Lag Time

The time difference between hearing the sonic wave and hearing the muzzle blast.

It increases the closer you are to the bullet travel path. That is, the greatest lag time is heard when directly in front (and hit) of the travel path of the bullet, and the smallest lag time is heard at larger distances and/or positions offset from the muzzle approaching 180.0 degrees.

How Do We Know It's a Gunshot

We don't! But when a bullet hit's you in the leg, then yes, you probably stop thinking about firecrakers and start to focus on guns.

A single sample of a sound in isolation is difficult to conclusively identify as a gunshot unless there is some close proximity physical evidence to support the conclusion. The quality of the recording contributes to the quality of the conclusion.

When there are multiple similiar sounds all in close proximity (time and distance) then a conclusion (theory) becomes more probable.

Every theory must be tested against alternate theories and judged on it's merits to both explain the observed evidence and to project future "events" similiarly suituated.

SEE BELOW FOR FURTHER CRITERIA

How Far Can The Muzzle Be Heard

How Far Can The Sonic Wave Be Heard

How Far Can a "hit" Be Heard

Observed

Real life is always messy. The images presented in this section are images of actual sounds recorded in the general vicinity of the tragedy.

Notes

Waveforms are normalized for that portion which is visible, so they may appear "louder" than they actually are, keep an eye on the units of scale of the Y axis displayed on the left hand side of the waveform.

Spectographs are also "auto adjusted" like waveforms, so they change color intensities base on the portions of the graph visible.

Much like the old Outer Limits televsion series, the user controls the vertical, horizontal, clarity, and all other aspects of the graph. There is always something more to see and analyze by simply changing the settings on the controls.

Generally

1 Shot 3+ Sounds

So you think you heard three people shooting? Think again. One shot from a supersonic rifle will produce up to three distinct and seperate sounds to the ear. First will come the supersonic "crack" a few fractions of a second later the sound of what the bullet hit, and then up to a couple seconds later (but usually within tenths of a second), the boom of the muzzle blast.

Put a hundred of these events in close proximity and it becomes a cacophony of cracks, thuds, snap, pops and booms. So much so it's nearly impossible to distinquish what is what. Sometimes the boom from the muzzle won't be heard till five bullets have hit nearby. Sometimes the sound of the muzzle will be heard after there are no more sonic cracks. But in the middle of things it's mass chaos.

This choas is very much complicated by the fact that the sonic snaps, don't precisely follow the timing of either the muzzle blasts or the actual firing of the bullets if the gun is changing (even a little) it's target.

Sonic vs. Ear

Sonic vs. Spectograph

Muzzle vs. Ear

Muzzle vs. Spectograph

Hit vs. Ear

Hit vs. Spectograph

Reflection vs. Ear

Reflection vs. Spectograph

Oasis Apartments

Location

We start with a recording made near the Oasis Apartment complex more than 1,500 feet east of Manadalay Bay. Distance to the stage is about 1,000 ft.

Environment & Noise

This location is far enough removed from the fray of the action that it is relative "quiet" compared to the concert ground and Vegas Blvd. The signal recorded has a good signal to noise ratio and the waveforms are clear and redily visible.

This location also has a relative clear line of site with few obstructions to both the concert area and Mandalay bay, yielding clear records of the gunshots with few reflections, refractions, or inteferences.

Waveform & Spectrum(s)

The db^2 and linear spectrum(s) at the 0.100 time scale, redily reveals a gunshot bursts. The sonic crack and the muzzle boom are distinct and seperated. The waveform is clear, and easily distinquishable.

Issues

The only trouble with this recording is that the 2nd channel has a substantially larger gain, or the 1st channel is partially blocked. That is the amplitudes on the 2nd channel are substantailly greater (note the auto-scale to the left).

How It Sounds

Both the sonic and muzzle sounds when replayed are present and distinct. The sonic sound is slightly louder than the muzzle sound.

The sonic wave sounds like a typewritter key hitting the paper. The muzzle wave sounds like a heavy metal tablespoon lightly tapping an 8x11 tablet of paper. Together and repeated many times, they sound like an old Tommy gun being fired inside a barn 1/2 mile away.

Cycle Rate, Lag Time

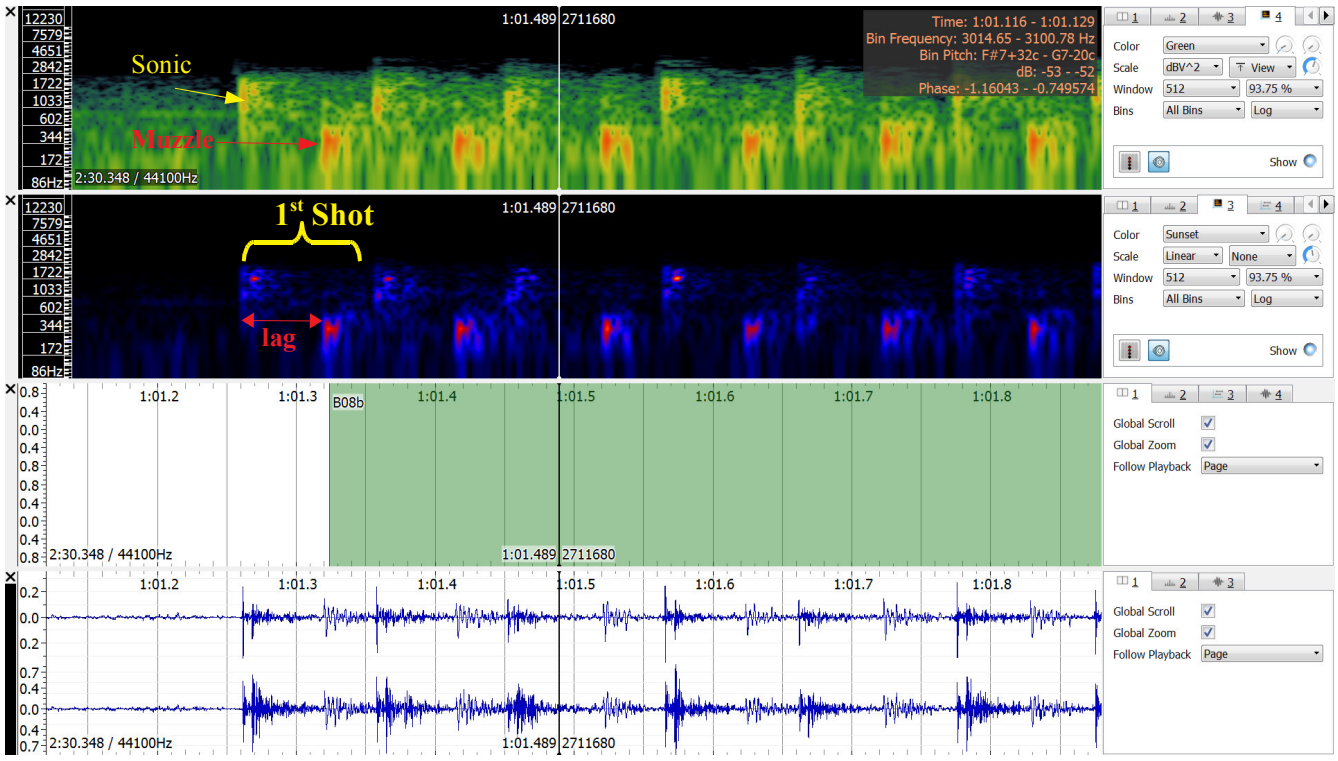
The first few shots clock in at 0.098s to 0.0114s, yielding somewhere around 10 rounds per second or 600 rounds per minute.

