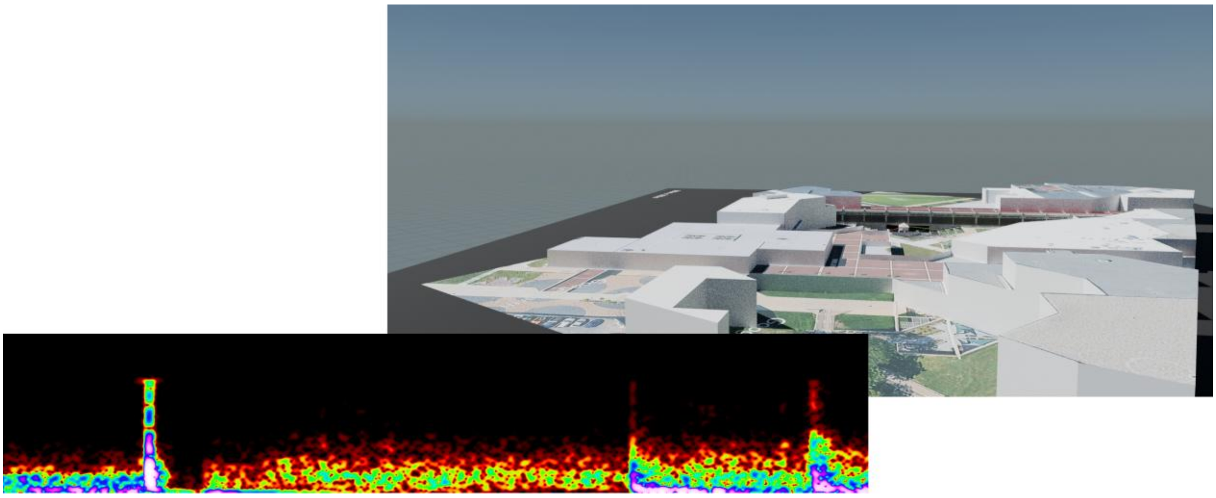
Charlie Kirk Shooting

from an OSINT perspective

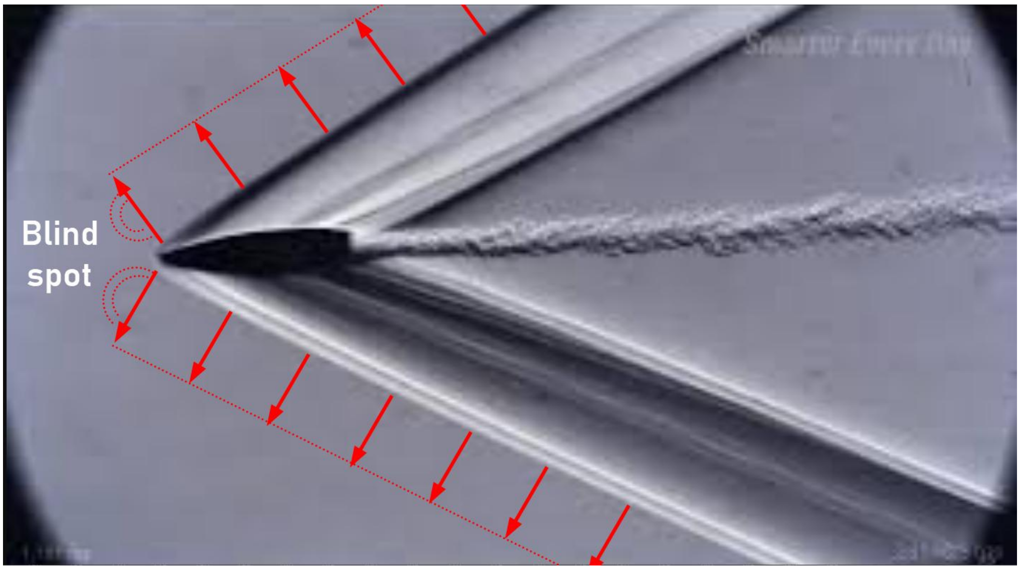


by Michael Kobs

Since the attack on Charlie Kirk, there have been countless theories about how he was shot. Most of these theories are based purely on ignorance. The most common claim is that the shot was fired at close range or that his microphone had been rigged. This is followed by claims that the shot was fired with a special, very slow bullet below the speed of sound. A third theory assumes that an inaudible shot was fired from behind or from the side, precisely synchronized with the shot from a roof, which was not responsible for the death.

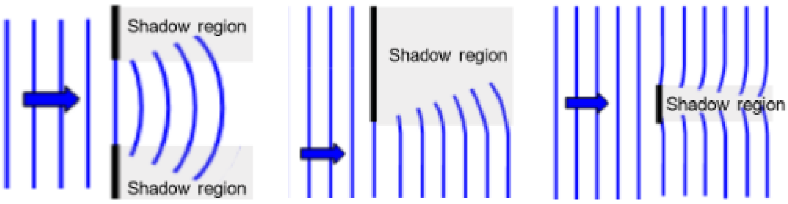
All these claims are refuted by the simple fact that a clear pattern of a supersonic "crack" followed by the actual sound of the shot can be heard in the microphone recordings in the audience. This pattern only occurs when a physically real projectile actually passes through the air near the microphones at at least the speed of sound. In addition, the microphone must be at a certain angle to the trajectory of the shot, as the crack propagates in a straight line.

The principle is very similar to the bow wave of a boat. The straight crack wave propagates perpendicular to the wave crest.

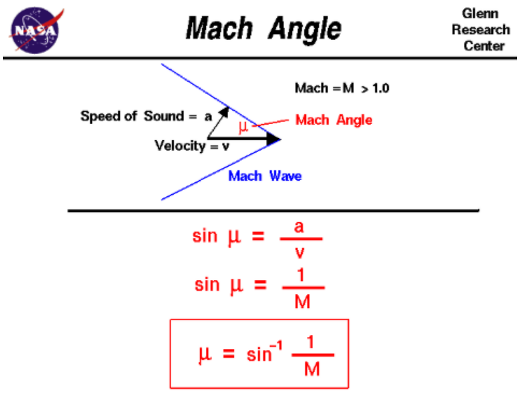


If the trajectory ends by hitting a target, a crack wave is no longer generated. This means that a dead zone is created behind the target, in which no crack can be heard. Near the edges of the ending wave, there may still be decaying effects due to diffraction and the wave fading out, but in general, no crack is to be expected in the dead zone.

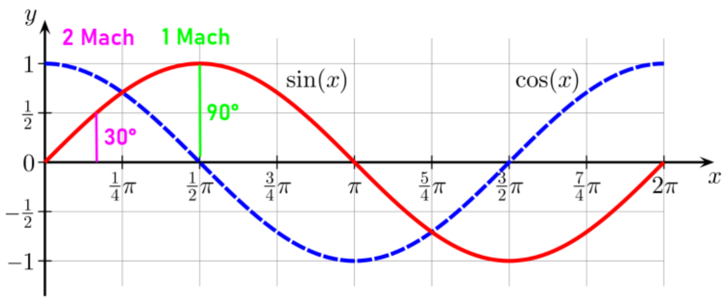
The diffraction of water waves behind an obstacle behaves similarly to a straight sound wave that abruptly breaks off.



It is also useful to know that the crack wave—even though it is called a shock wave—behaves like a normal sound wave. This means that it does not propagate at supersonic speed, but at normal sound speed perpendicular to the wave front.



This inevitably results in a right-angled triangle with the characteristic Mach angle μ. And because the sine of an angle corresponds to the quotient of the opposite side and the hypotenuse, **sine(μ) = speed of sound / bullet velocity**. If the projectile flies at exactly the speed of sound, the quotient (i.e., the sine) becomes equal to 1, which means that the crack forms like a disc around the projectile, with the wave front traveling at the same speed as the projectile and stacking wave crest upon wave crest—the so-called sound barrier. At higher speeds, the Mach cone collapses like an umbrella. If the projectile flies at Mach 2, the sine drops to ½ and the Mach cone is only 30° open.



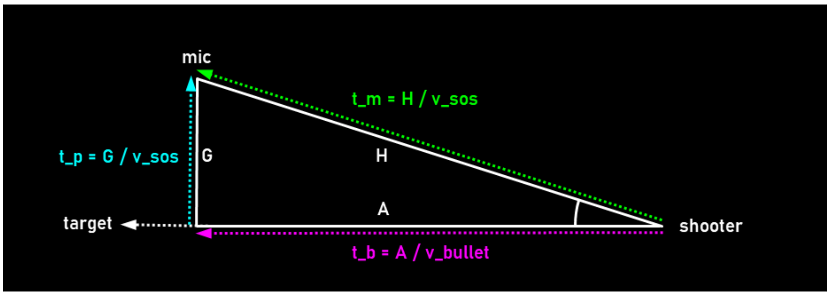
How does this help with the Charlie Kirk case?

The difficulty in analyzing cell phone videos in the Charlie Kirk case is that everything happens in a small space. The videos often have a variable frame rate, so the best synchronization has an indeterminate error of +/- 0.033 seconds. However, if the cameraman is only 5 meters away from the trajectory, he forms a triangle with one side only 5 meters long, while the other side can be 100 or 200 meters long. If the error due to the frame rate is 22 meters, then any result is only a very vague assertion.

So, in order to extract something useful from the data, only the audio track with a sample rate of up to 48 kHz is available, and we have to find a way that does not rely on synchronism.

Crack-Bang Time Difference

In the simplest case (at 1Mach), the time difference that we can measure in the audio track results from the muzzle sound (t_m), which propagates spherically and therefore directly (H) to the microphone (mic) at the speed of sound (v_{sos}). For simplicity, H stands for hypotenuse.

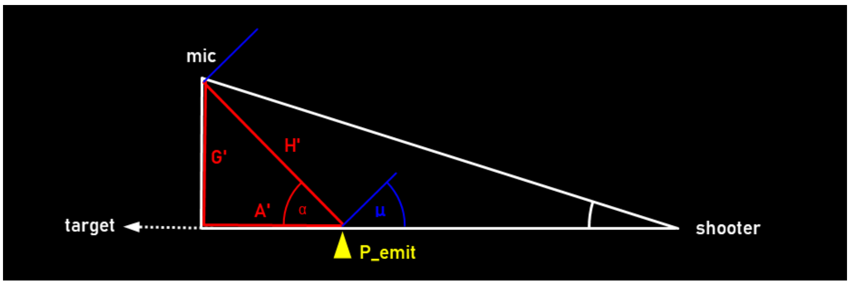


If we look at the triangle from the shooter's perspective, the projectile travels at projectile velocity (v_b) along the trajectory (A) and generates the crack at the moment of closest approach to the microphone. This crack then travels along the vertical line (G) at the speed of sound. G and A represent the opposite and adjacent sides in the right-angled triangle.

