

MARSQUAKES AND MUONS: AN UNDERGRADUATE RESEARCH EXERCISE

ANTHONY NESBITT

DR. TAK CHEUNG

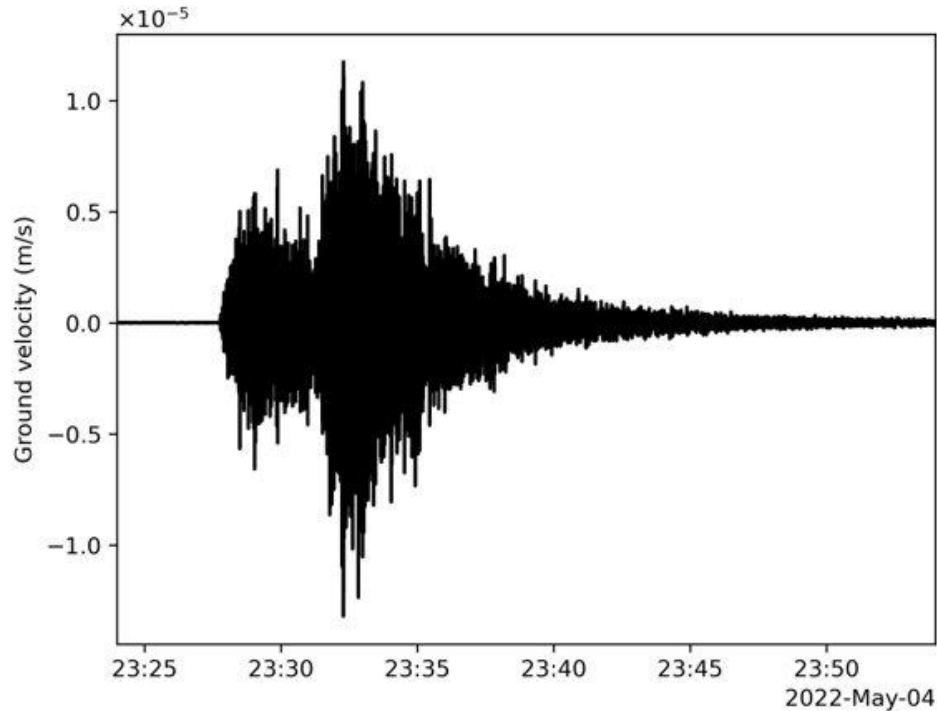
DR. RAUL ARMENDARIZ

PROGRAM SYNOPSIS

- Undergraduate research exercise provided by Queensboro Community College in collaboration with the National Science Foundation.
- Ten-week program designed to give undergraduate students experience in academic research.
- My focus was split evenly between two separate projects under Dr. Cheung and Dr. Armendariz.
- Dr. Cheung: Martian sound/vibration data analysis.
- Dr. Armendariz: Rebuilding a cosmic ray telescope.

Image credit:
NASA

MARSQUAKE ANALYSIS



- Under Dr. Cheung's guidance, I was given an open-ended task to analyze Martian sound/vibration data.
- Quickly settled on investigating a recent magnitude 5 marsquake detected by the NASA InSight lander.
- Challenges included learning to use MATLAB to perform data analysis, computer issues, and reconstruction of original seismic data.

INITIAL OBSERVATIONS

- Marsquake was a very long-duration event, lasting nearly six hours in total.
- Two distinct seismic events with slightly different characteristics, one potentially causing the other
- Strong resemblance to many volcanic earthquakes, including seismic activity related to 1980 eruption of Mt. St. Helens.