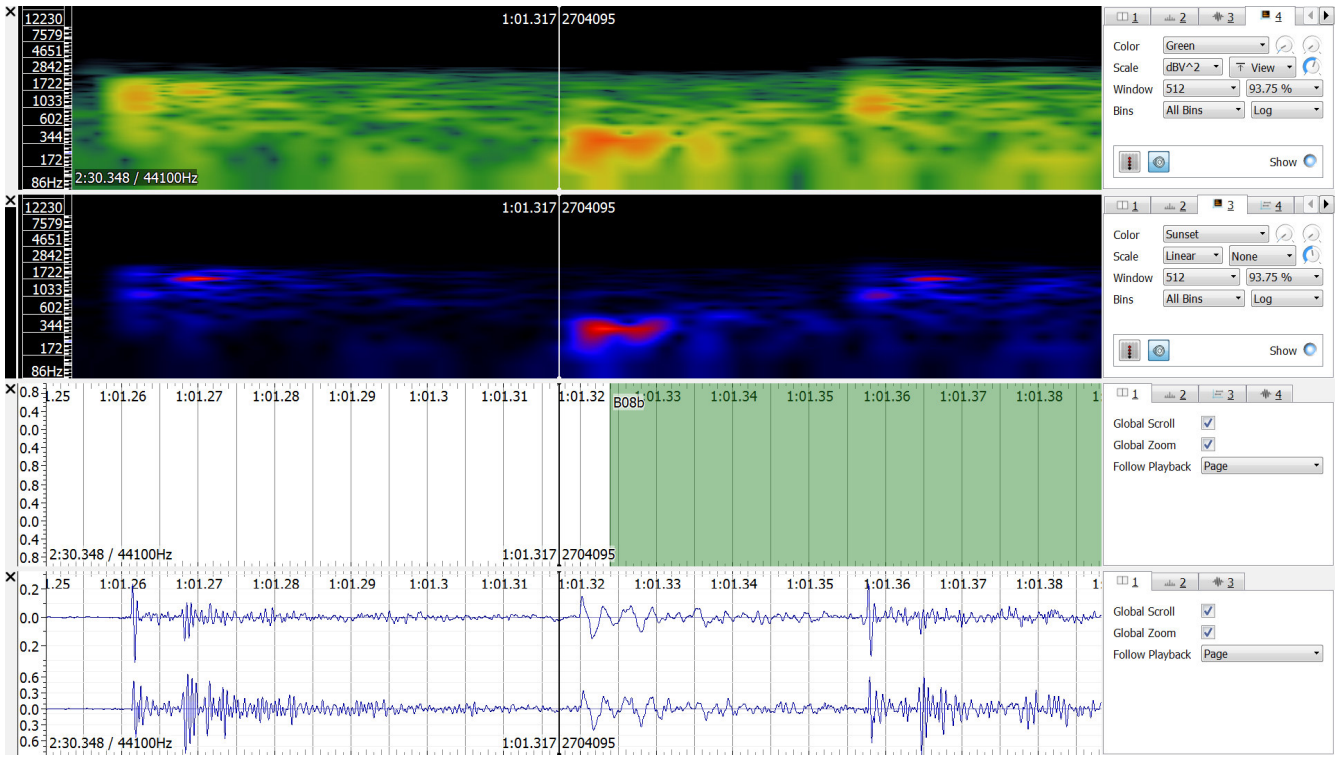
Lag between the first sonic wave and first muzzle wave is 0.059s. Lag for the first few shots varies from 0.059 to 0.067s

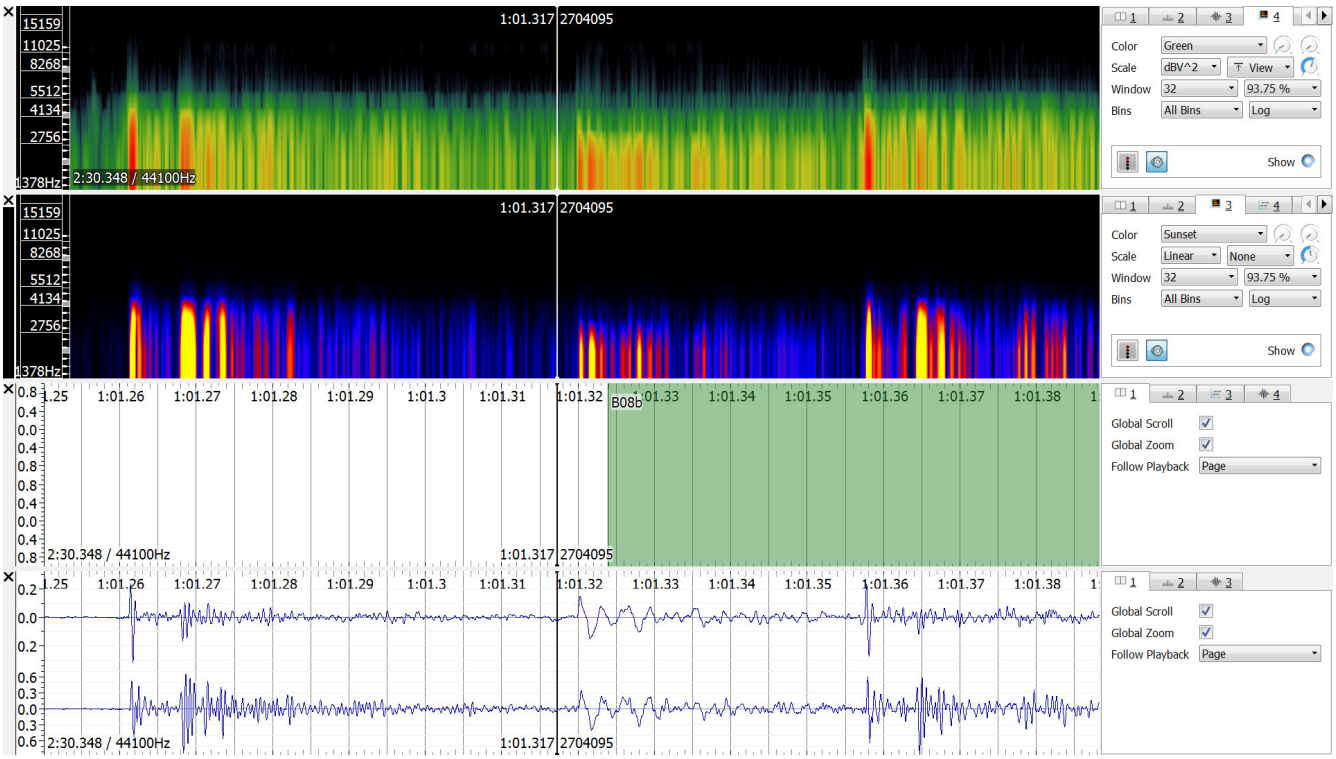
Frequencies

Nominal and distinct seperation between sonic and muzzle with sonic higher than muzzle (as expected).

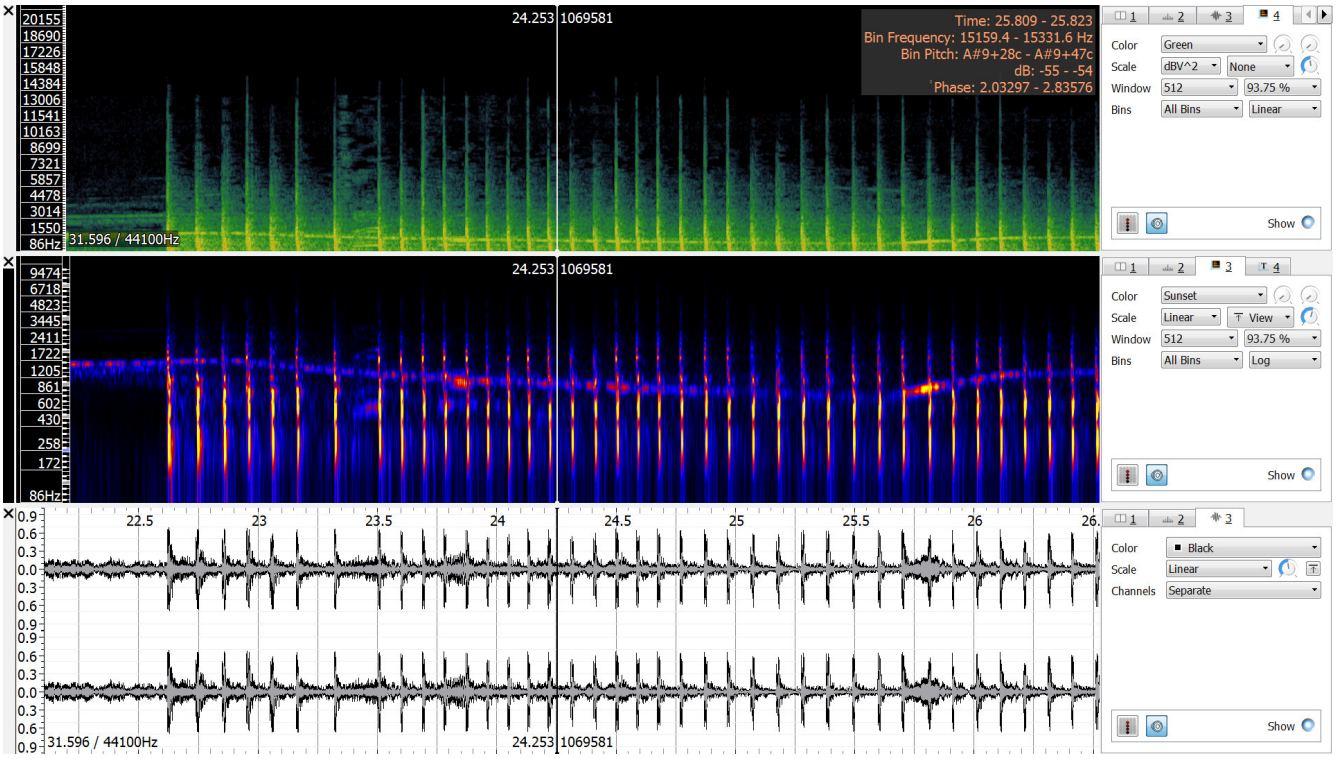
Both sonic and muzzle suffer from attenuation due to distance.