The muzzle sound and the crack therefore meet at the microphone with a time delay. This results in the following time difference (Δt):

$$\Delta t = t_m - (t_b + t_p) = (H - G) / v_{sos} - A / v_b$$

The problem is that, apart from Δt and v_{sos} (speed of sound), all other variables are unknown. And because v_b is also unknown, we have to assume a reasonable speed of around 2-3 Mach. This results in a second triangle that must be taken into account when calculating Δt.



The easiest way to do this is to reduce the Mach cone model to the original right-angled model by "correcting" the measured Δt for the hypothetical case in which the crack would actually have to take the detour via the right angle. This means we calculate the time difference between the two paths and correct the measured "shortcut" via H'. The difference is as follows:

$$\Delta t_{diff} = \Delta t - \Delta t_{90} = - A' / v_b + (H' - G) / v_{sos}$$

$$\Delta t_{diff} = G \tan(\mu) / v_b + G / v_{sos} (1 / \cos(\mu) - 1)$$

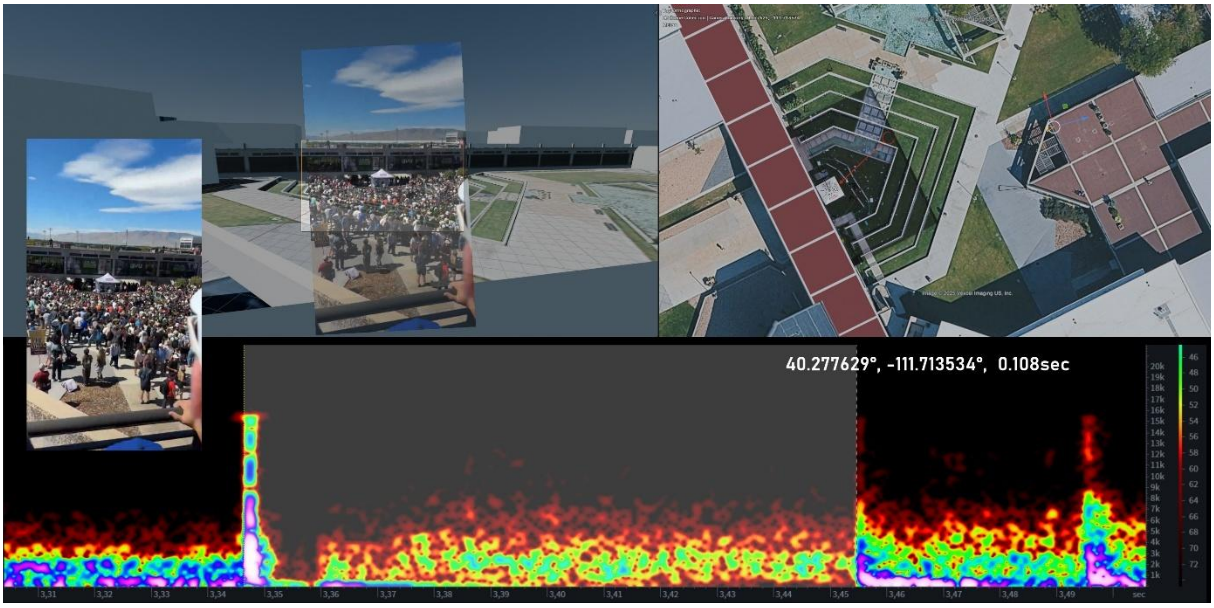
With this adjustment, it is possible to specify v_b to rotate a hypothetical line of fire around the target, calculate the distance to one of the microphones for each angle, and derive the position of the shooter from the time delay that would produce the measured time delay.

Localization of microphones

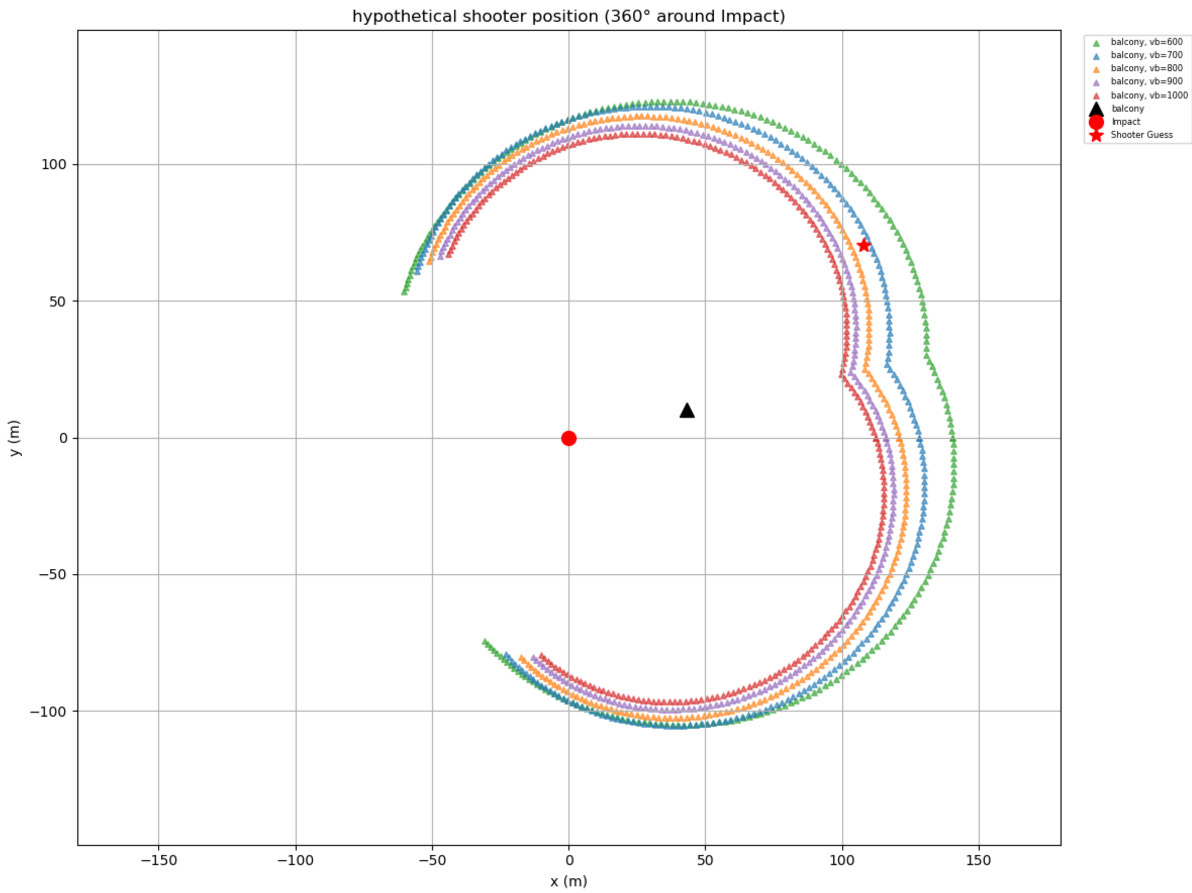
Camera: „balcony“

Lat/Lon: 40.277629°, -111.713534°

Δt: 0.108 sec



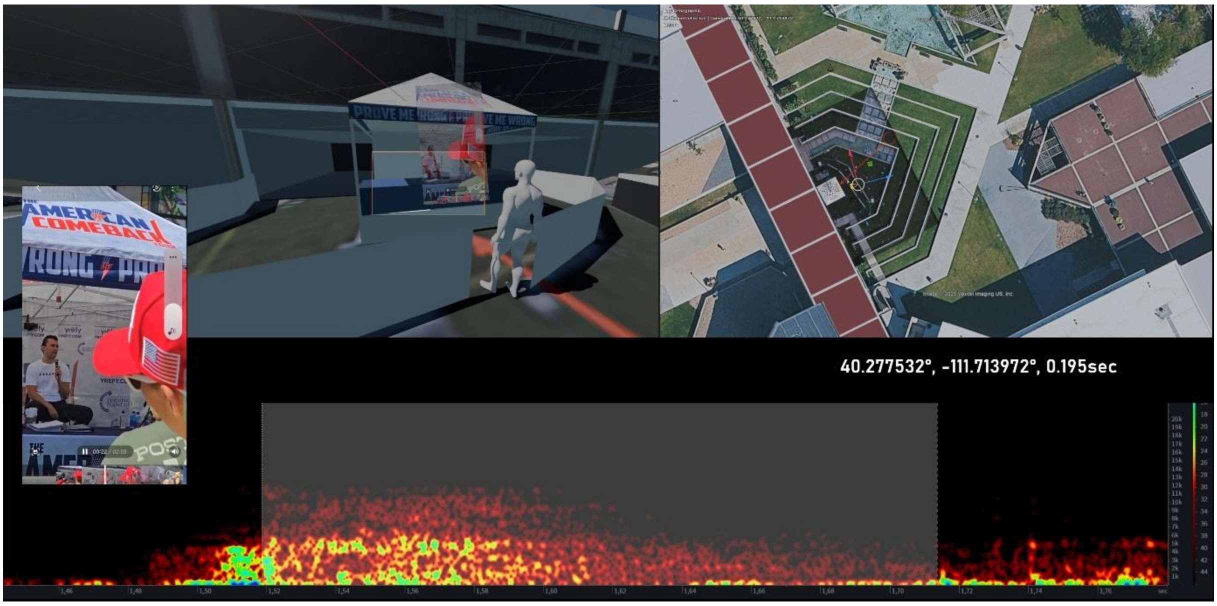
Possible shooter positions for v_b = 600 to 1000 m/s



