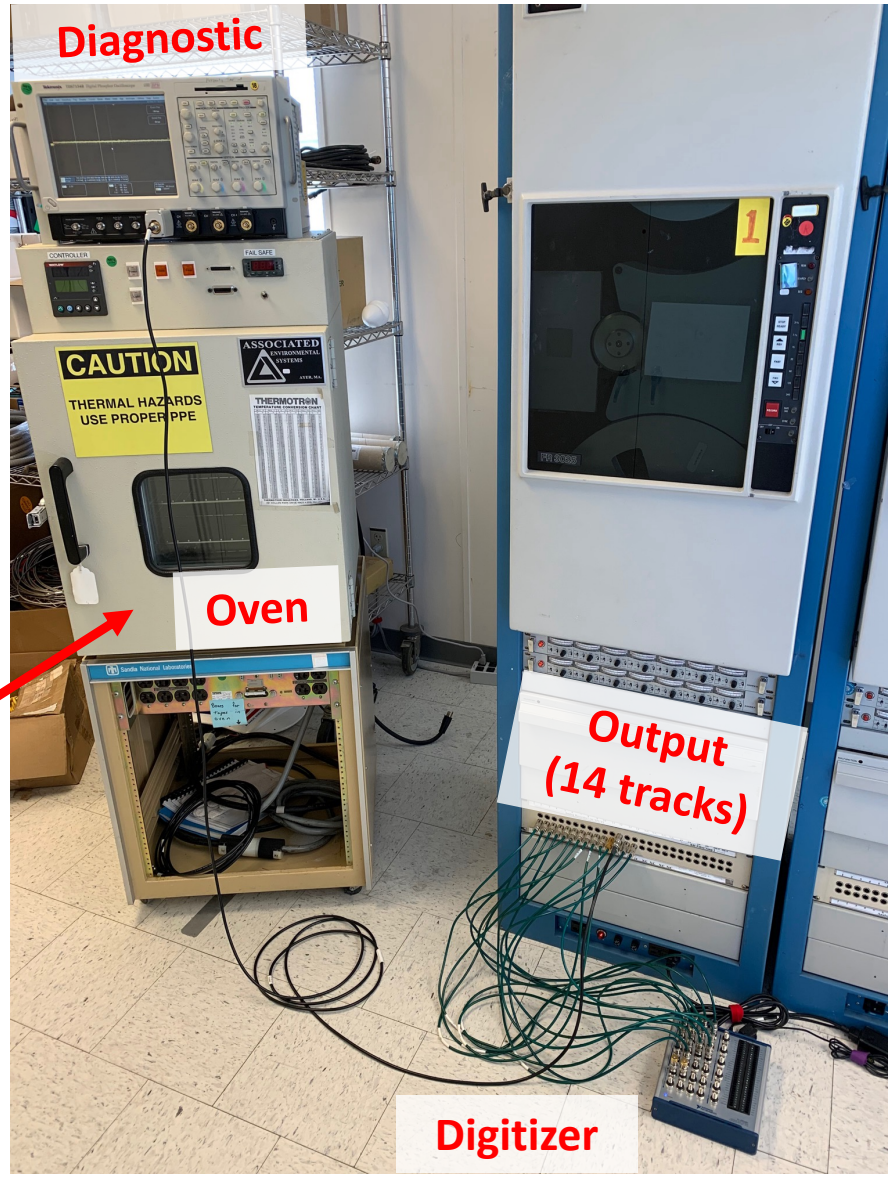
Play them, and digitize the output!

Then process as digital signals.