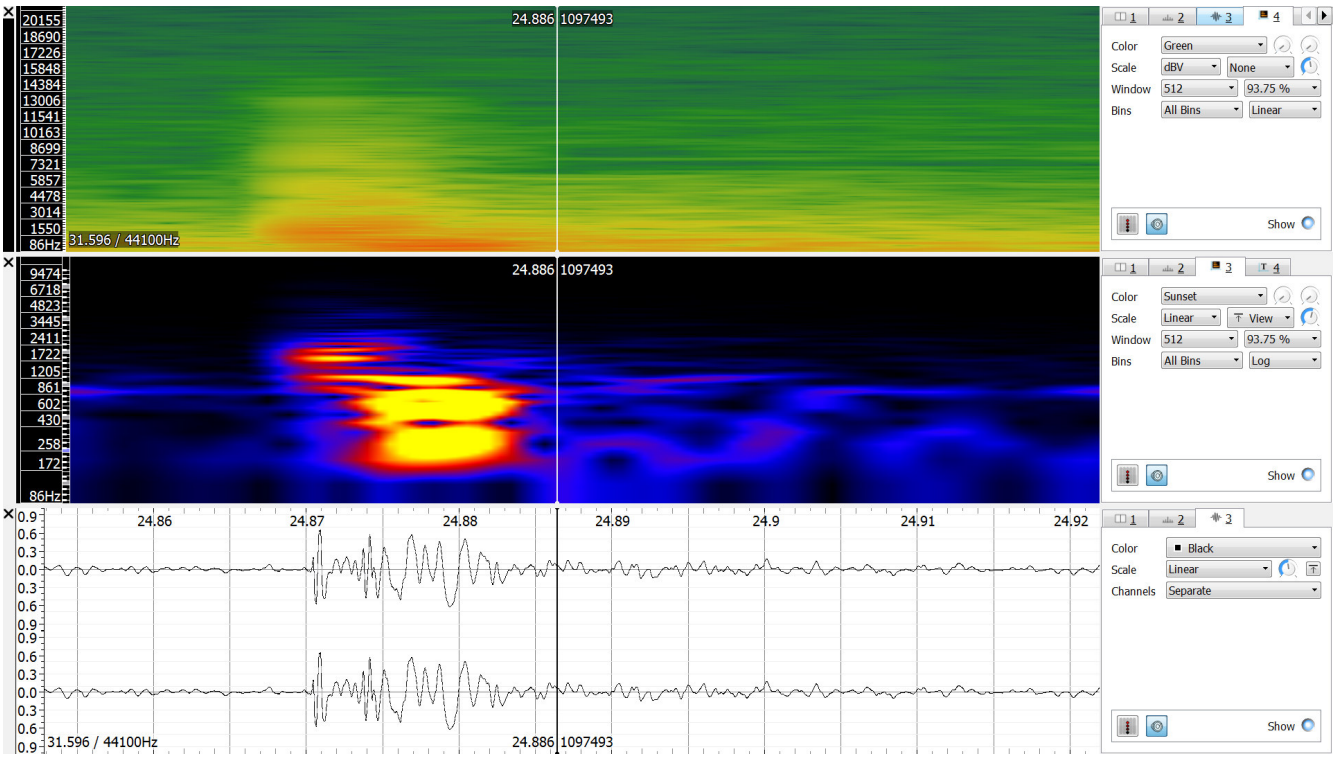

Sonic
Muzzle
1st Shot
lag
B08b
Time: 1:01.116 - 1:01.129
Bin Frequency: 3014.65 - 3100.78 Hz
Bin Pitch: F#7+32c - G7-20c
dB: -53 - -52
Phase: -1.16043 - -0.749574
1:01.489 2711680
2:30.348 / 44100Hz

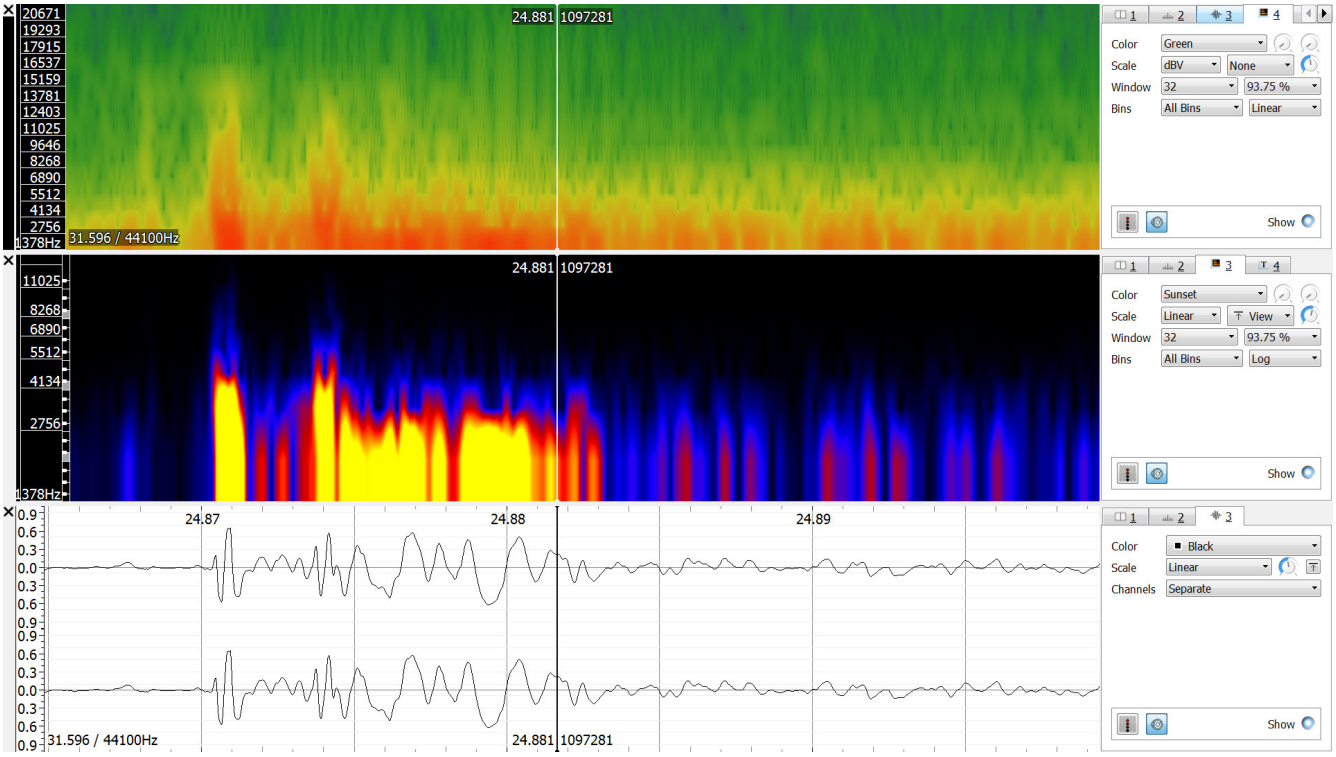

B08b
1:01.317 2704095
2:30.348 / 44100Hz


15159
11025
8268
5512
4134
2756
1378Hz
1:01.317 2704095
2:30.348 / 44100Hz
Color
Green
Scale
dBV^2
View
Window
32
93.75 %
Bins
All Bins
Log
Show
Sunset
Linear
None
0.8
0.4
0.0
0.2
0.6
0.3
1:01.25
1:01.26
1:01.27
1:01.28
1:01.29
1:01.3
1:01.31
1:01.32
B08b
1:01.33
1:01.34
1:01.35
1:01.36
1:01.37
1:01.38
Global Scroll
Global Zoom
Follow Playback
Page