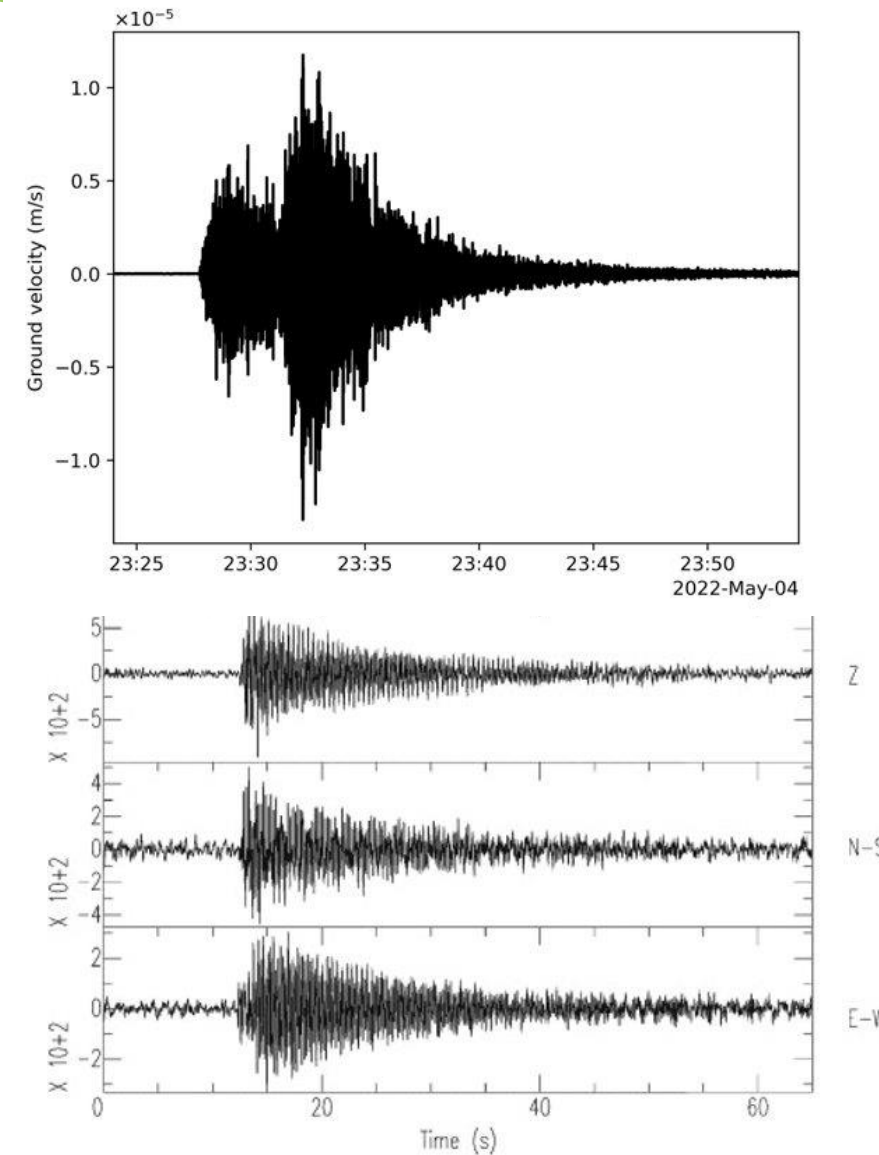


Image Credit: K.I. Konstantinou

Repetitive marsquakes in Martian upper mantle

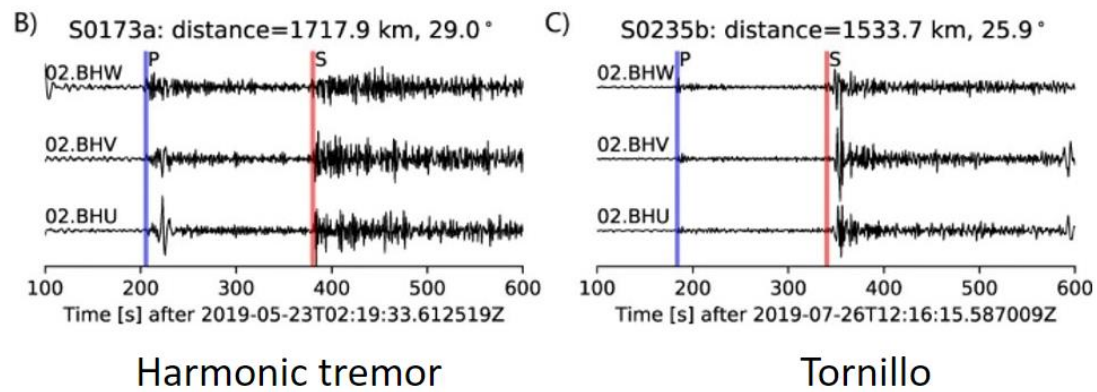
Weijia Sun & Hrvoje Tkalčić 

Nature Communications 13, Article number: 1695 (2022) | [Cite this article](#)

5616 Accesses | 1 Citations | 664 Altmetric | [Metrics](#)

Citation:

Sun, W., Tkalčić, H. Repetitive marsquakes in Martian upper mantle. *Nat Commun* 13, 1695 (2022). <https://doi.org/10.1038/s41467-022-29329-x>

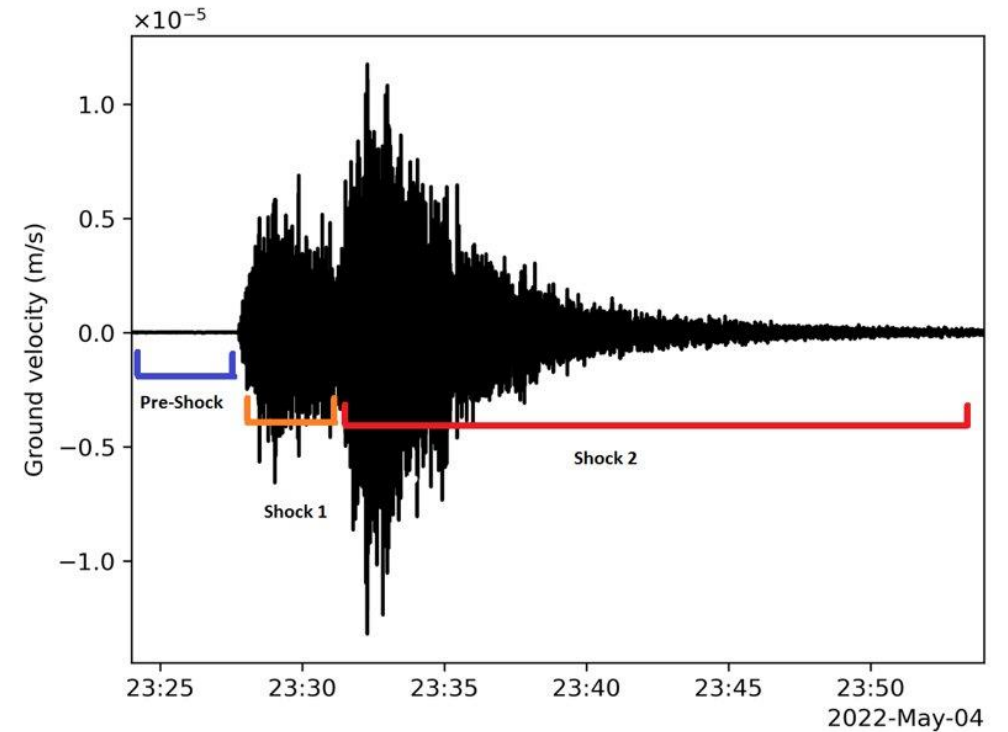


RESEARCH BEGINS

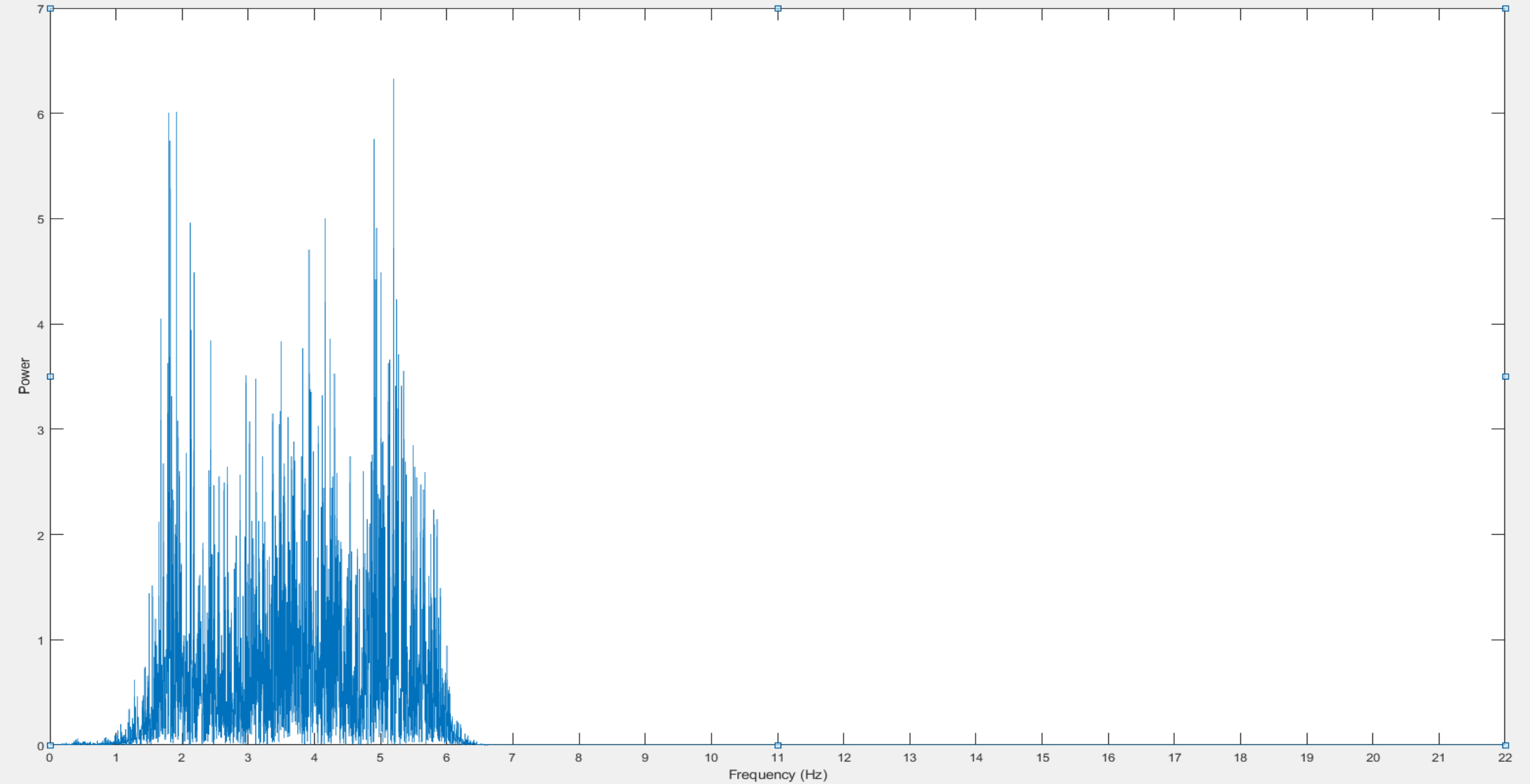
- Paper published 30 March 2022 links several previously detected, smaller tremors to magmatic activity below the Martian surface.
- Two types of magmatic tremors are apparent: "harmonic tremors" and "tornillos."
- Volcanic marsquakes were observed to be predominantly low-frequency events, just as on Earth.
- Geologically recent eruptive activity just discovered on Mars, ~53,000 years ago in the Cerberus Fossae region, leaving door open for possible active volcanic processes on the surface.