Beware "Sticky Shed"



https://blogs.imperial.ac.uk/videoarchive/creating-this-blog-is-a-sticky-business/



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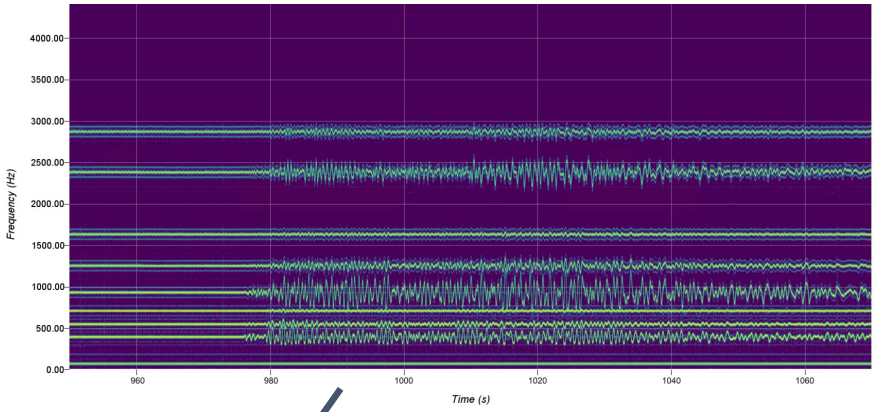
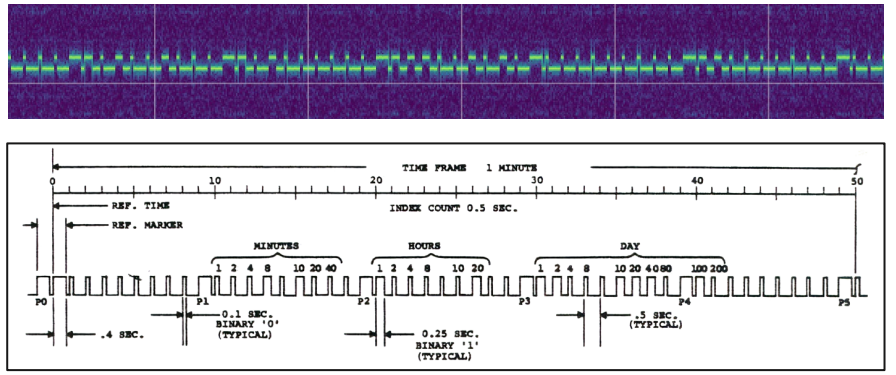
Methods / Data