Hotel 8


24.253 1069581
Time: 25.809 - 25.823
Bin Frequency: 15159.4 - 15331.6 Hz
Bin Pitch: A#9+28c - A#9+47c
dB: -55 - -54
Phase: 2.03297 - 2.83576
31.596 / 44100Hz
Color Green
Scale dBV^2 None
Window 512 93.75 %
Bins All Bins Linear
Show
Color Sunset
Scale Linear View
Bins All Bins Log
Color Black
Scale Linear
Channels Separate


24.886 1097493
31.596 / 44100Hz
Color Green
Scale dBV None
Window 512 93.75 %
Bins All Bins Linear
Show
Color Sunset
Scale Linear View
Bins All Bins Log
Color Black
Scale Linear
Channels Separate


20671
19293
17915
16537
15159
13781
12403
11025
9646
8268
6890
5512
4134
2756
1378Hz
31.596 / 44100Hz
24.881 1097281
Color Green
Scale dBV None
Window 32 93.75 %
Bins All Bins Linear
Show
11025
8268
6890
5512
4134
2756
1378Hz
24.881 1097281
Color Sunset
Scale Linear View
Window 32 93.75 %
Bins All Bins Log
Show
0.9
0.6
0.3
0.0
0.3
0.6
0.9
24.87
24.88
24.89
31.596 / 44100Hz
24.881 1097281
Color Black
Scale Linear
Channels Separate
Show

Ladies in Car Near Venue

Location, Time, Situation

Two women, inside a car, slightly east of the intersection of Mandalay Bay Rd. and South Las Vegas Blvd encouter the tragedy at about 10:11pm. While the position of the vehicle varies a little, generally they are about 900-950 feet from Mandalay Bay Tower and 250 feet east of the intersection directly south of the concert stage heading west. At 1:11 on tape display says 29 degrees celcius and 10:12pm. The car can be seen from the video captured atop the Mandalay Bay JFK lounge.

Environment & Noise

This location represents a substantially noisier environment than the Oasis Apartment location. There are engine and car noises, people speaking, sirens nearby, cars nearby, as well as a few people and police.

Even with all this mixture of "noises" this video has fairly clear and distinct gunshots recorded.

This location has a relatively clear line of sight to levels four and above on the Mandalay bay, as well as a clear line of sight to much of the happenings at the intersection of Mandaly Bay Rd. and South Las Vegas Blvd.

Waveform & Spectrum(s)

The db^2 and linear spectrum(s) at the 0.100 time scale, redily reveals a gunshot bursts. The sonic crack and the muzzle boom are distinct and seperated. The waveforms are clear, and easily distinquishable.

Issues

The only trouble with this recording is that the 2nd channel has a substantially larger gain, or the 1st channel is partially blocked. That is the amplitudes on the 2nd channel are substantailly greater (note the auto-scale to the left).

How It Sounds

Both the sonic and muzzle sounds when replayed are present and distinct. The sonic sound is slightly louder than the muzzle sound.

The sonic wave sounds like a typewritter key hitting the paper. The muzzle wave sounds like a heavy metal tablespoon lightly tapping an 8x11 tablet of paper. Together and repeated many times, they sound like an old Tommy gun being fired inside a barn 1/2 mile away.

Cycle Rate, Lag Time

The first few shots clock in at 0.098s to 0.0114s, yielding somewhere around 10 rounds per second or 600 rounds per minute.

Lag between the first sonic wave and first muzzle wave is 0.059s. Lag for the first few shots varies from 0.059 to 0.067s

Frequencies

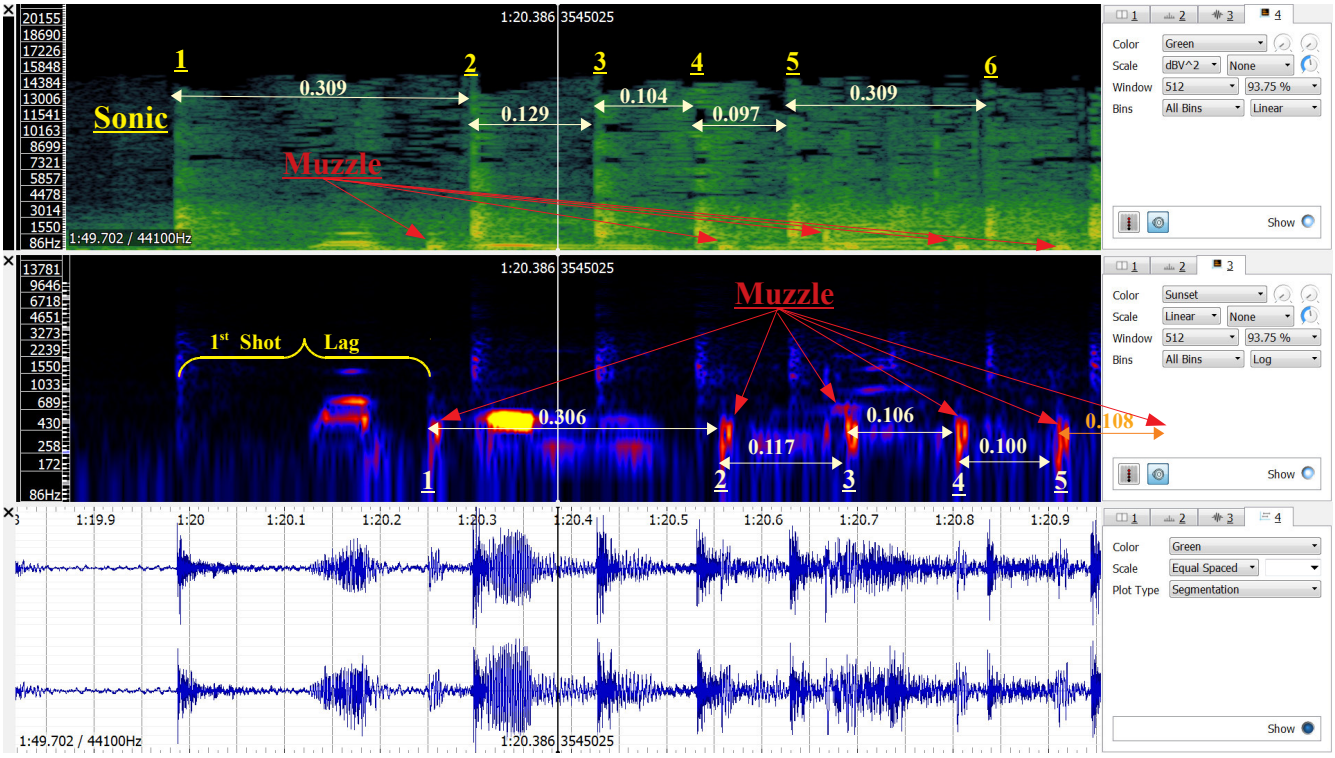
Nominal and distinct seperation between sonic and muzzle with sonic higher than muzzle (as expected).

Both sonic and muzzle suffer from attenuation due to distance.

Voices, Sirens, Engine Noise

Strong Sonic, Medium Muzzle

Captured near 1:20 in video. Amplitude scale is max 0.7 .