MARSQUAKE DATA ANALYSIS

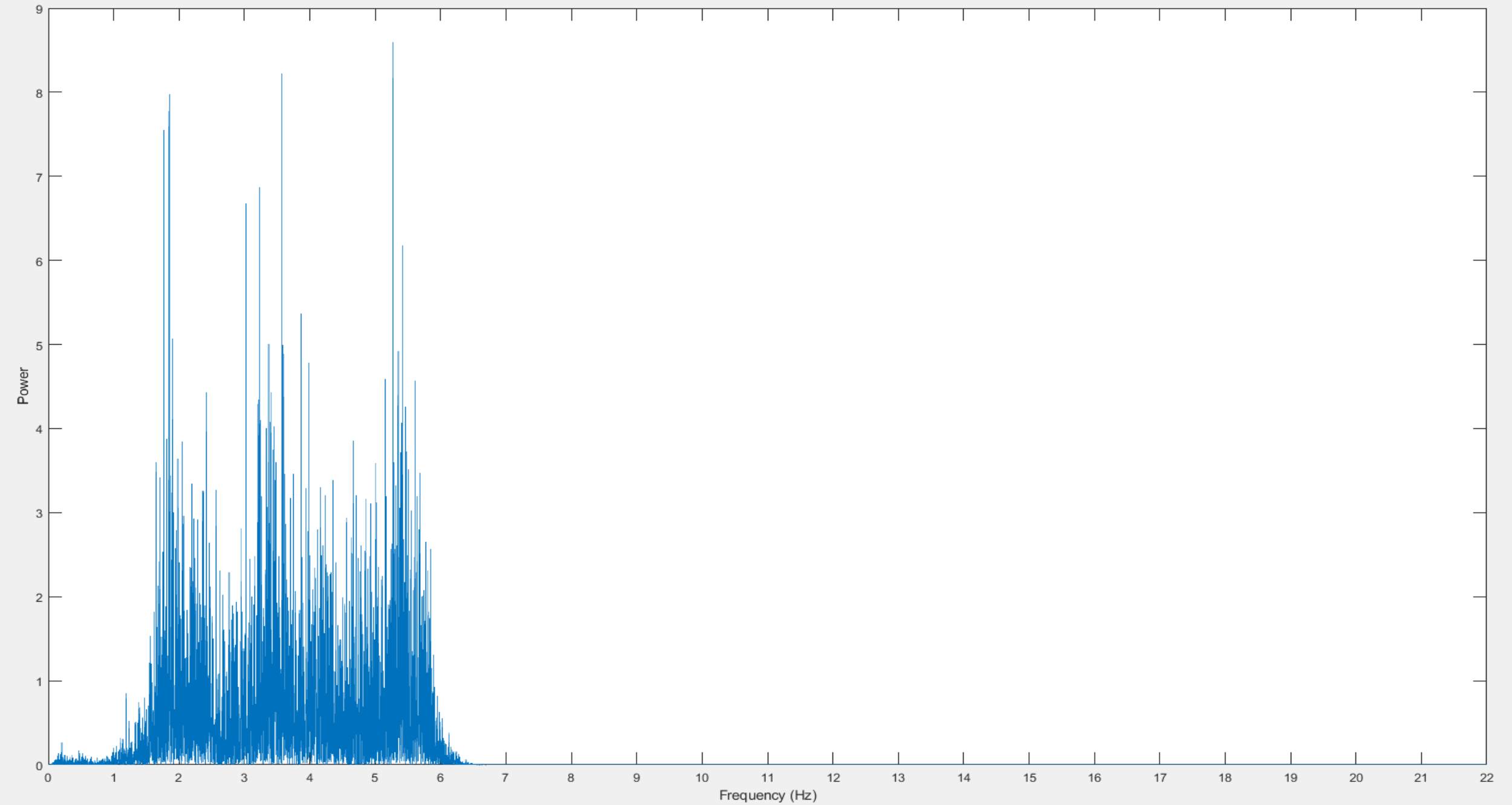
- Raw data from Insight(full six-hour event) not yet publicly released.
- Reconstructed seismic data using publicly released sonification of marsquake.
- Around thirty minutes of seismic data compressed into thirty second audio for public release, shifted frequency down by x60 in MATLAB to restore to near-original with inherent margin of error.
- Broke dataset down into three separate components for individual analysis.