Demodulate the data



Decipher IRIG timing signal

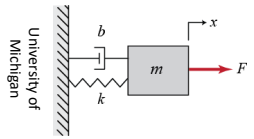


Equations of motion

Newton's & Hooke's Laws

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

Damped mass-on-a-spring



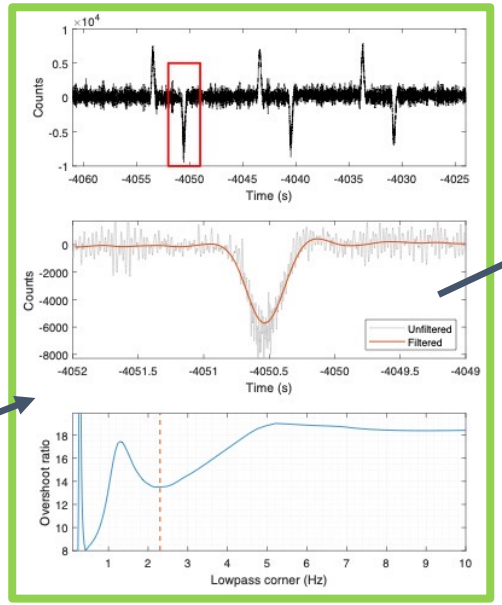
$$m\ddot{x} + b\dot{x} + kx = 0$$

Seismometer

$$\ddot{x} + 2\lambda\omega_0\dot{x} + \omega_0^2 x = 0$$

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

Model the weight lift



Instrument constants

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

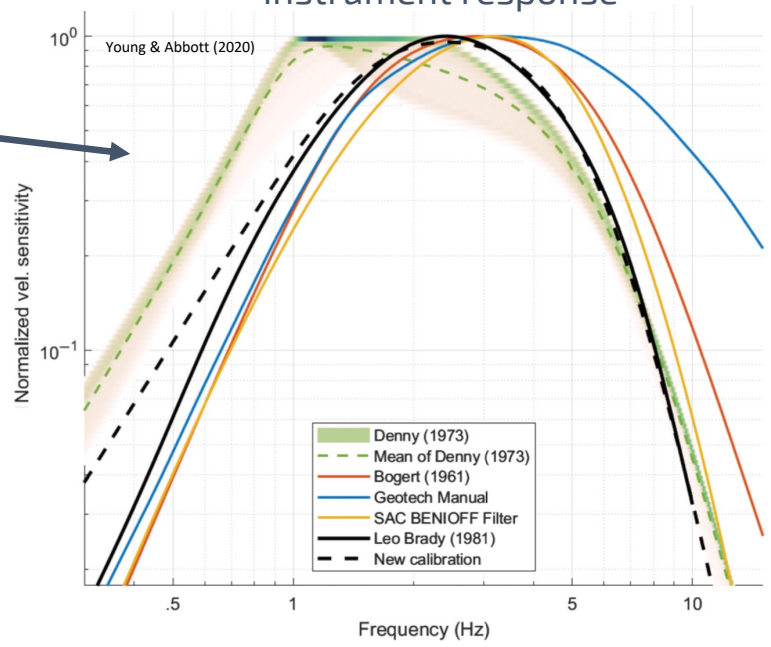
$$\hat{T}_s(\omega) = \frac{-\omega^2}{-\omega^2 + i2\lambda\omega\omega_0 + \omega_0^2}$$