Strong Sonic, Weak Muzzle

Very Very Low Sonic, Low Muzzle

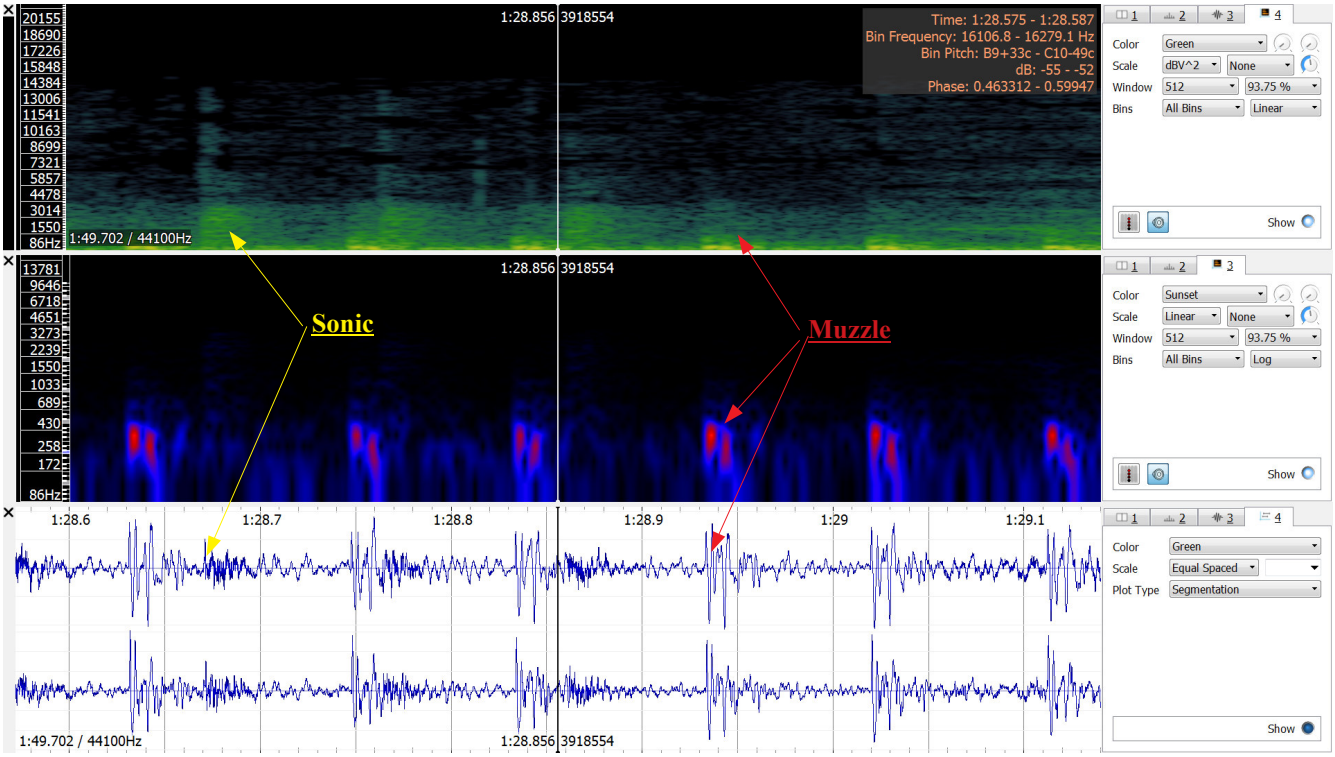
Captured near 1:28 in video.

Sounds like very very distant machine gun thud thud thud thud.

Ladies were ducked down low so phone was muffled. Windows were likely up also.

Amplitude scale maxes at about 0.2, so very low by all accounts. Max amplitude over entire tape is 0.8.

Vehicle was facing Mandalay Bay during this sound segment.



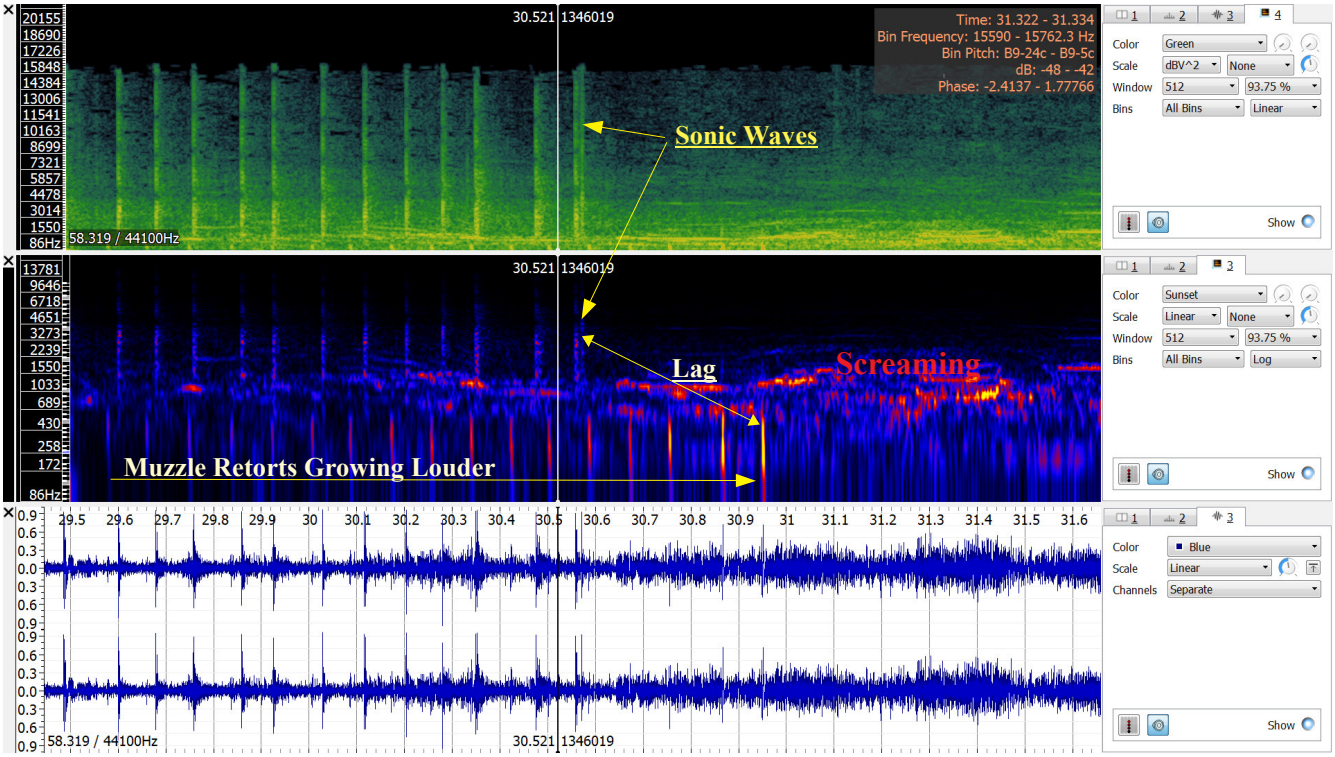
Concert Crowd Early, End of Runway, Stage Left (Mandalay Side)

Bullets Flying, Snap & Boom

The figure below illistrates the tail end of a burst of shots. In this particular instance the bullet sonic waves are more audible than the muzzle retorts. The muzzle retorts grow louder towards the tail end. Note that the last five retorts substantially "lag" the final sonic waves.

At the time of these graphs the cellphone was elevated above the crowd and facing east towards Mandalay Bay with an unobstructed view.

The changing intensity of the muzzle retorts indicates direction movement at the point of shooting. That is, the rifle was not consistantly firing at the same location.