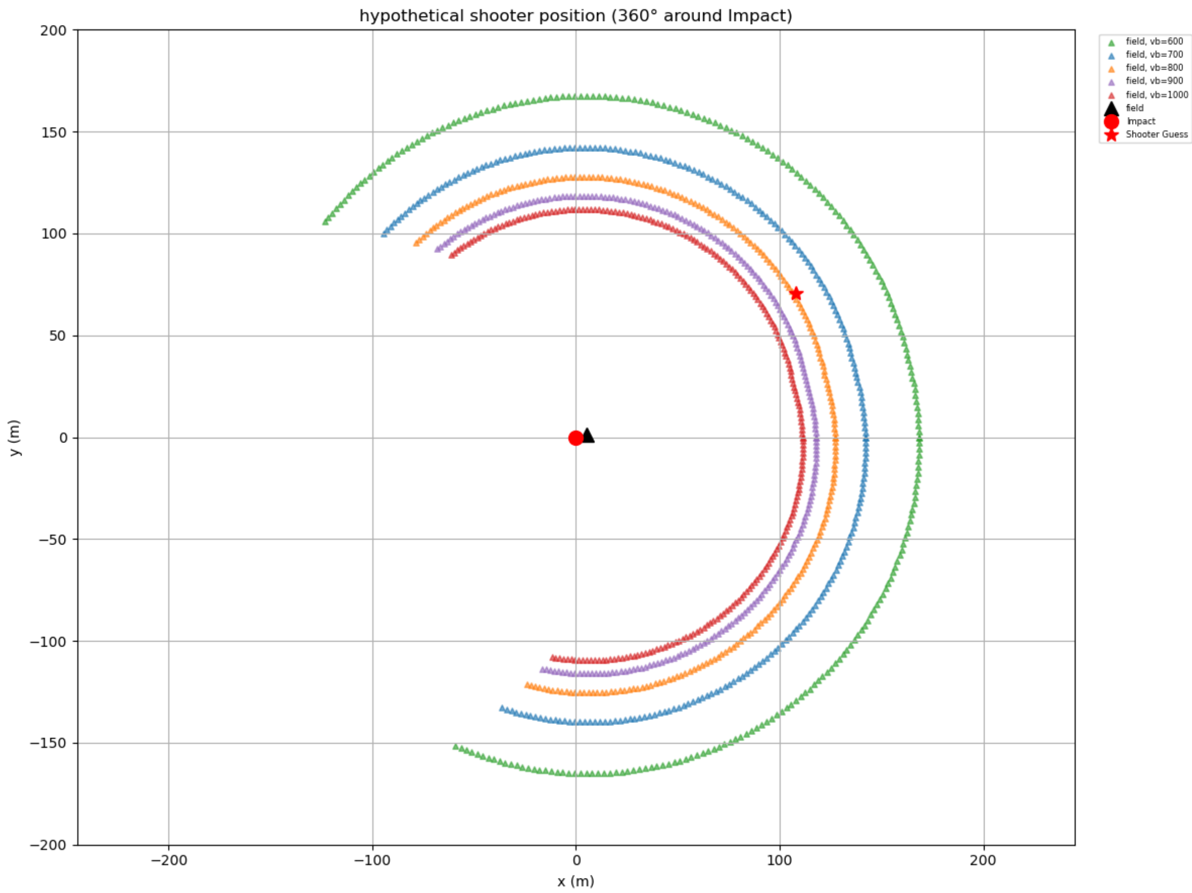
Camera: „field"

Lat/Lon: 40.277532°, -111.713972°

Δt: 0.195 sec



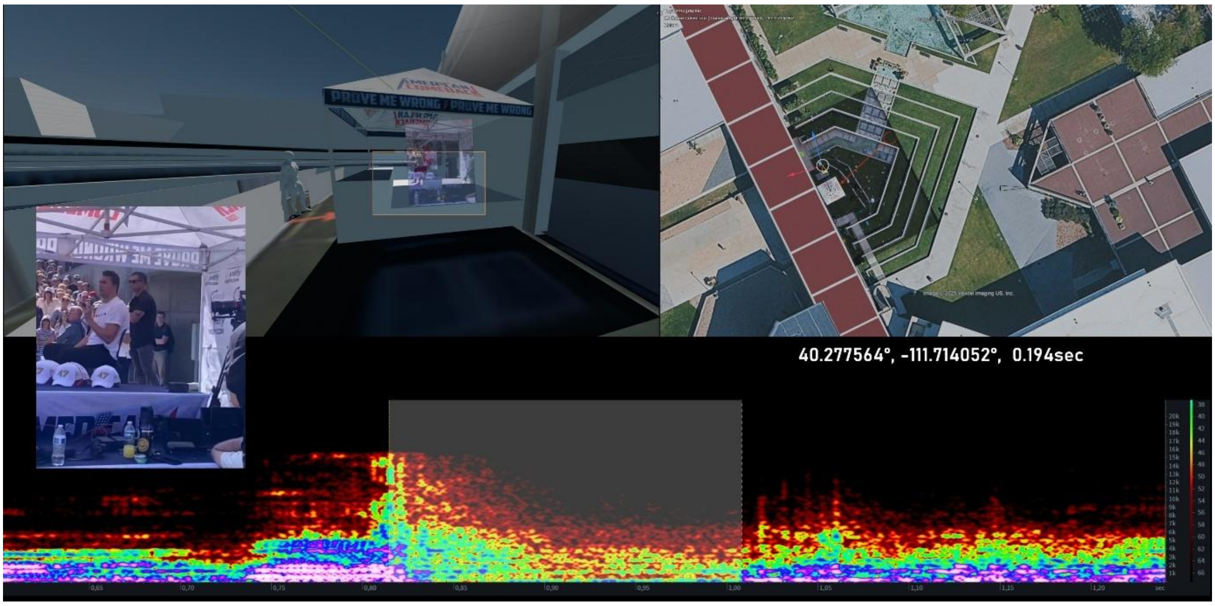
Possible shooter positions for v_b = 600 to 1000 m/s



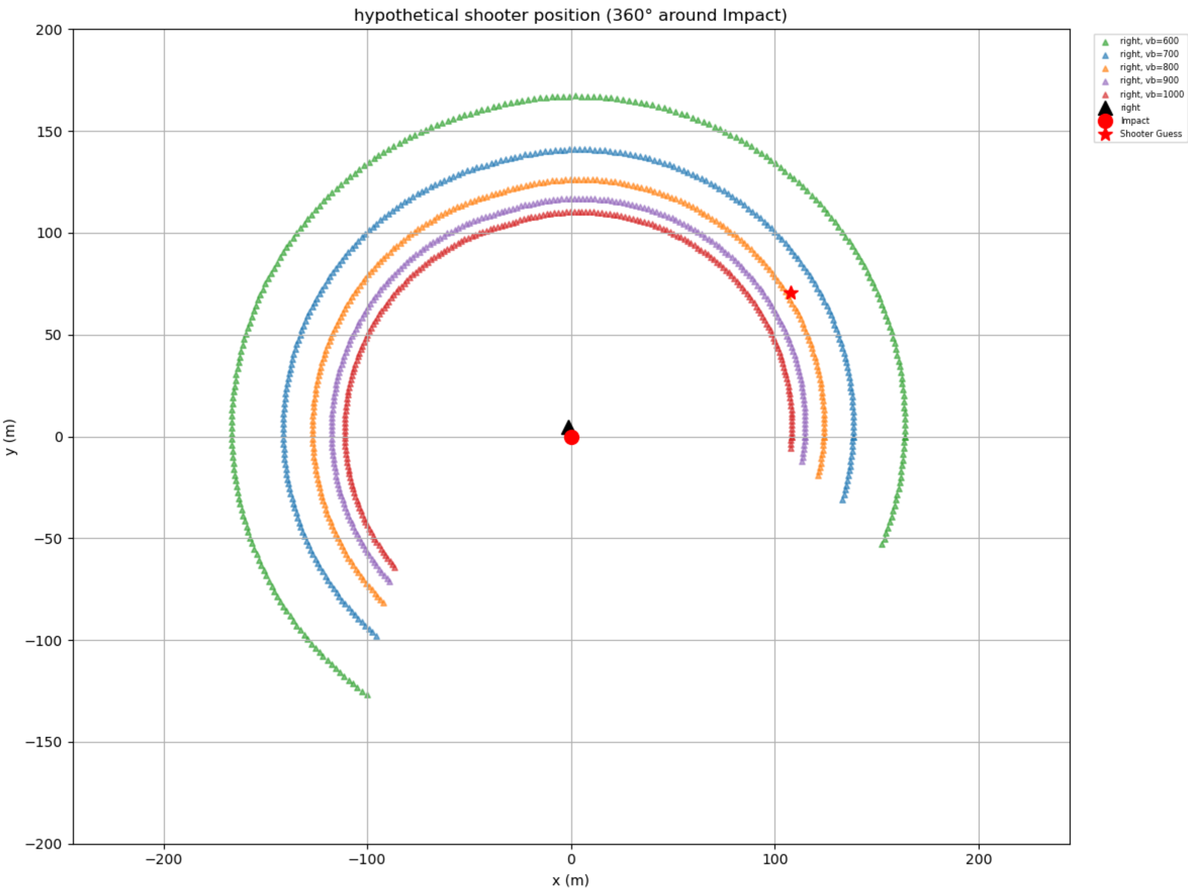
Camera: „right"