SHOCK 1

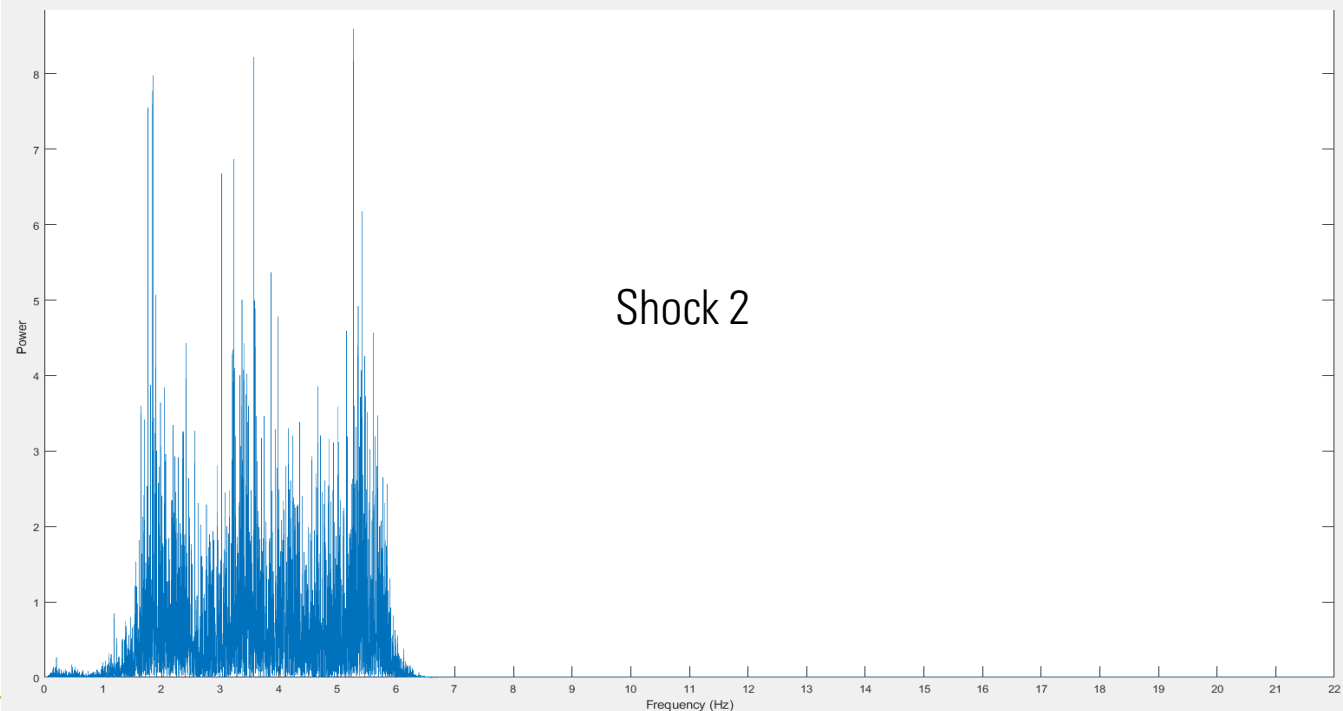
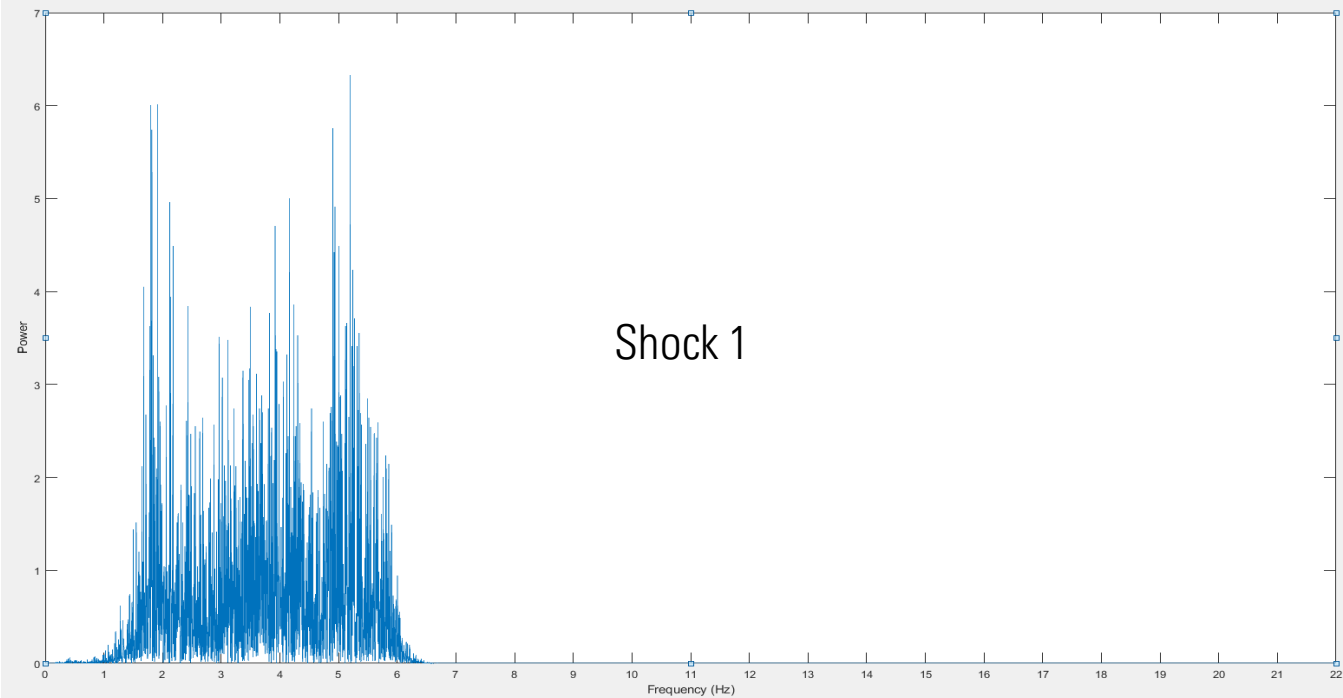