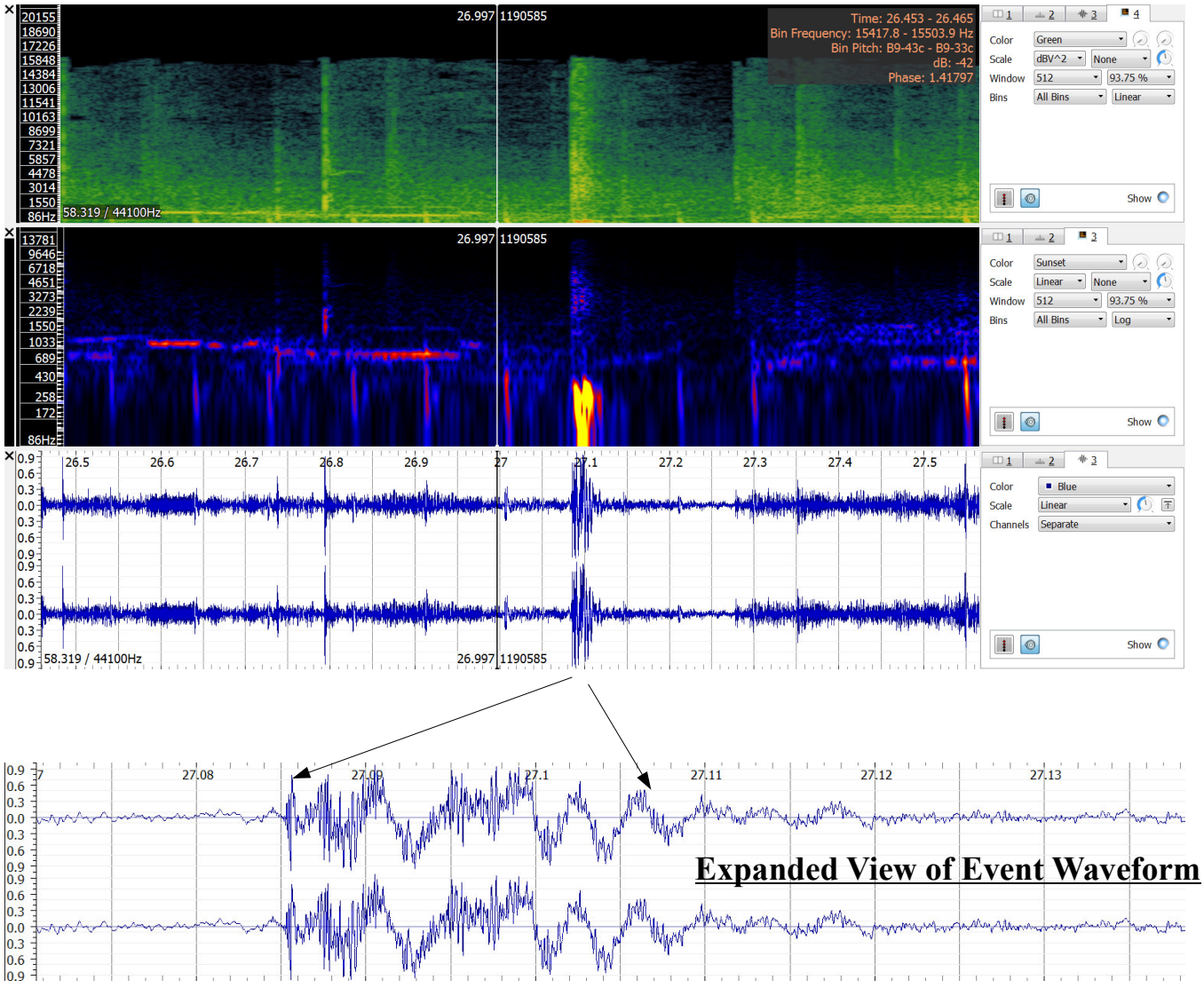


Something Hit

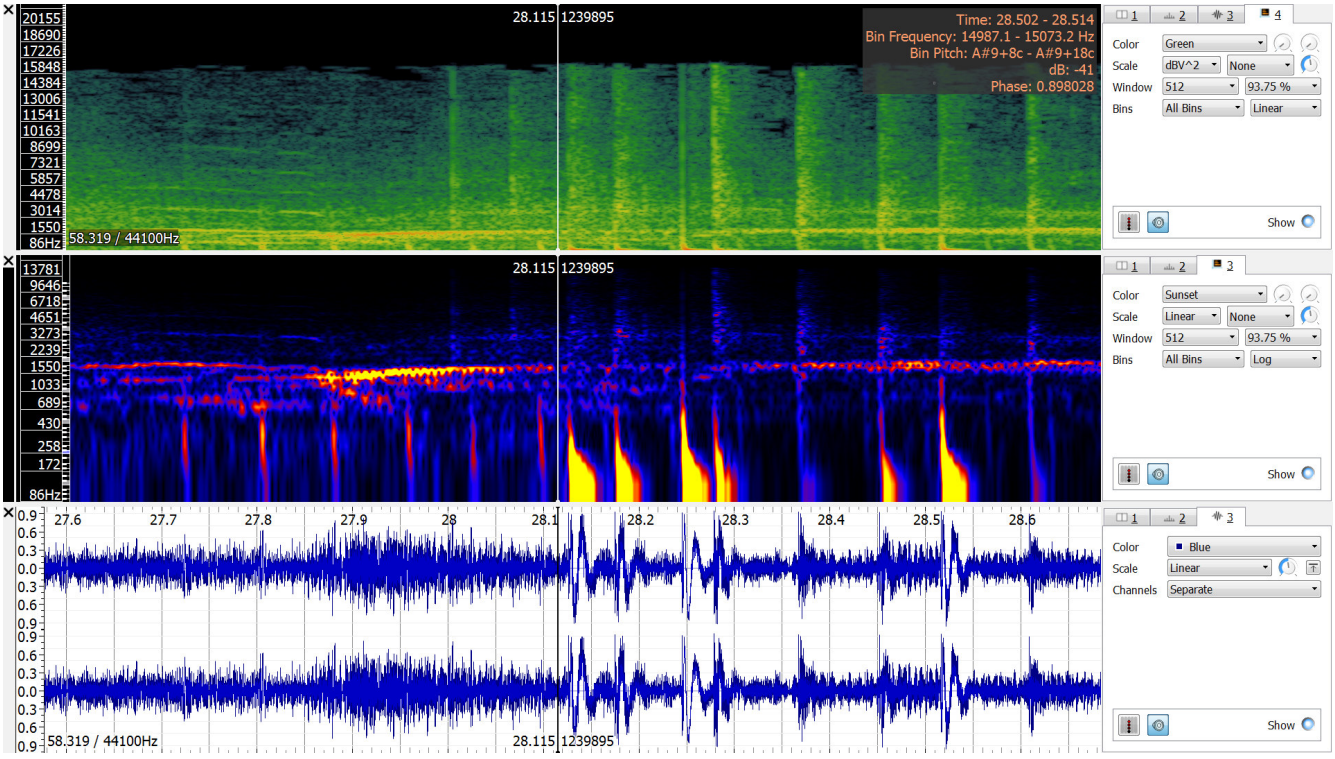
Below is illustrated 1 or 2 sonic waves and 10 muzzle blasts that are audible. The faded and smeared sonic waves are essentially in-audible.

In the middle of the burst is a large event which is intense at both the high and low frequencies. Since neither sonic booms or muzzle blasts grow in energy over time, this is a good example of the bullet hitting something and imparting it's kienetic energy to the thing that it hit. That transferrence of engergy produces resonance with a dominant frequency near 170-200 Hz superimposed on a frequency near 3200 Hz. Based on the lower frequency, the object has a reonant length/mass of about 3-5 feet, but also has a much stiffer component of much smaller length possibly indicating some form of metal component. Best guess is that the bullet hit a nearby wall (or stage runway) composed of wood and metal.