Lat/Lon: 40.277564°, -111.714052°

Δt: 0.194 sec



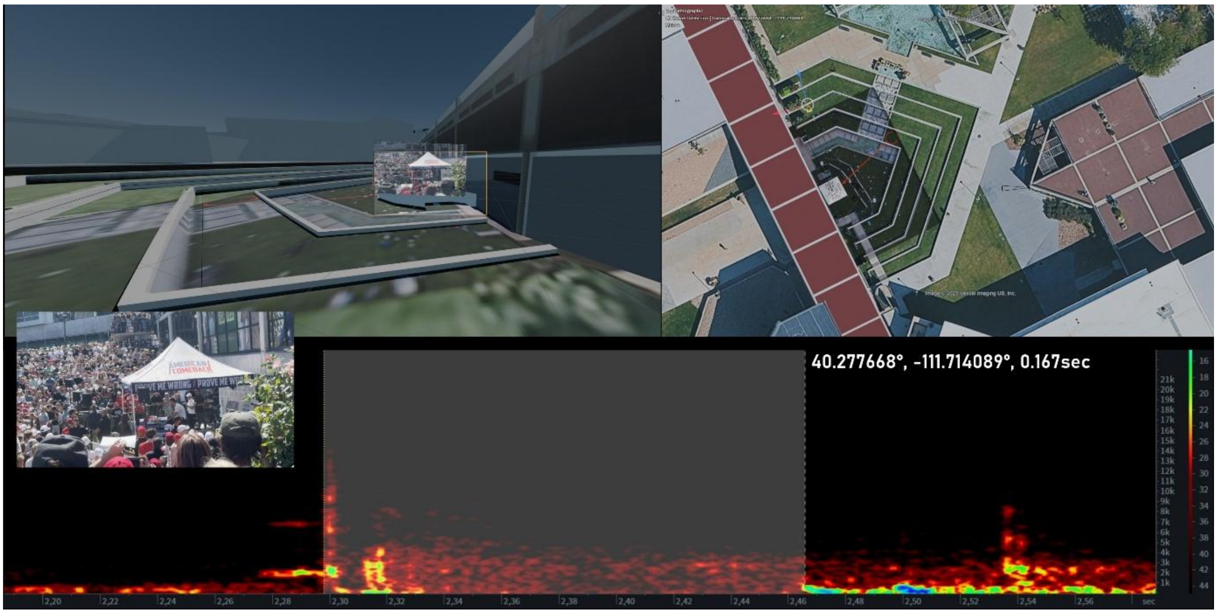
Possible shooter positions for v_b = 600 to 1000 m/s



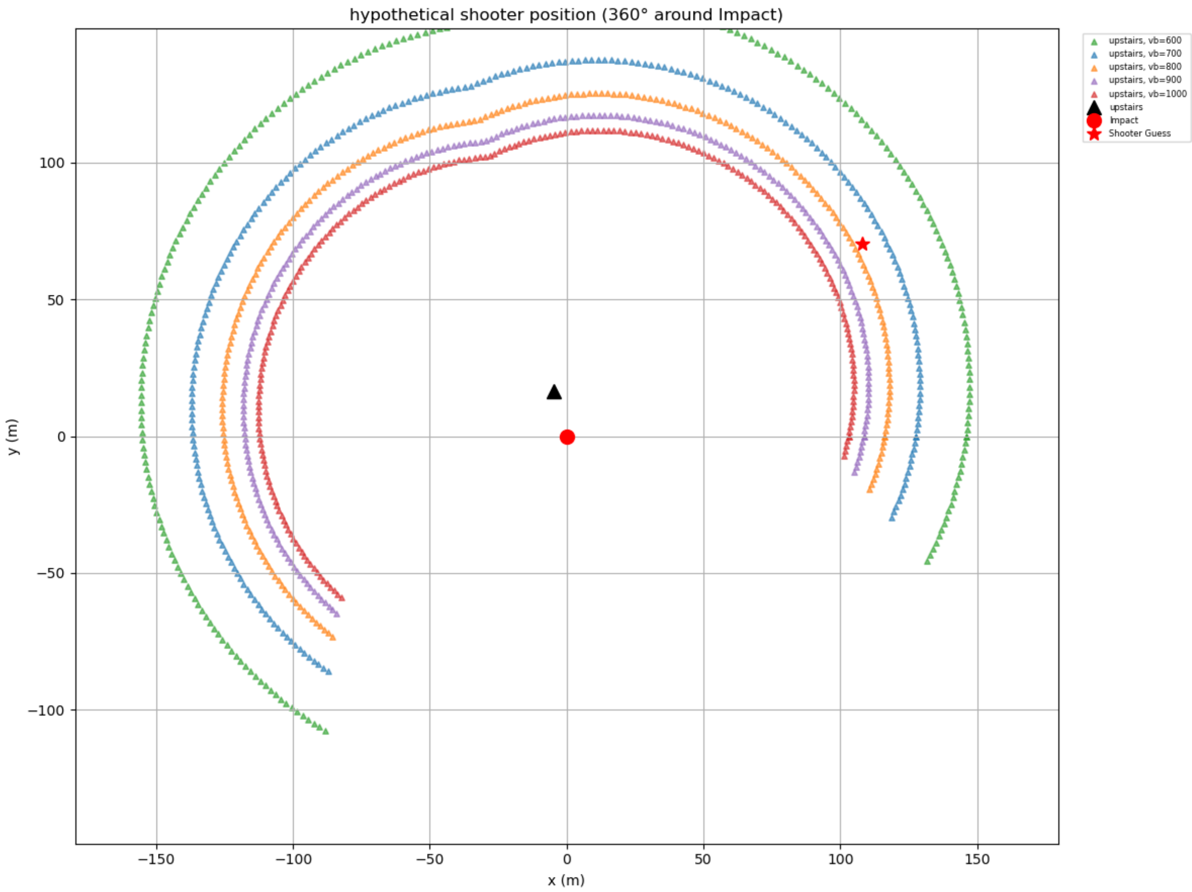
Camera: „upstairs“

Lat/Lon: 40.277668°, -111.714089°

Δt: 0.167 sec



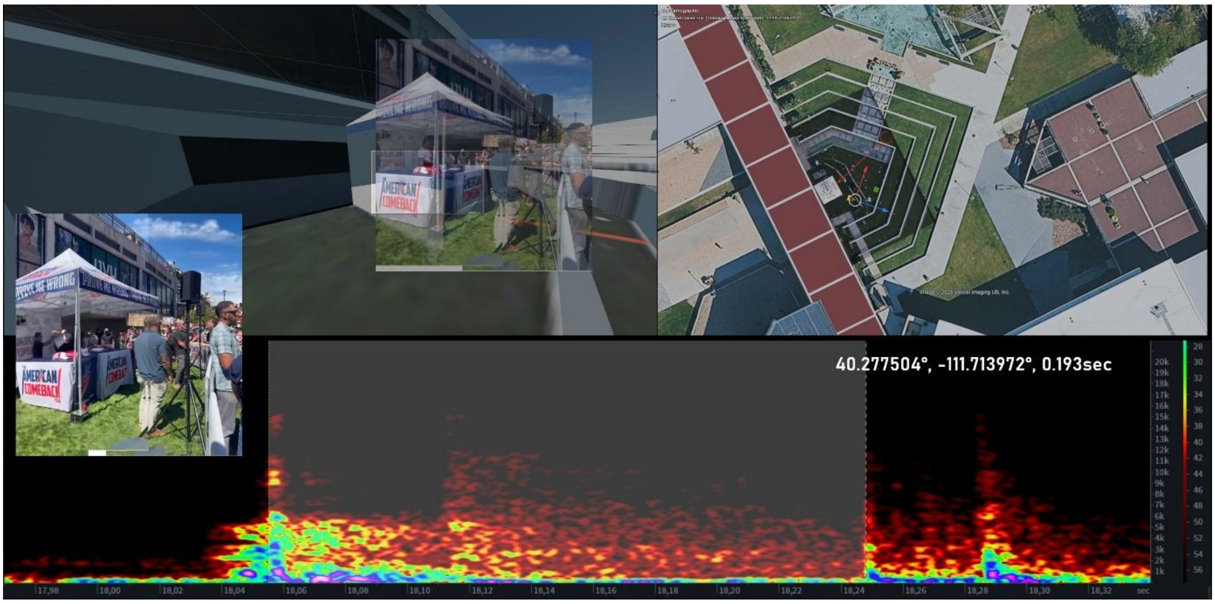
Possible shooter positions for v_b = 600 to 1000 m/s



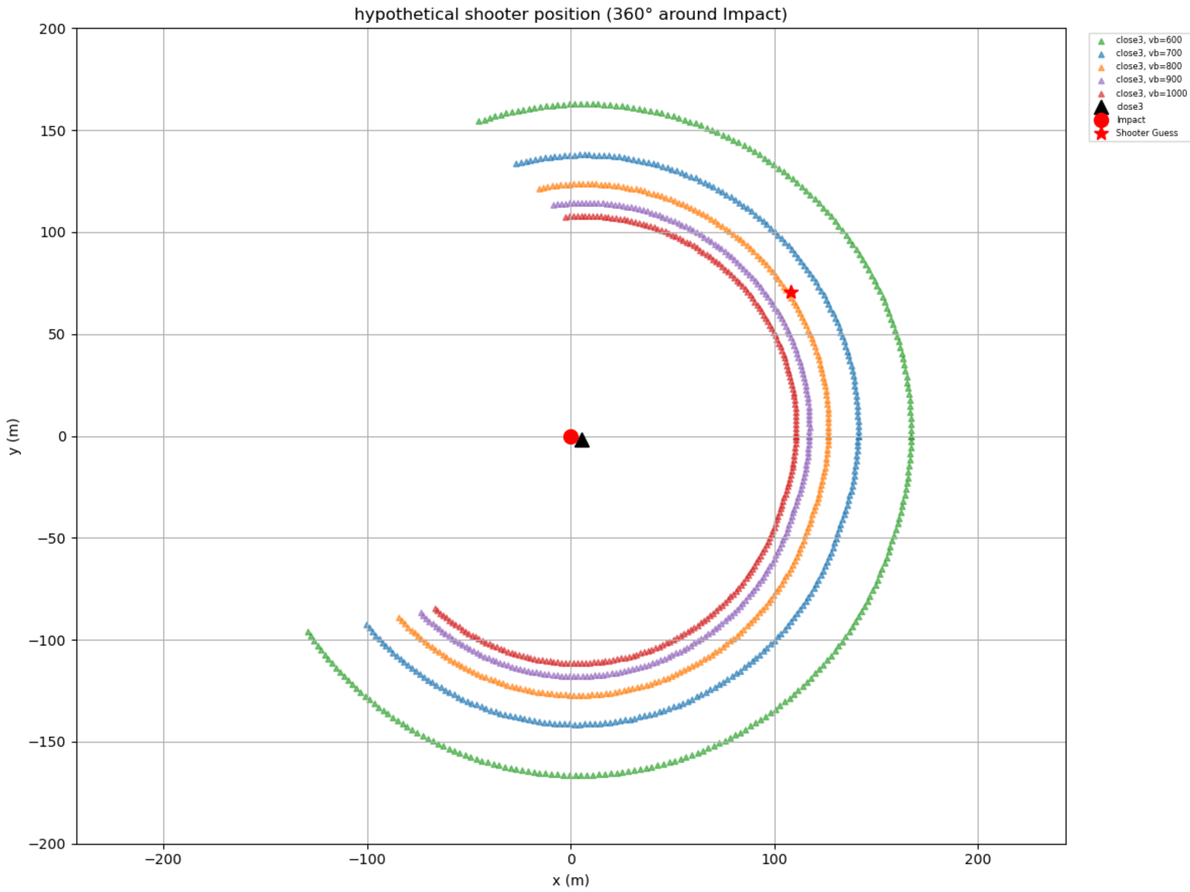
Camera: „close3"