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

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

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

Instrument response



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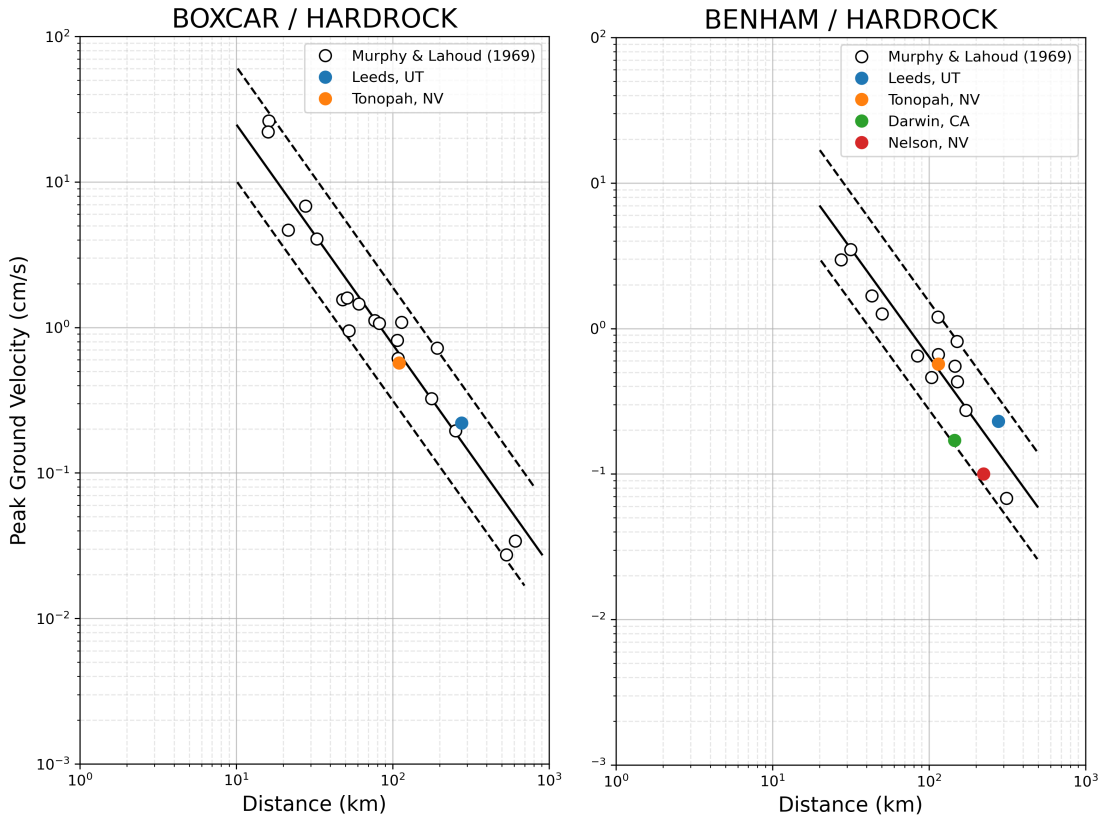
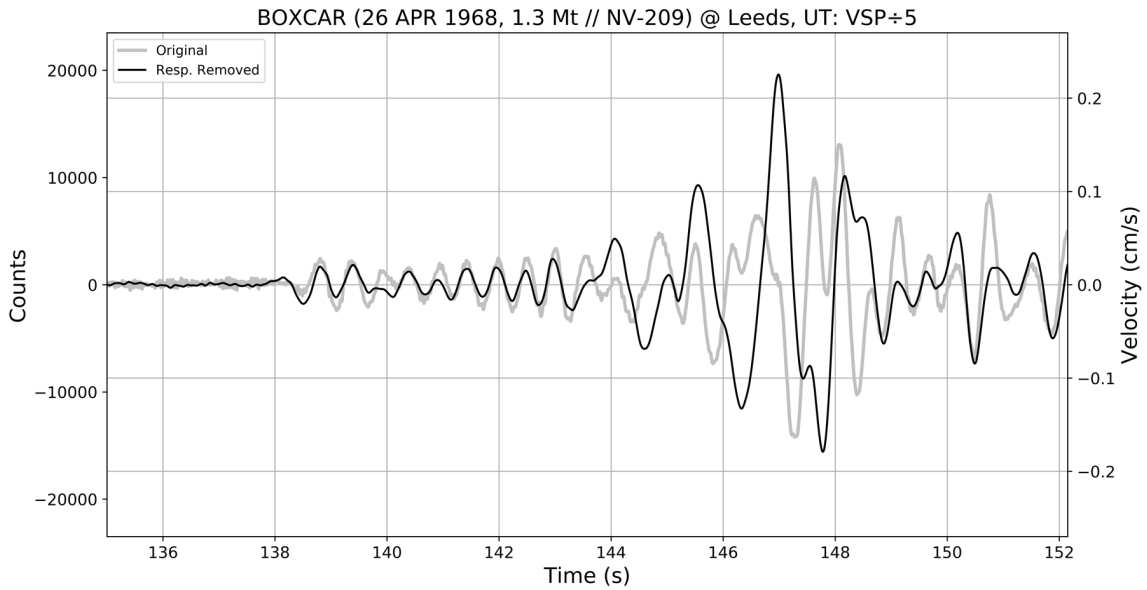
Results

1. Successfully calibrated short-period waveforms
   - *Full instrument response*
   - *Compares well with historical data (see below)*
2. Established workflow for mass recovery
3. Thousands of "new" old waveforms

1966-02-24	REX	1968-03-14	POMMARD	1969-10-29	CALABASH
1967-01-19	NASH	1968-04-26	BOXCAR	1970-03-06	CYATHUS
1967-05-26	KNICKERBOCKER	1968-12-08	SCHOONER	1970-04-21	SNUBBER
1967-06-29	UMBER	1968-12-19	BENHAM	1970-12-17	CARPETBAG
1967-09-21	MARVEL	1969-09-10	RULISON	1971-07-08	MINIATA
1968-01-18	HUPMOBILE	1969-10-29	CRUET	1972-09-26	DELPHINIUM
1968-01-26	CABRIOLET	1969-10-29	POD		