SHOCK 2

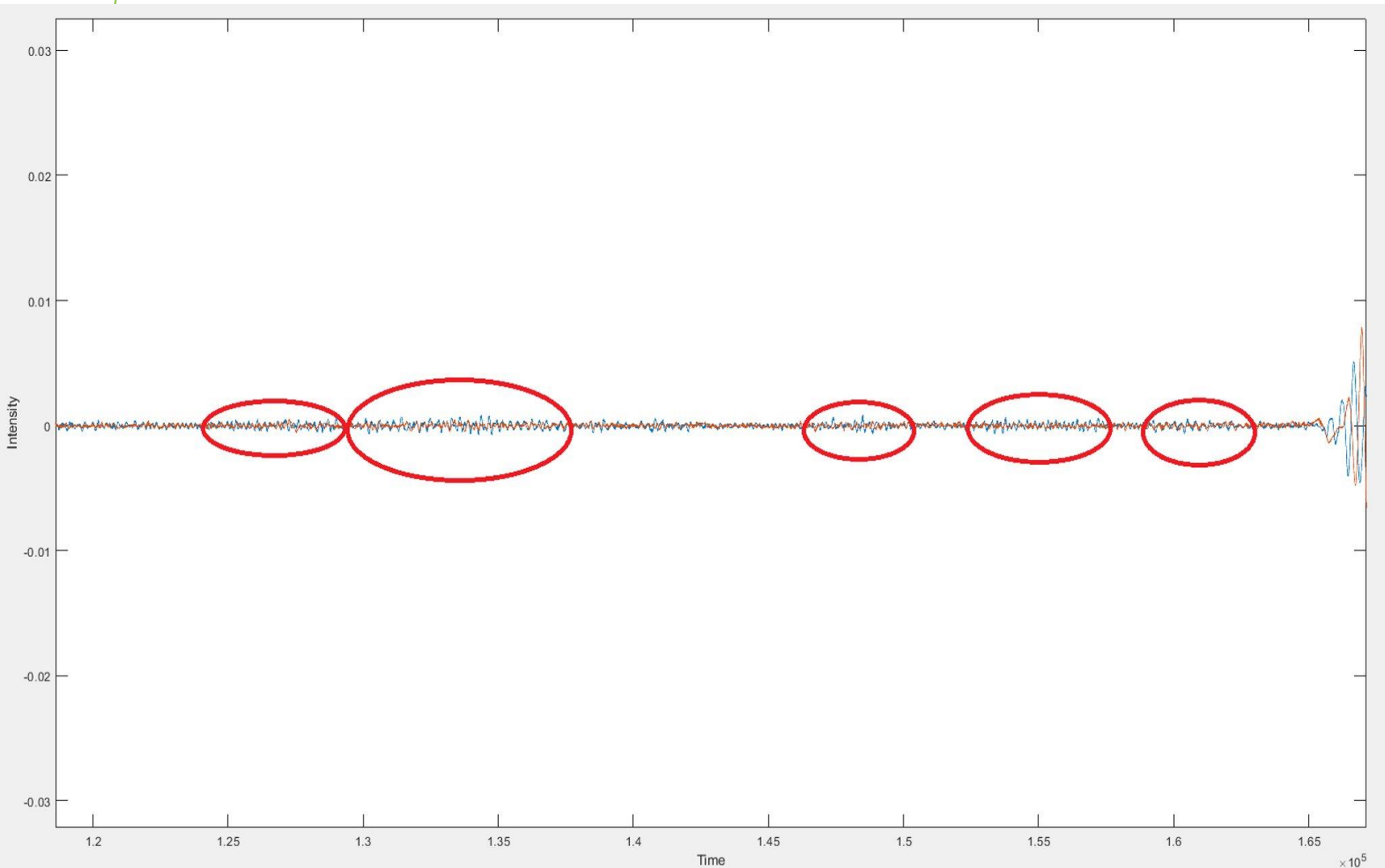


COMPARING SHOCKS 1&2

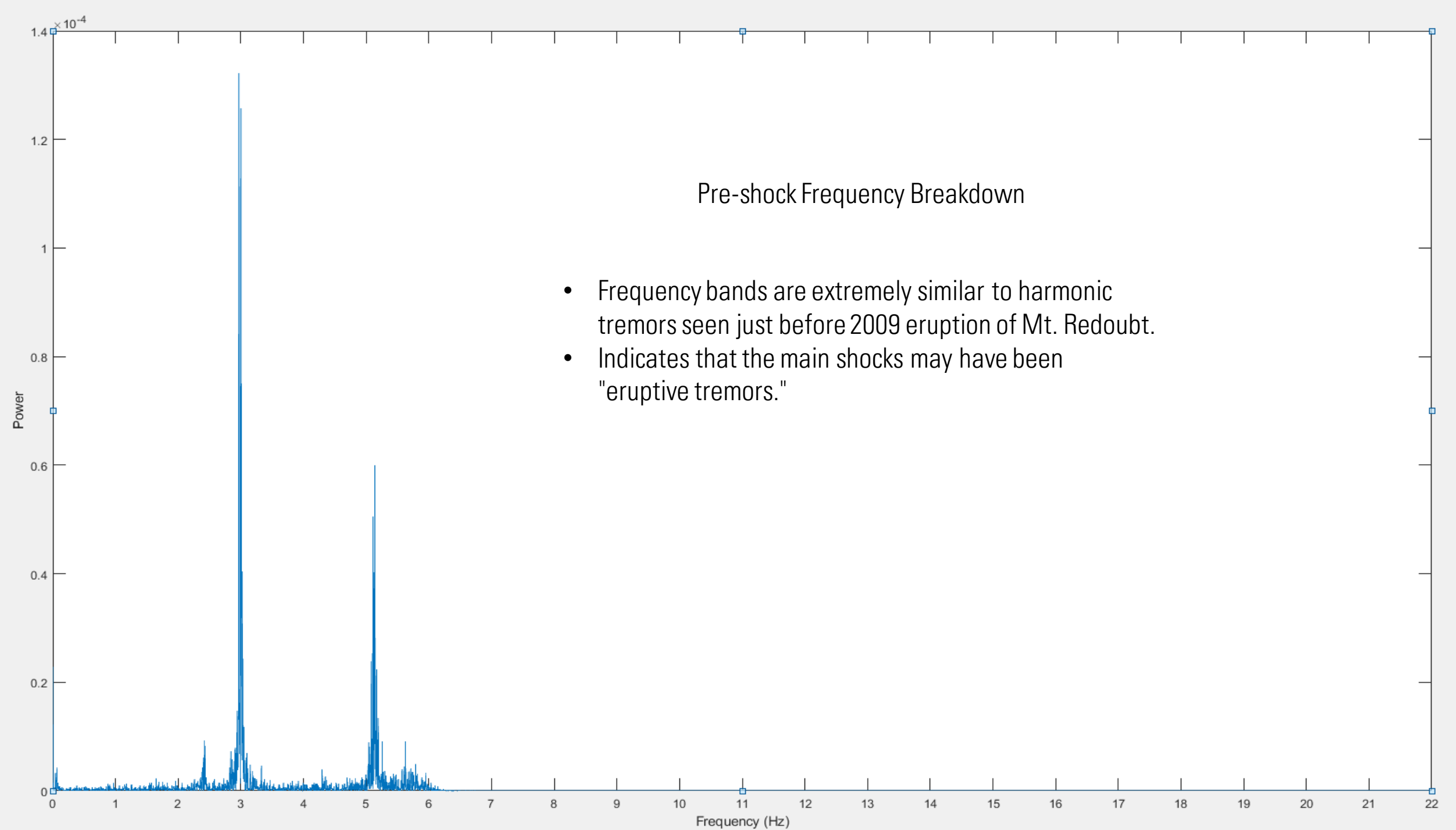
- Very similar frequency range.
- Possibility of S2 being a corresponding S-wave event to S1's P-waves is rather low, indicating that S1 and S2 were separate distinct events.
- Consistent with potential volcanic origins, although it does partially resemble some deep-origin intraplate earthquakes (excepting apparent lack of S-waves).



PRE-SHOCK ANALYSIS



- Inspired by recent publication where researchers went back over apparent noise/data and were able to find overlooked microquakes.
- Numerous candidate long-duration events were found in the apparent quiescence before the main tremors, becoming more numerous as the main seismic activity approached.
- Appearances are very similar to harmonic tremors preceding eruptions here on Earth, ex: Mt. Redoubt, Mt. St Helens.



P waves? unlikely
S waves?

Shock 1
165,000 - 410,000

Shock 2
410,000 - End

Pre-Shock
0 - 165,000

↑
Spotted several possible harmonic tremors in noise
likely!