Lat/Lon: 40.277504°, -111.713972°

Δt: 0.193 sec



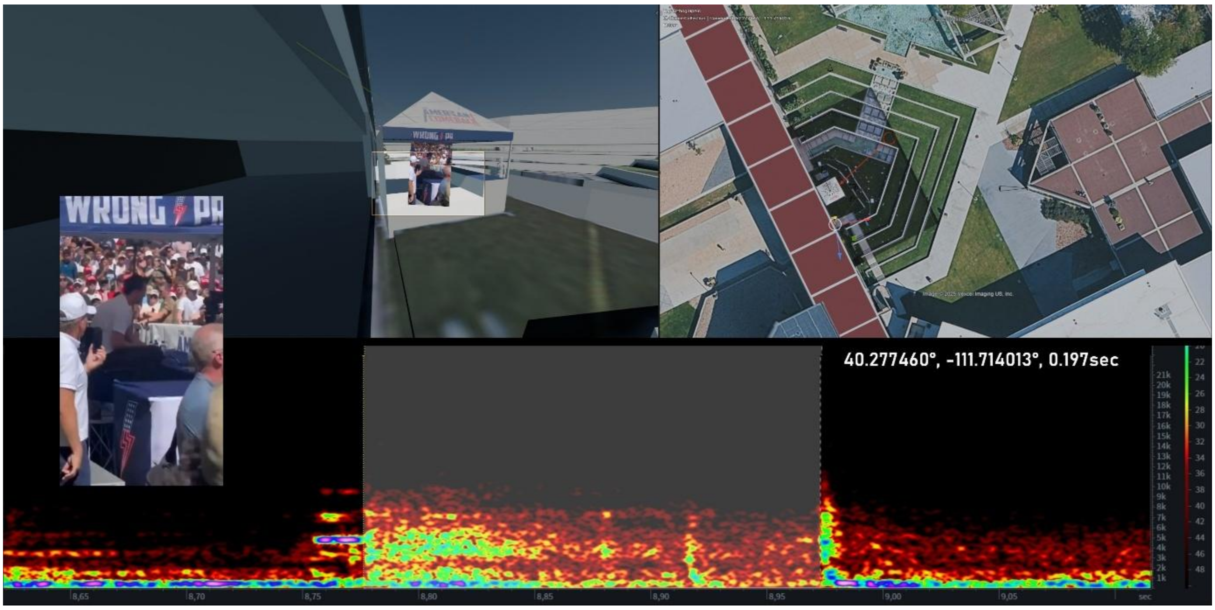
Possible shooter positions for v_b = 600 to 1000 m/s



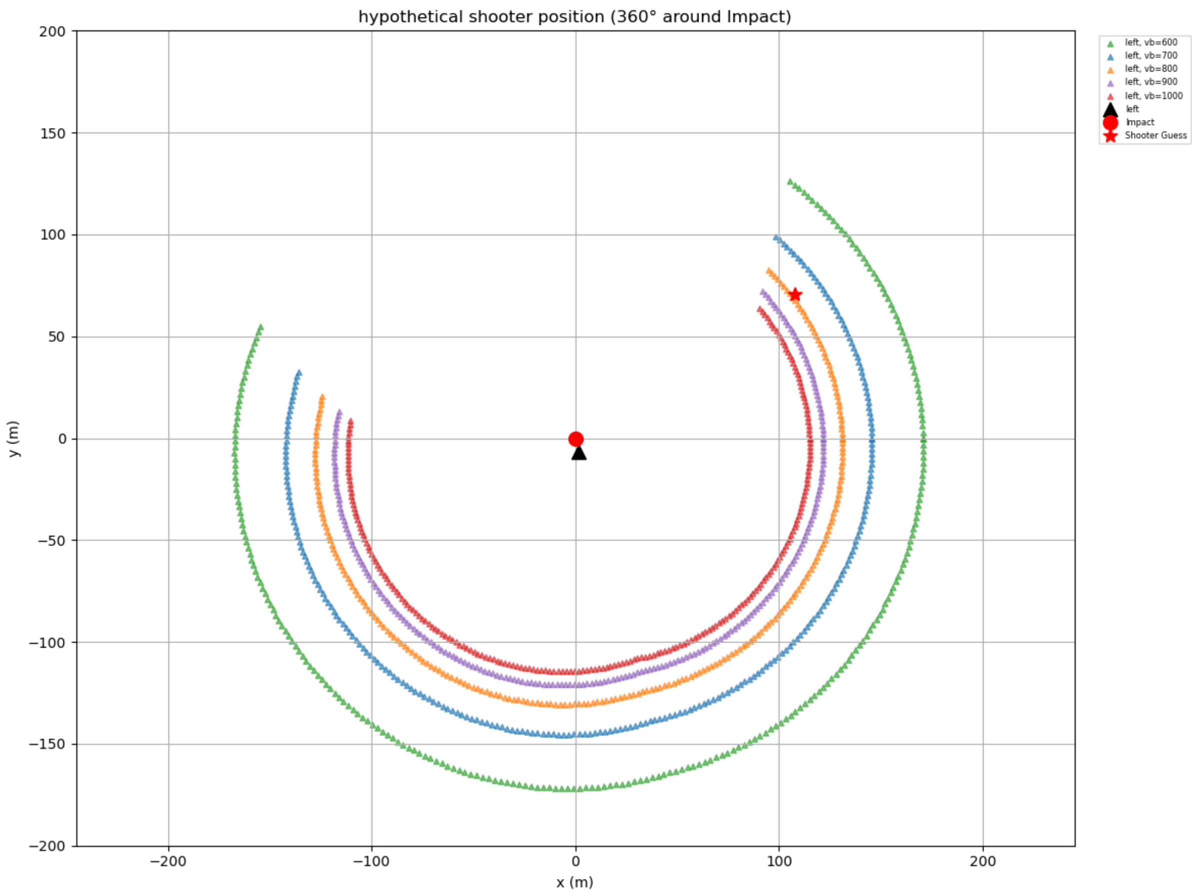
Camera: „left"

Lat/Lon: 40.277460°, -111.714013°

Δt: 0.197 sec



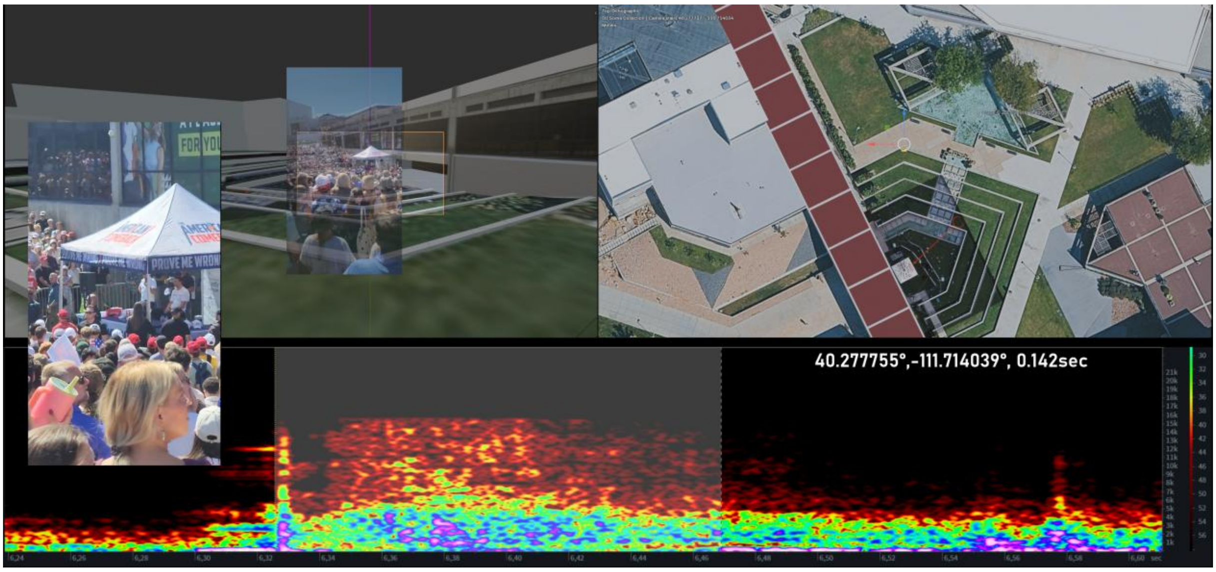
Possible shooter positions for v_b = 600 to 1000 m/s