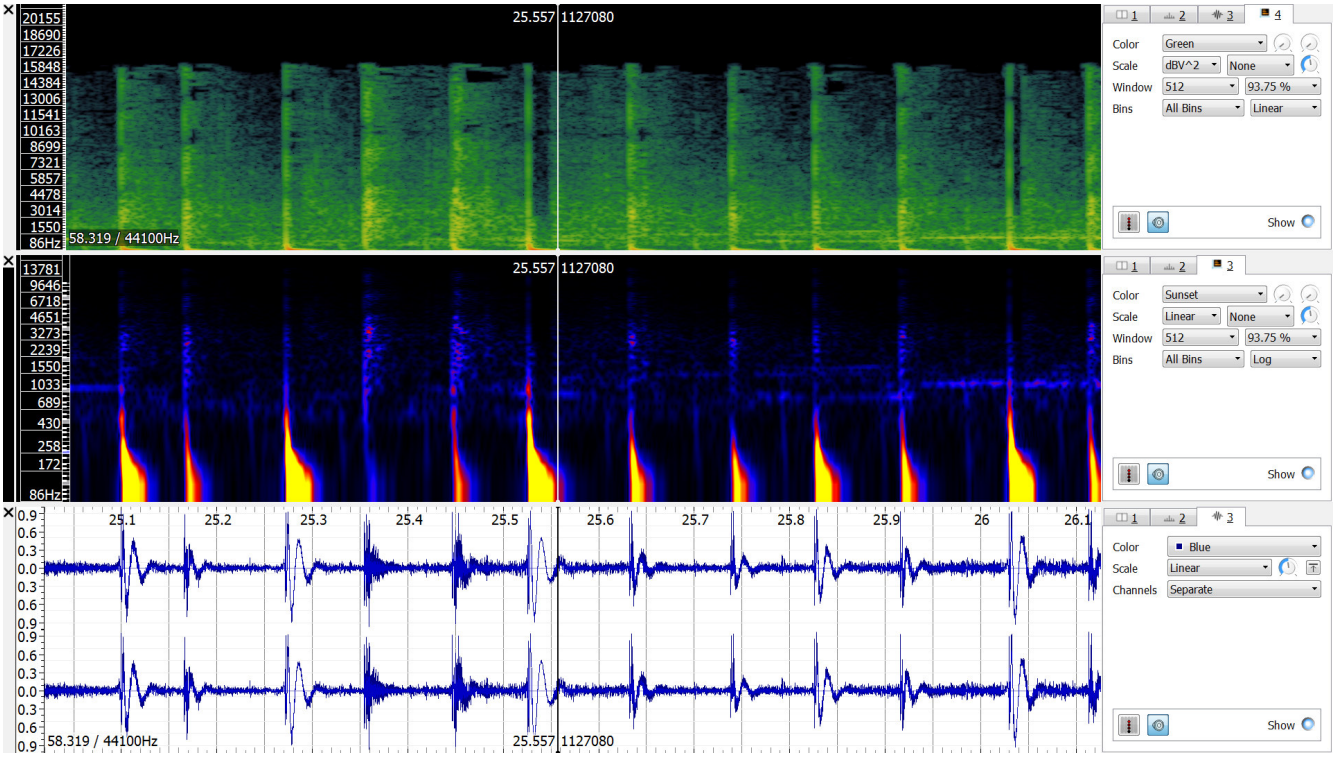
The waveform for this "hit" has been included in expanded time axis.