• Seismic data ~30 min long (1800 sec)
• audio compressed to 30 sec

f_i shifted $\uparrow \times 60$

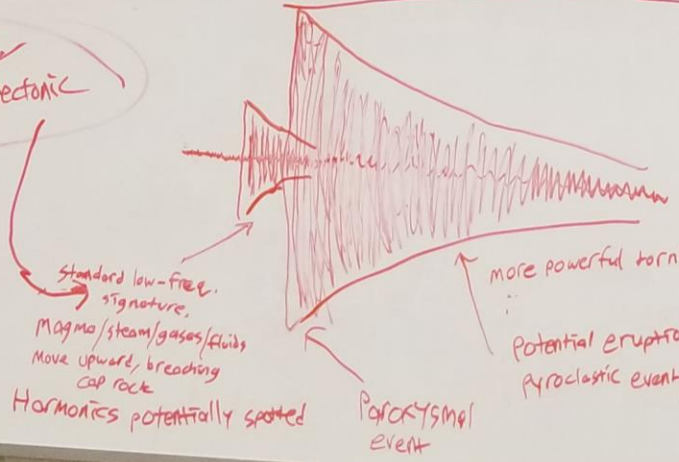
$f_s = 48000 \rightarrow 800$
plot FFT

No S-waves on Mars?
Shaking lasted 6 hours, very long duration event

ELYSIUM QUADRANGLE Potential volcanic mechanisms

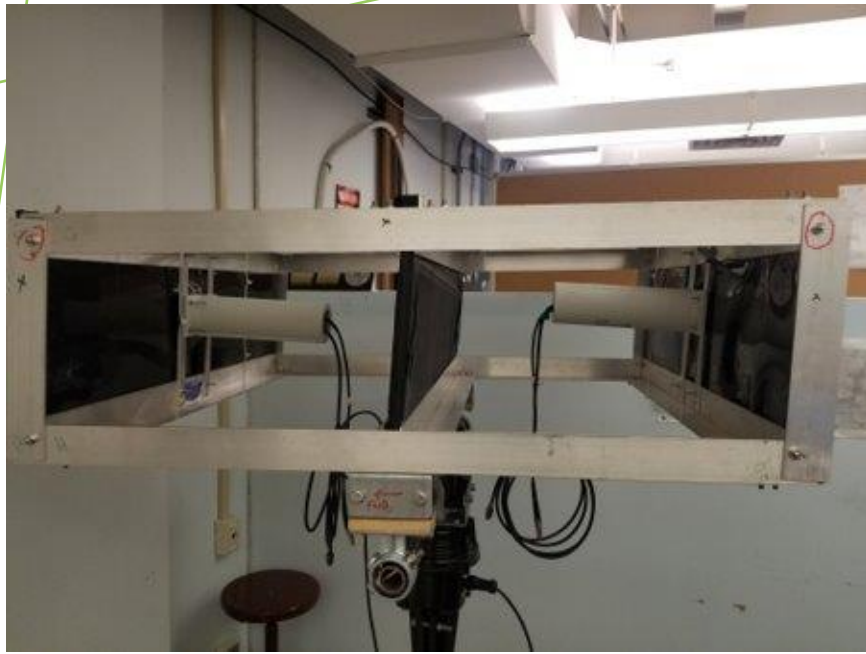
DO NOT ERASE

Hybrid tornillo volcanotectonic



Earth Analogue: MT ST HELENS, 1980
Pinatubo
Mt. Redoubt

Potential eruption, probably violent/explosive, but short-lived
Pyroclastic event / vulcanian / sub-plinian / phreatomagmatic?



COSMIC RAY TELESCOPE REBUILD

- Under Dr. Armendariz's guidance, I was tasked with rebuilding a faulty cosmic ray telescope.
- Multi-part task that involved mechanical engineering, equipment maintenance and repair, and generous amounts of elbow grease.
- Challenges involved troubleshooting malfunctioning equipment, materials acquisition, and ability to produce machined parts.

COSMIC RAY DETECTION

- High-energy particles from space can penetrate Earth's magnetosphere and collide with nuclei in Earth's atmosphere, producing "showers" of secondary particles.
- Secondary particles can be detected by "scintillation counters," consisting of scintillating materials coupled with a photomultiplier tube.
- Cosmic Ray "Telescope" consisted of an array of three stacked scintillator counters and a tracking motor assembly.
- Majority of detected particles are muons, an elementary particle that decays into electrons.

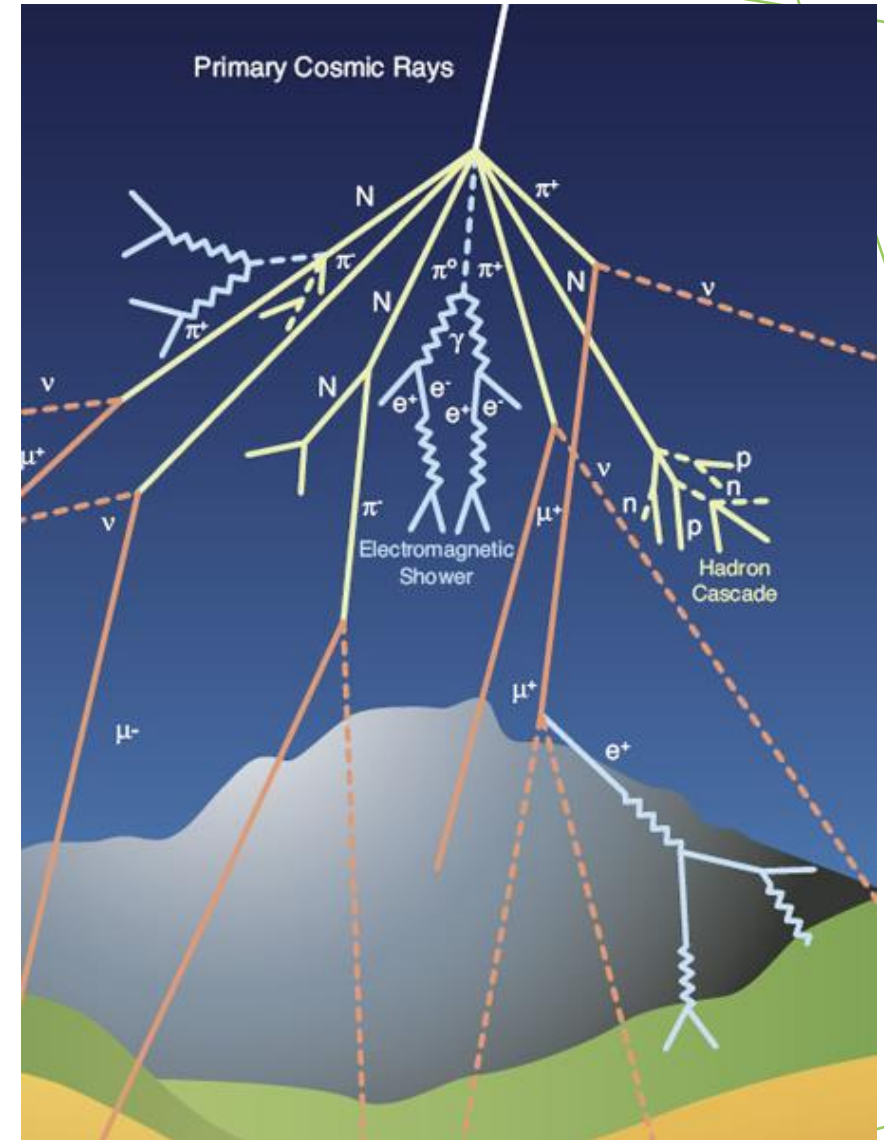


Image credit: CERN

TELESCOPE DISASSEMBLY

- Very delicate process, as the photomultiplier tubes and scintillation sheets are fragile and extremely expensive.
- Difficult due to damage to frame, poor design that did not allow for easy maintenance.
- Needed assistance from Gabe and Armando to ensure no expensive equipment was dropped (helping hands to support loosened components).
- Disassembly accomplished in about 30 minutes with no damage caused to any critical components.