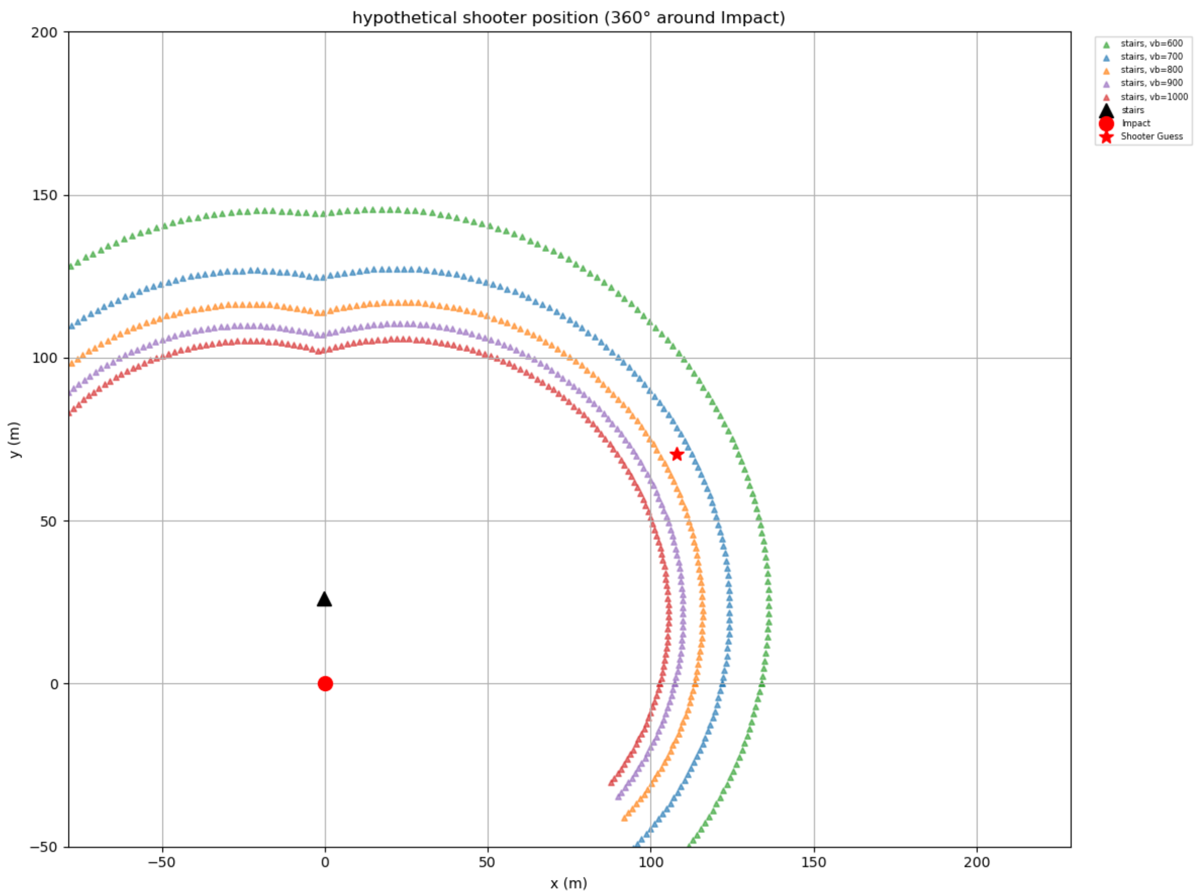
Camera: „stairs"

Lat/Lon: 40.277755°, -111.714039°

Δt: 0.142 sec



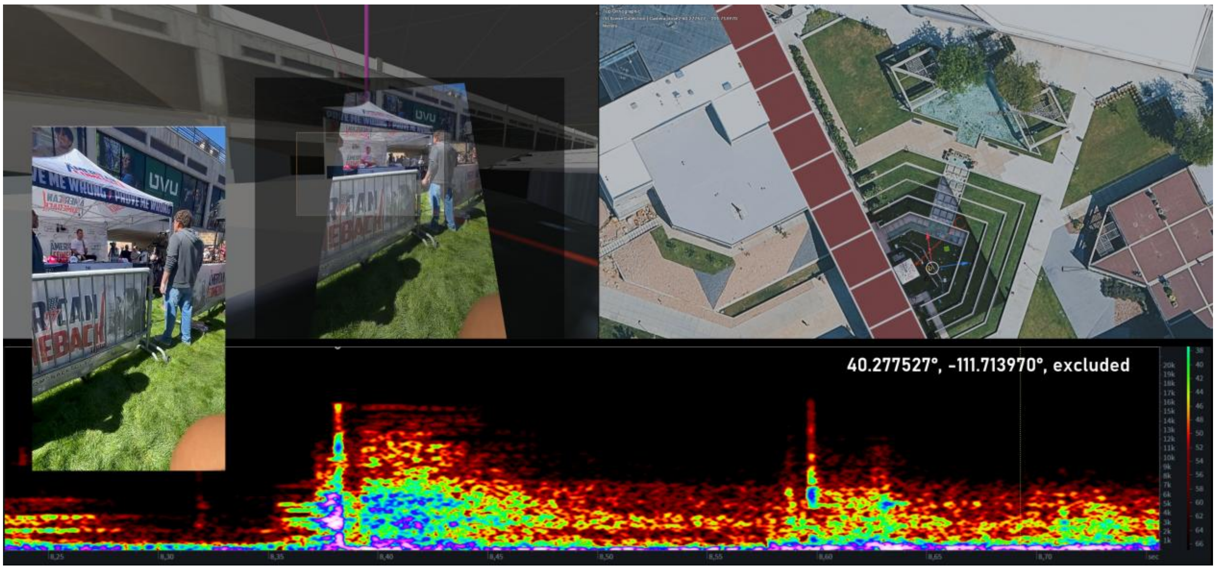
Possible shooter positions for v_b = 600 to 1000 m/s



Camera: „close2" - excluded

Lat/Lon: 40.277527°, -111.713970°

Δt: none

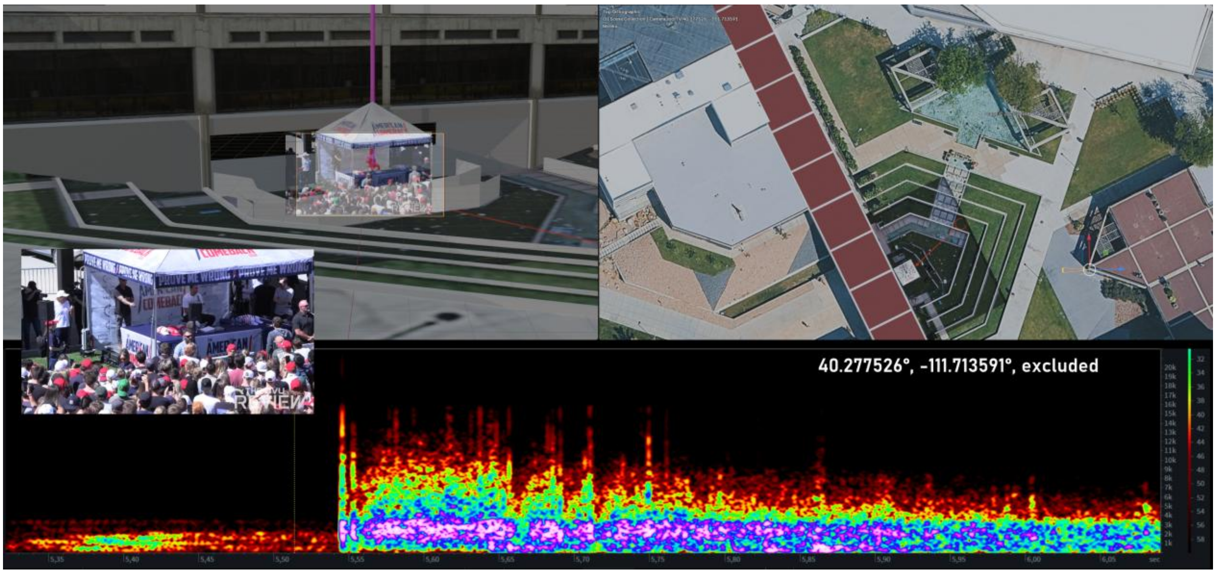


This camera contains a clearly recognizable audio pattern. However, the measurable times differ so greatly from neighboring cameras that it is possible that the sample frequency was also changed during post-processing, e.g., frame rate conversion.