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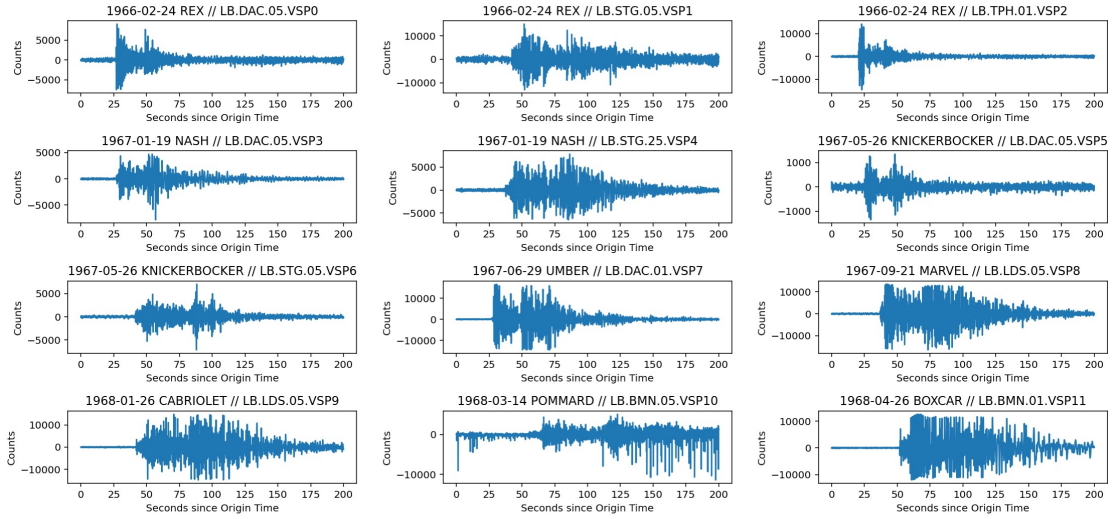
Conclusions

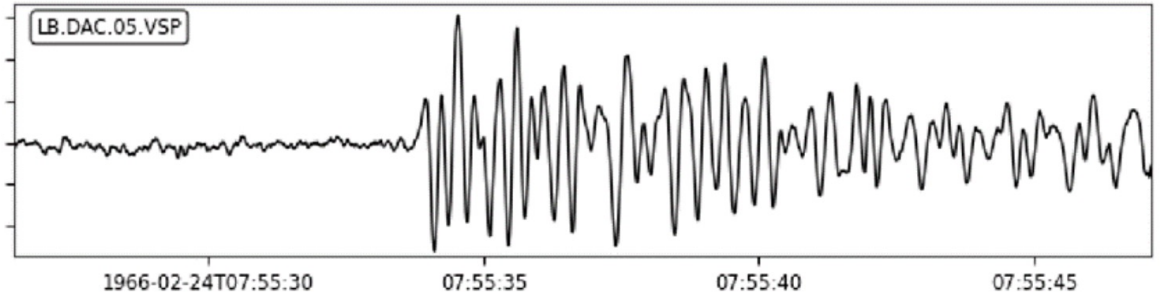
- 20 historical events
- 1297 recovered waveforms
- 449 unique channels
- 151 calibrated short-period waveforms
- 71% success calibrating short-period waveforms
- 90% success calibrating at least one unique waveform per event
- Data available on IRIS as an "assembled dataset"
  - https://ds.iris.edu/mda/23-007/

Sample of recovered data



(*DOE NV/209 Rev. 16*)

REX (1966 Feb 24, 19 kt) recorded ~165 km away at Darwin, CA



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Acknowledgements

- Thanks to the NNSA Office of Nuclear Verification and U.S. Department of State for sponsoring this work

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U.S. DEPARTMENT OF ENERGY

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