SET UP NEW 3D PRINTER FOR PARTS PRODUCTION

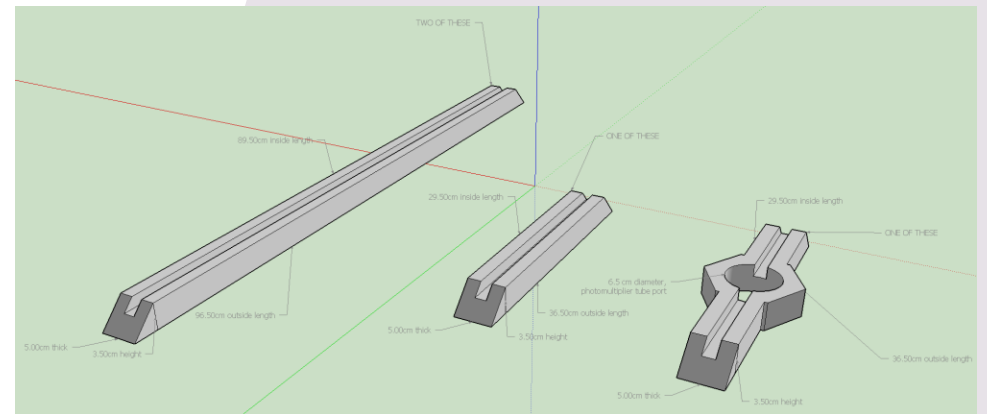
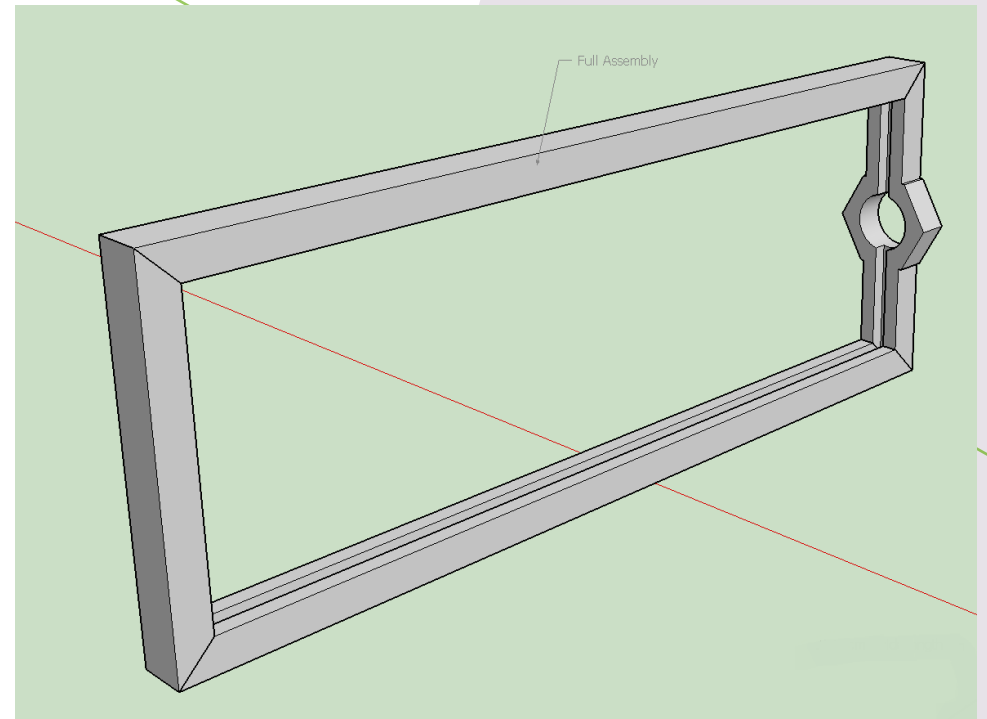
REWRAPPED SCINTILLATOR SHEETS

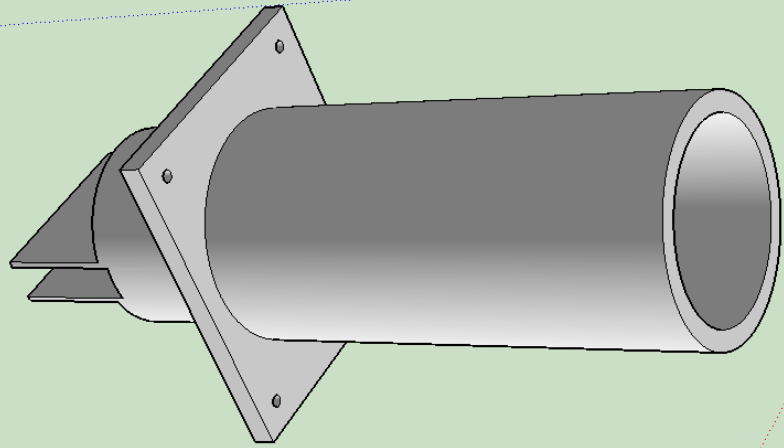
- X-MAX 3D PRINTER INSTALLED AND SET UP IN LAB IN ORDER TO FACILITATE PARTS PRODUCTION.
- PANELS WERE UNWRAPPED, CLEANED WITH ALCOHOL, WRAPPED IN MULTIPLE LAYERS OF PROTECTIVE TYVEK WRAP, THEN ENCASED BY A BLACK, LIGHT-TIGHT LAYER OF EMF-BLOCKING SHEETING.



BASIC DESIGN CREATED FOR NEW SCINTILLATION COUNTER FRAME, MATERIALS ACQUIRED.

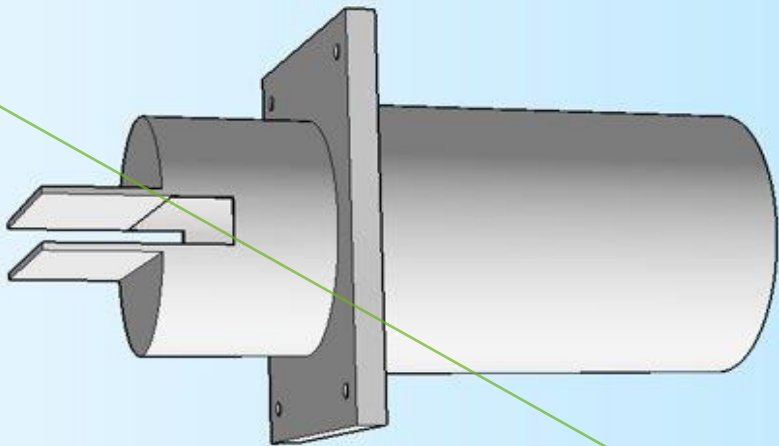
- Frame functions like a picture frame, holding the scintillator panels internally within a padded groove running along the perimeter of the panel.
- Mounting port is provided for photomultiplier tube/housing to be attached to the scintillator panel.
- Wood purchased from Home Depot to construct frame components.





NEW PHOTOMULTIPLIER TUBE HOLDER DESIGNED

- Designed to provide a tighter fit between PMT lens and scintillator plate.
- Holder is snug around the PMT while leaving the rear accessible for cables and bracket/spring tensioner assembly.
- First design iteration took 48 hours to print.
- Later iterations made from black filament instead of red, use less material, and cut print times down to around 18 hours.