Camera: „roofTV" - excluded

Lat/Lon: 40.277526°, -111.713591°

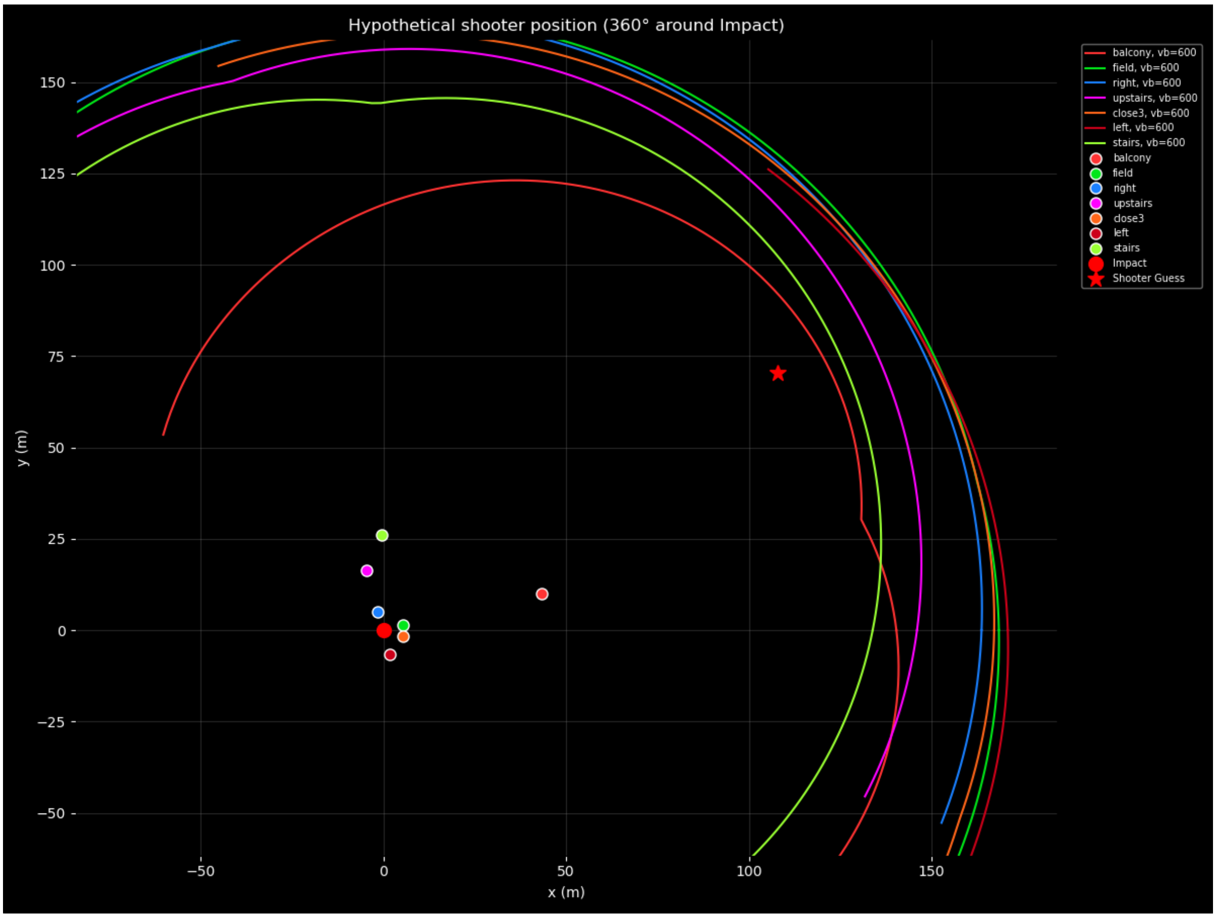
Δt: none



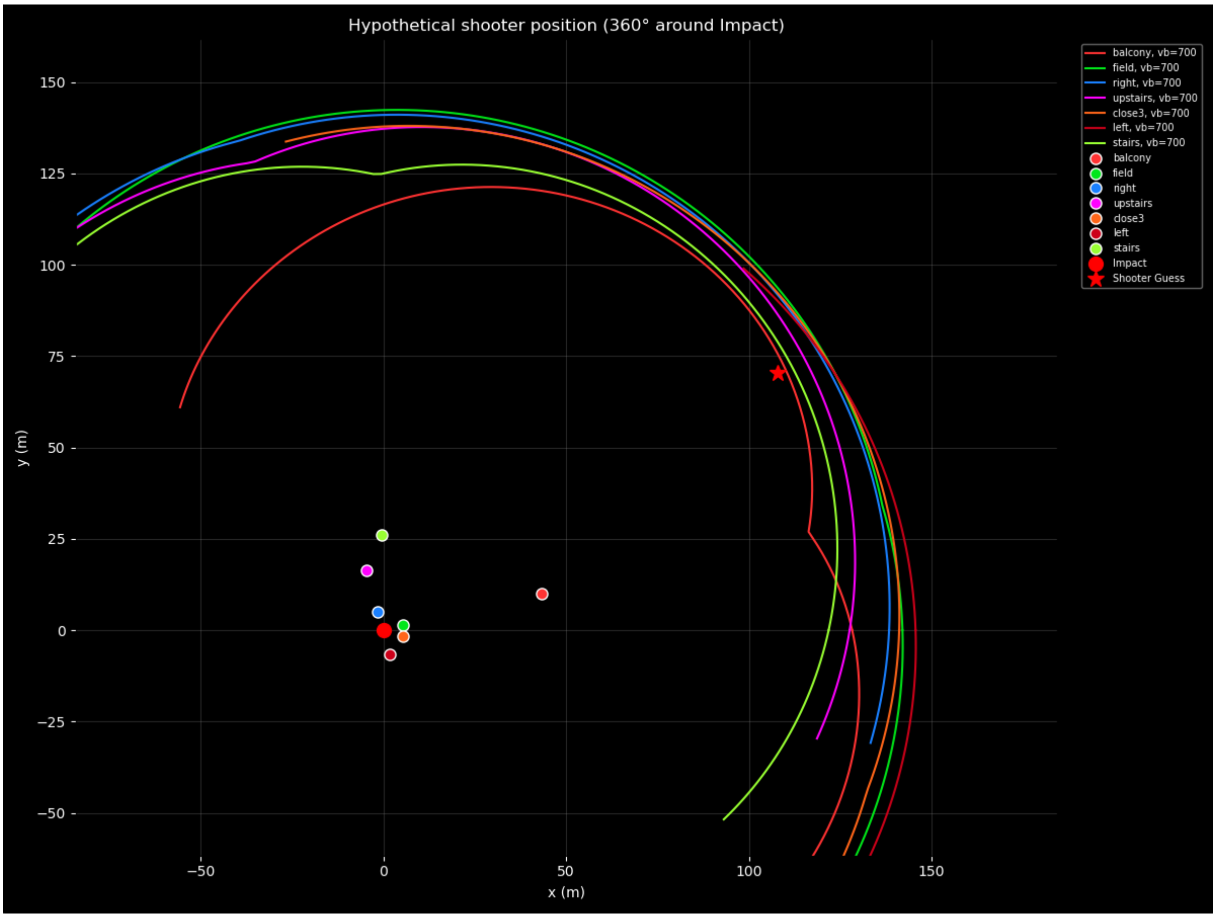
After a clearly identifiable crack, the audio for this video contains so many echoes and such a high level of background noise that no muzzle sound can be identified with any degree of certainty. It is possible that the audio track was compressed or otherwise edited after the fact, causing it to differ unexpectedly from the "balcony" camera, which was only a few meters away.