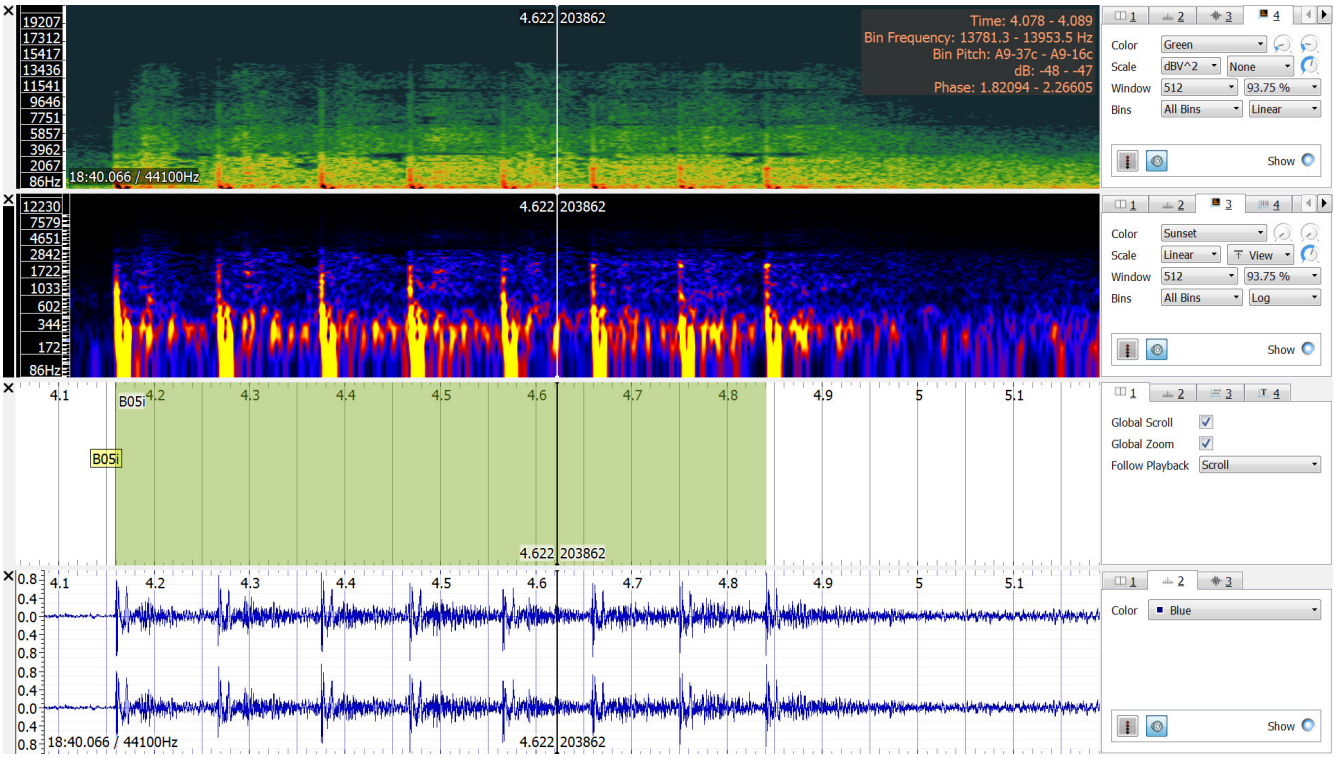
Closing In

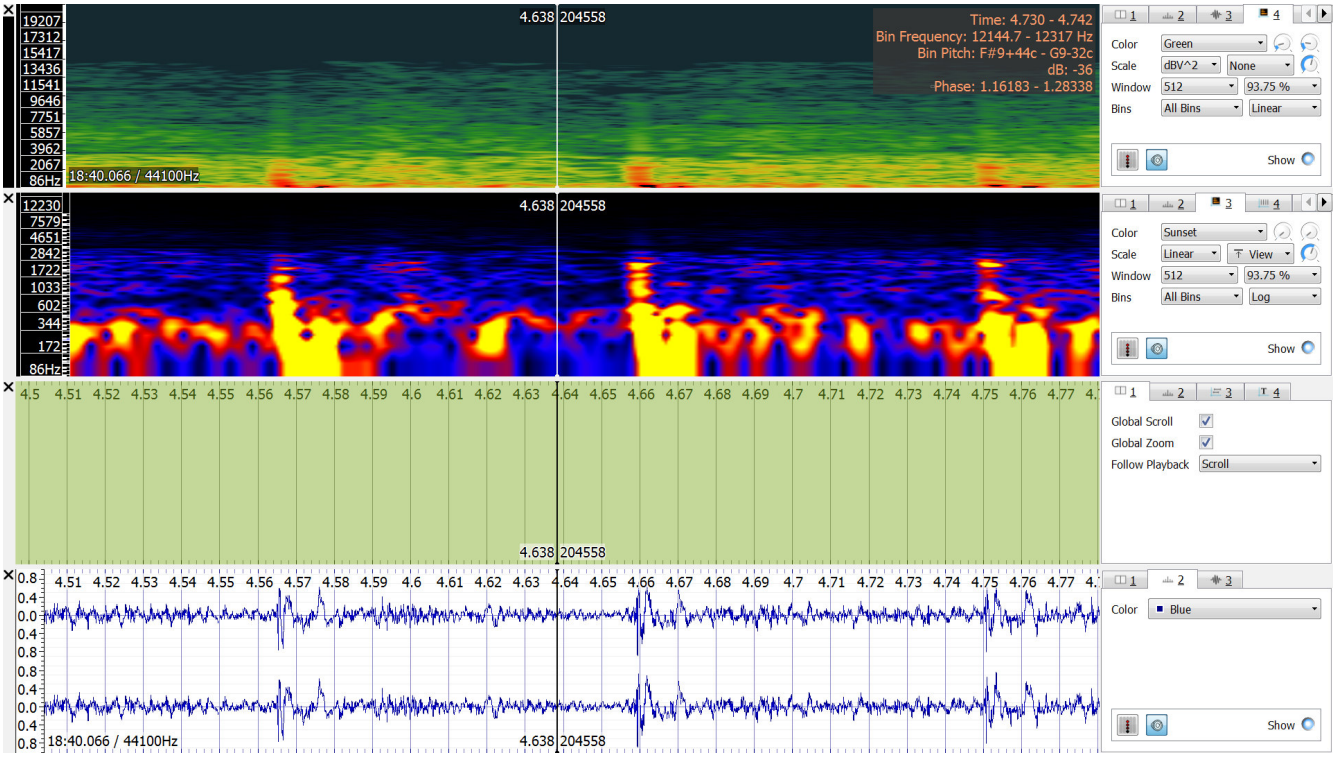

20155
18690
17226
15848
14384
13006
11541
10163
8699
7321
5857
4478
3014
1550
86Hz
28.115 1239895
58.319 / 44100Hz
Time: 28.502 - 28.514
Bin Frequency: 14987.1 - 15073.2 Hz
Bin Pitch: A#9+8c - A#9+18c
dB: -41
Phase: 0.898028
1 2 3 4
Color Green
Scale dBV^2 None
Window 512 93.75 %
Bins All Bins Linear
Show
13781
9646
6718
4651
3273
2239
1550
1033
689
430
258
172
86Hz
28.115 1239895
1 2 3
Color Sunset
Scale Linear None
Window 512 93.75 %
Bins All Bins Log
Show
0.9
0.6
0.3
0.0
0.3
0.6
0.9
27.6
27.7
27.8
27.9
28
28.1
28.2
28.3
28.4
28.5
28.6
58.319 / 44100Hz
28.115 1239895
1 2 3
Color Blue
Scale Linear
Channels Separate
Show

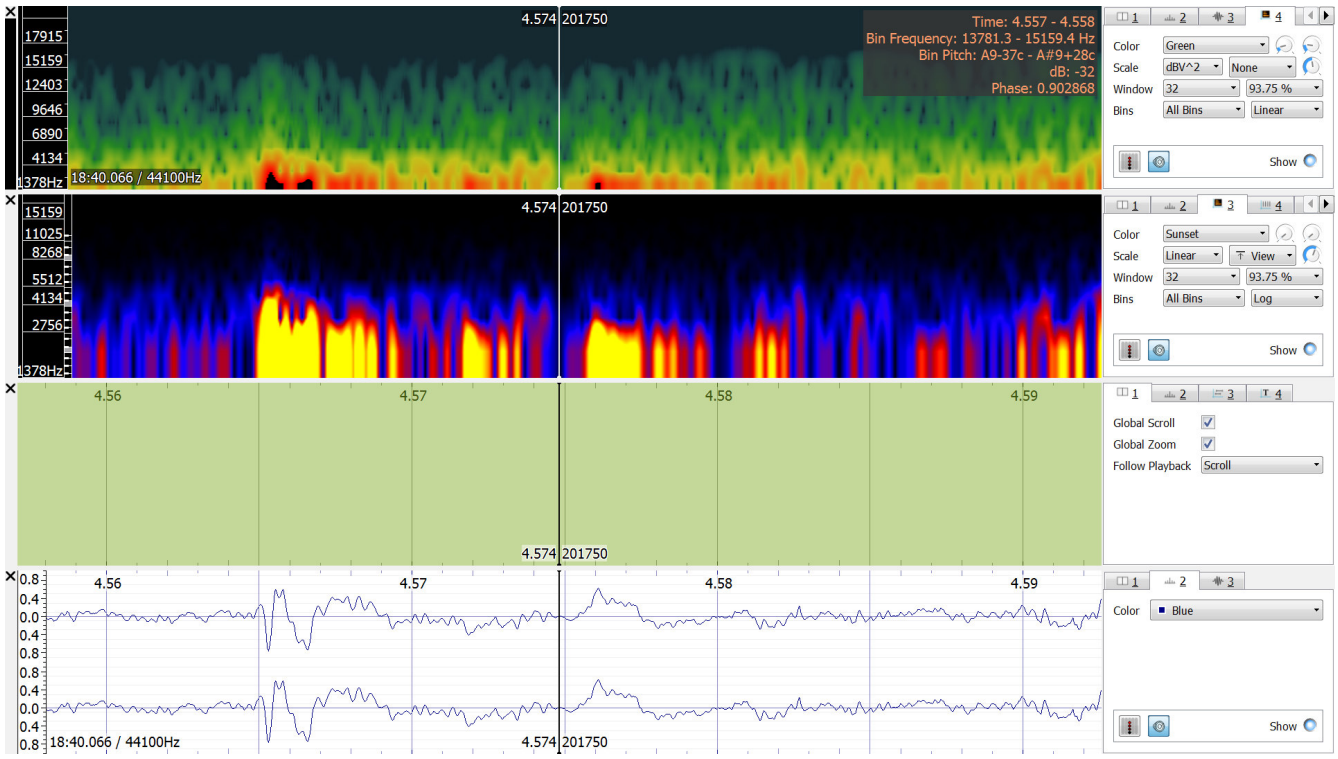
Danger Zone


20155
18690
17226
15848
14384
13006
11541
10163
8699
7321
5857
4478
3014
1550
86Hz
58.319 / 44100Hz
25.557
1127080
Color
Green
Scale
dBV^2
None
Window
512
93.75 %
Bins
All Bins
Linear
Show
13781
9646
6718
4651
3273
2239
1550
1033
689
430
258
172
86Hz
Sunset
Log
0.9
0.6
0.3
0.0
25.1
25.2
25.3
25.4
25.5
25.6
25.7
25.8
25.9
26
26.1
Blue
Channels
Separate

Mandalay Bay Taxi






4.574 201750
Time: 4.557 - 4.558
Bin Frequency: 13781.3 - 15159.4 Hz
Bin Pitch: A9-37c - A#9+28c
dB: -32
Phase: 0.902868
17915
15159
12403
9646
6890
4134
1378Hz
18:40.066 / 44100Hz
Color Green
Scale dBV^2 None
Window 32 93.75 %
Bins All Bins Linear
Show
15159
11025
8268
5512
4134
2756
1378Hz
Color Sunset
Scale Linear View
Window 32 93.75 %
Bins All Bins Log
4.56
4.57
4.58
4.59
Global Scroll
Global Zoom
Follow Playback Scroll
0.8
0.4
0.0
0.4
0.8
Color Blue

"Pistol" Shot(s) Characteristics

The last two shots heard on the video recorded at the Mandalay bus stop before the crowd gets on the bus have different characteristics than most other shots.

1. Initial impulse is wider
2. No sonic wave
3. Smeared response
4. Lower High Frequency respone in decibel scale
5. Less LowFrequency response in linear scale
6. Different sound than either sonic "snap" or muzzle blast "boom"

These two shots, are similiar to combining a sonic with a muzzle and then removing the top end and bottom end frequency respones as well as lower the overall intensity and power.

Observations

Video Tape

Basic video tape properties:

Source:	Las Vegas Police Department
Medium:	You Tube Video
Type:	.mp4
Duration:	3:03.666s
Duration:	5510 frames
Resolution:	1280x720
Audio:	Stereo, 44Khz sample rate
Speed:	29.97 fps
Size:	41 MB

Syncronization Info

For syncronization purposes, the first frame showing the visible time of 10:09:07 PST occurs at the video time of zero minutes four and one-hundreth second (0:04.100). Which implies that the first frame of the video occurs at **10:09:2.9**

Whatever time an event occurs in the audio (or video) then add 10 hours 9 minutes and 2.9 seconds. For our obsertations:

Video Time	Global Start Time	Duration	Event Name
5.110566893	10:09:08.01	0.010340136	B05a
12.019387755	10:09:14.92	0.009070295	B05b