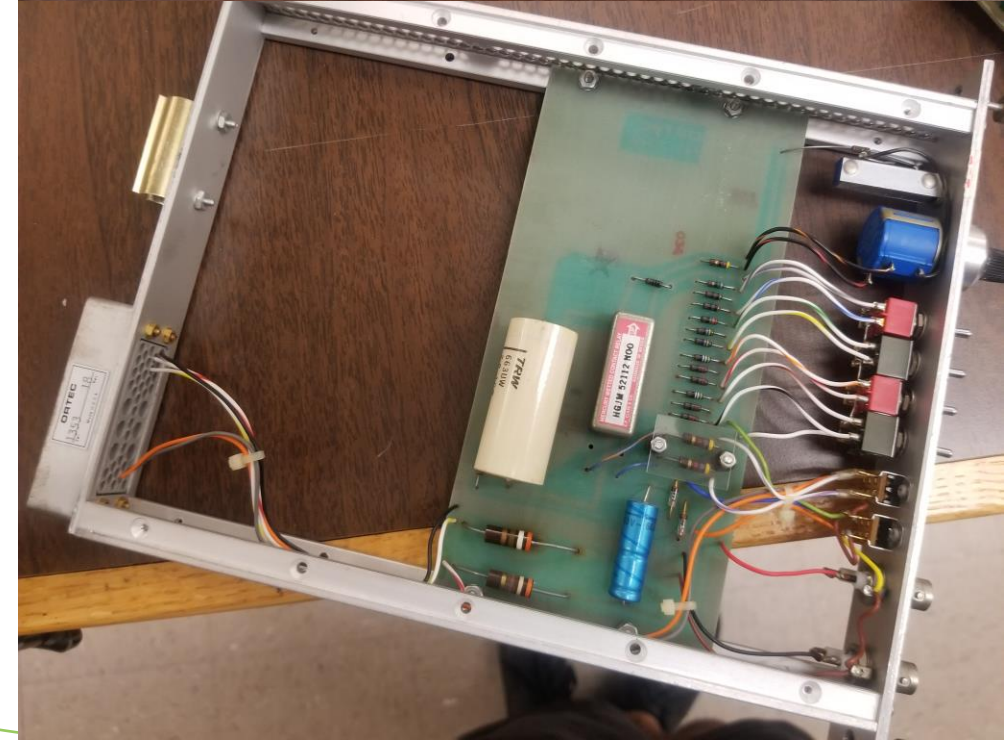
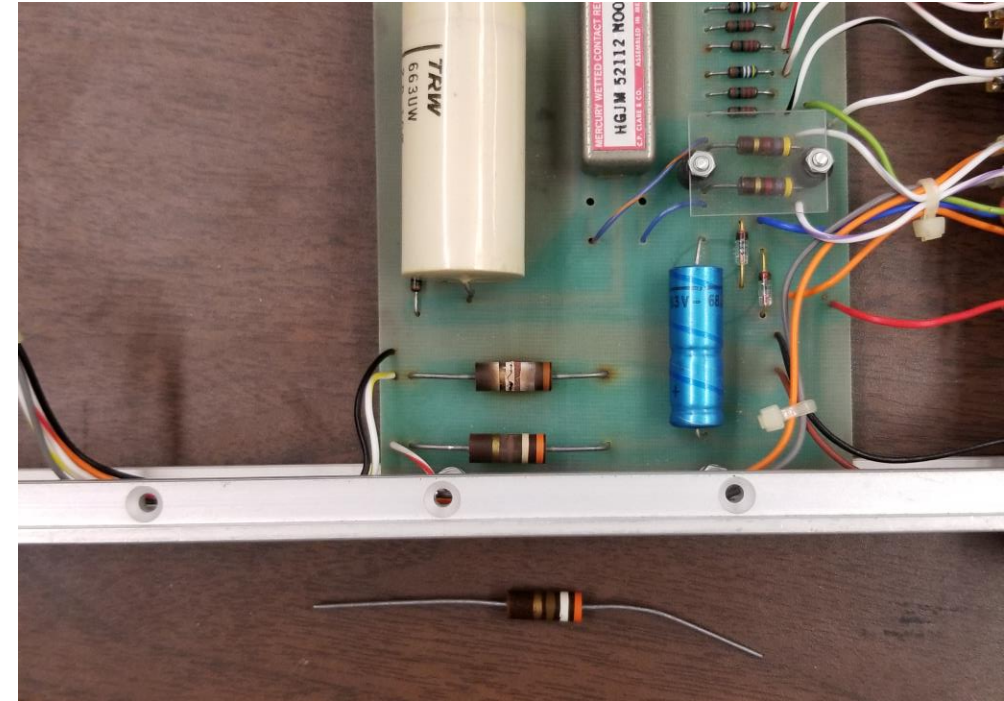
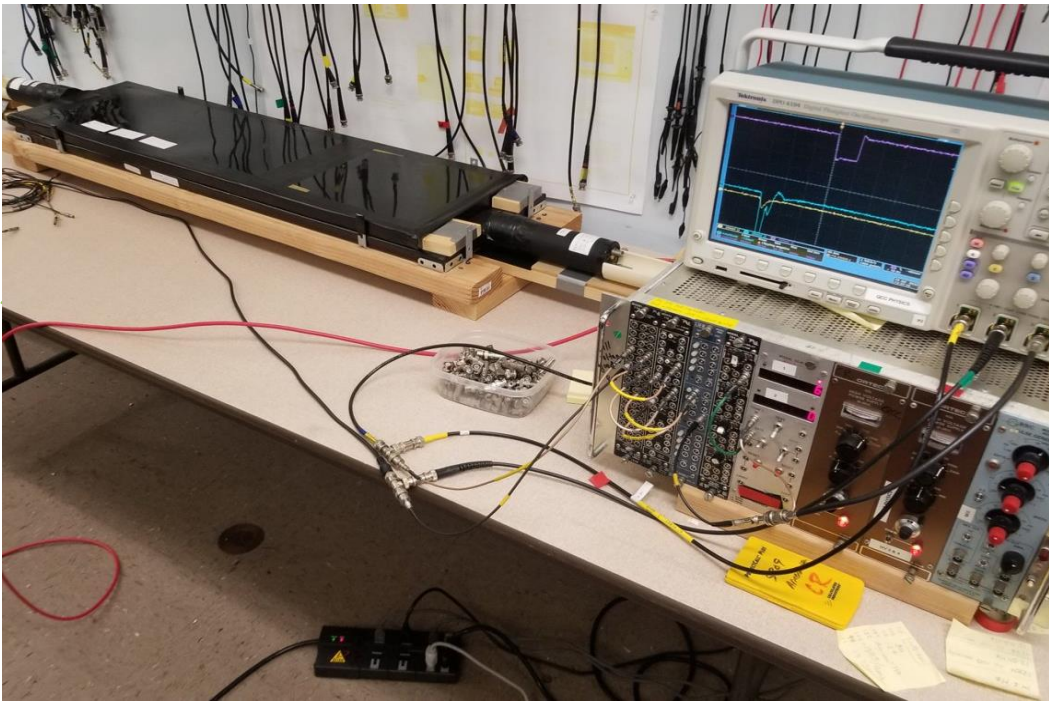
PROTOTYPE FRAME PIECES MACHINED, FRAME ASSEMBLED

- Enlisted help of QCC machinist and maintenance staff for assistance on working wood to make frame components.
- Obtained foam padding to be installed within the frame, purchased more necessary components from Home Depot.
- Hinged with clasp to allow easy removal of scintillator panel for maintenance purposes.
- Frame works very well, though I would like to cut down on weight if possible.



EQUIPMENT TROUBLESHOOTING

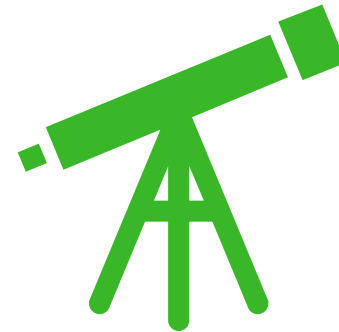
- While attempting to test scintillation counters, we were unable to get accurate data.
- Inability to accurately record particle counts was traced to two faulty modules in the laboratory equipment we were provided.
- New temporary equipment setup allows us to proceed with testing.
- Also found that some of the lab equipment was overheating for extended periods of time, emergency fix was arranged while a permanent solution is prepared.
- I was also tasked with performing repairs and maintenance on several other modules pulled out of storage.



NEXT STEPS



Wait for raw InSight data to be released before marsquake analysis can be resumed, investigate potential non-volcanic explanations for marsquake.



Construct two more scintillation counter frames, begin testing scintillation counters and fine-tuning settings, then reassemble cosmic-ray telescope.