Combined results

v_b 600m/s

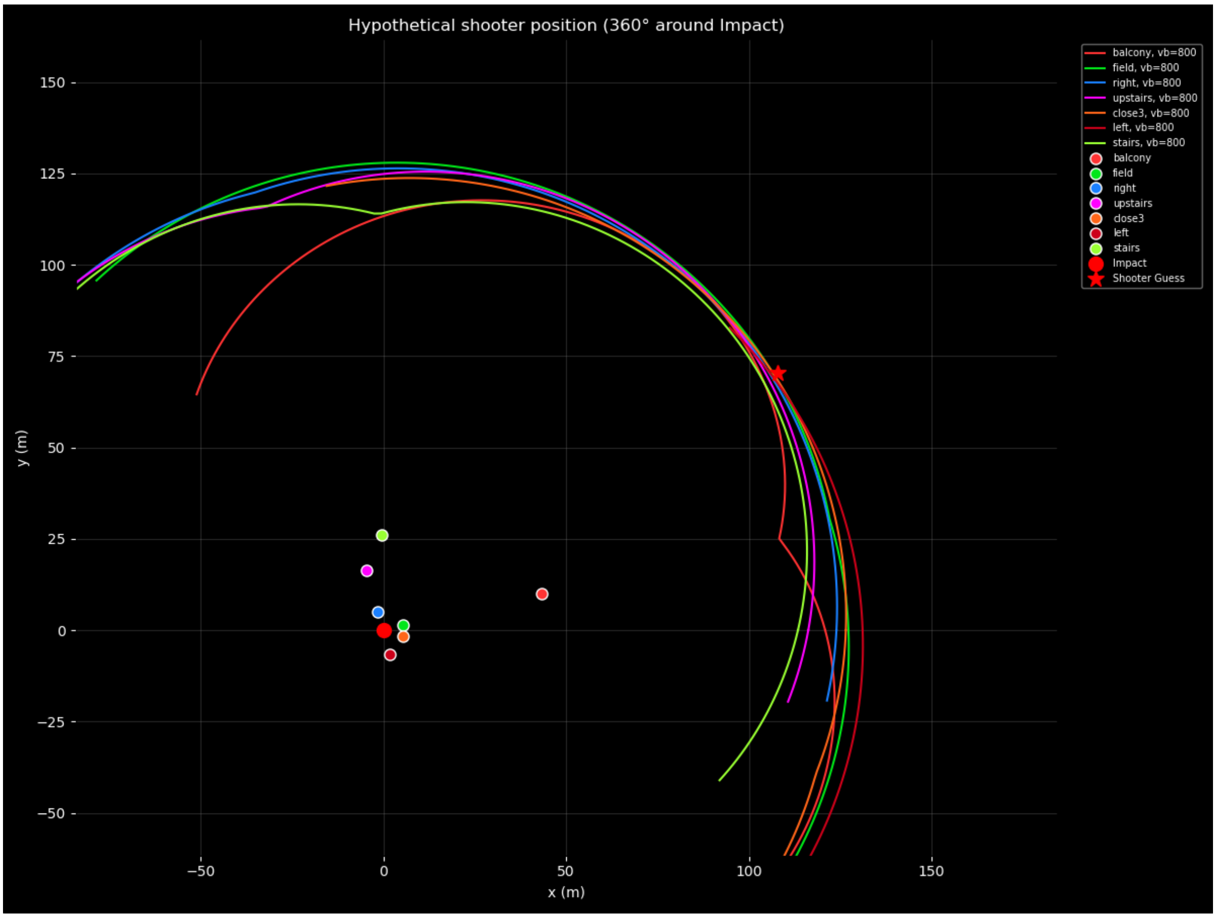


v_b 700m/s



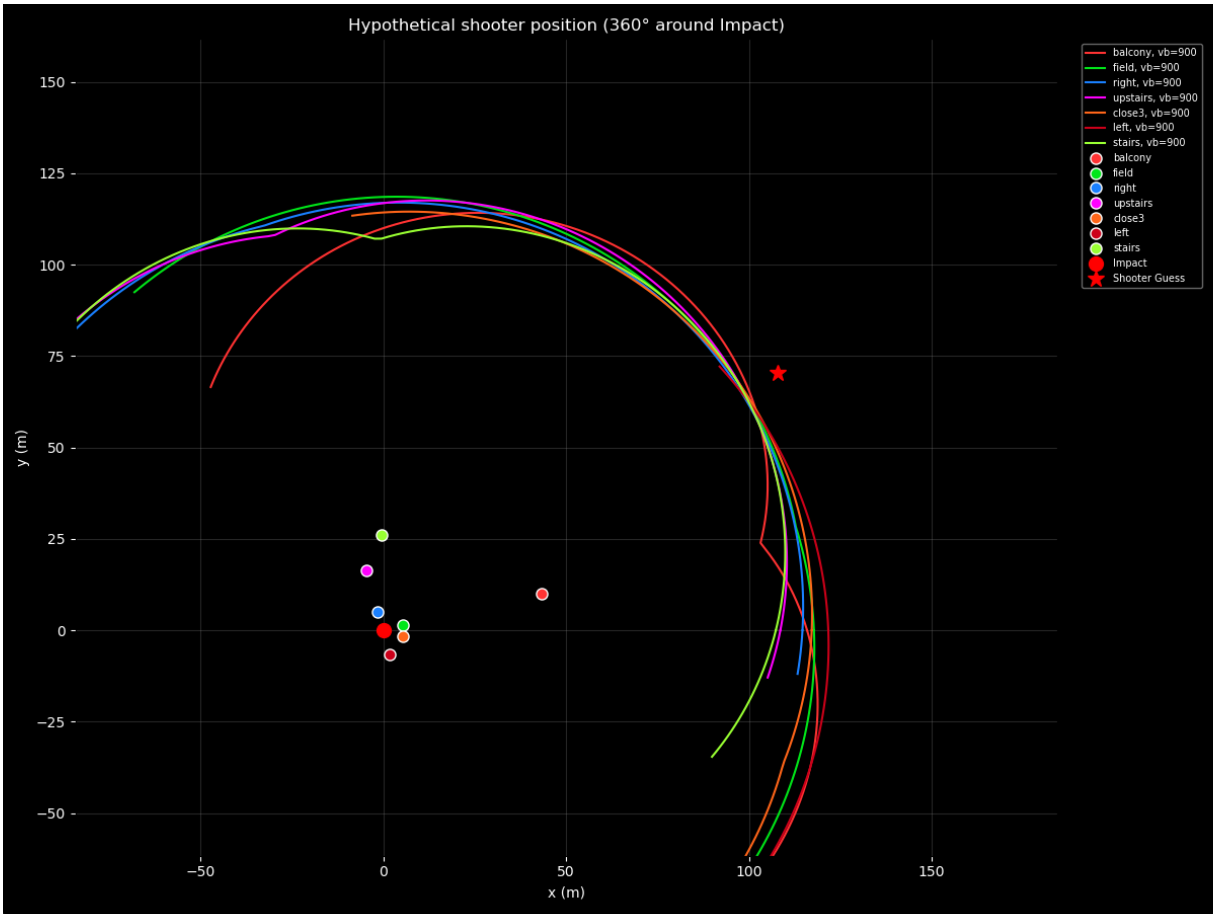
Hypothetical shooter position (360° around Impact)
balcony, vb=700
field, vb=700
right, vb=700
upstairs, vb=700
close3, vb=700
left, vb=700
stairs, vb=700
balcony
field
right
upstairs
close3
left
stairs
Impact
Shooter Guess
y (m)
x (m)
150
125
100
75
50
25
0
−25
−50
−50
0
50
100
150

v_b *800m/s*



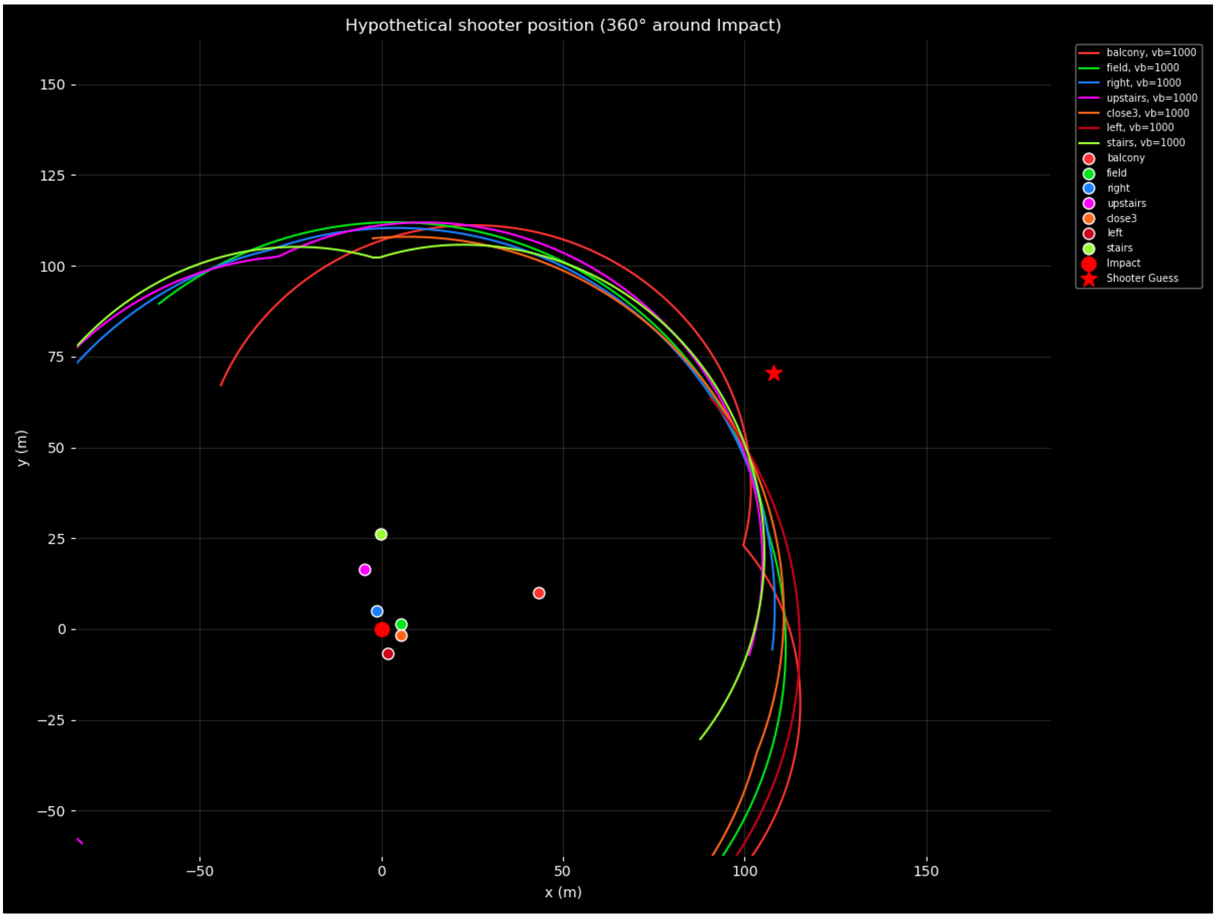
Hypothetical shooter position (360° around Impact)
y (m)
x (m)
balcony, vb=800
field, vb=800
right, vb=800
upstairs, vb=800
close3, vb=800
left, vb=800
stairs, vb=800
balcony
field
right
upstairs
close3
left
stairs
Impact
Shooter Guess

v_b *900m/s*



Hypothetical shooter position (360° around Impact)
balcony, vb=900
field, vb=900
right, vb=900
upstairs, vb=900
close3, vb=900
left, vb=900
stairs, vb=900
balcony
field
right
upstairs
close3
left
stairs
Impact
Shooter Guess
y (m)
x (m)
150
125
100
75
50
25
0
−25
−50
−50
0
50
100
150

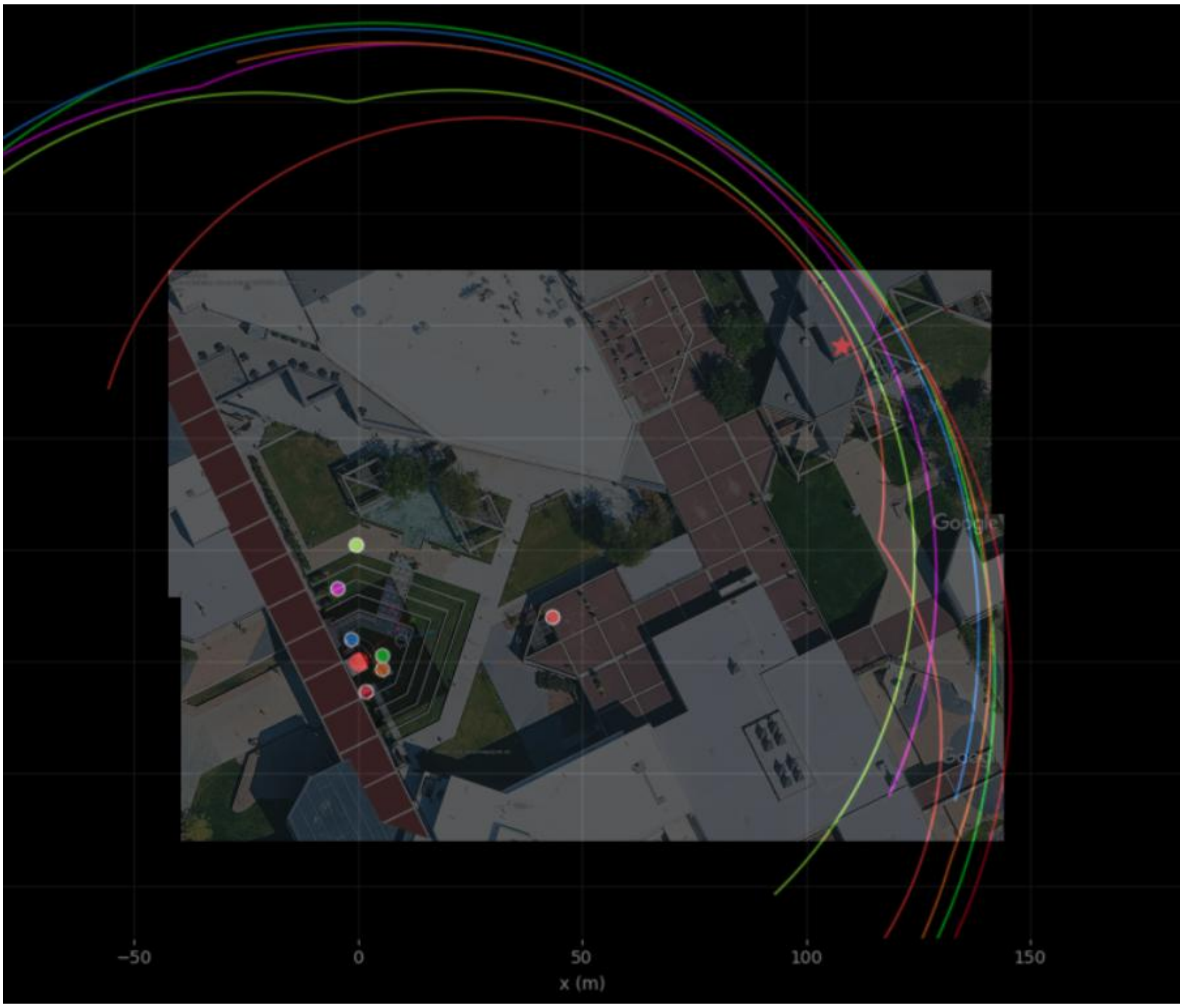
v_b 1000m/s



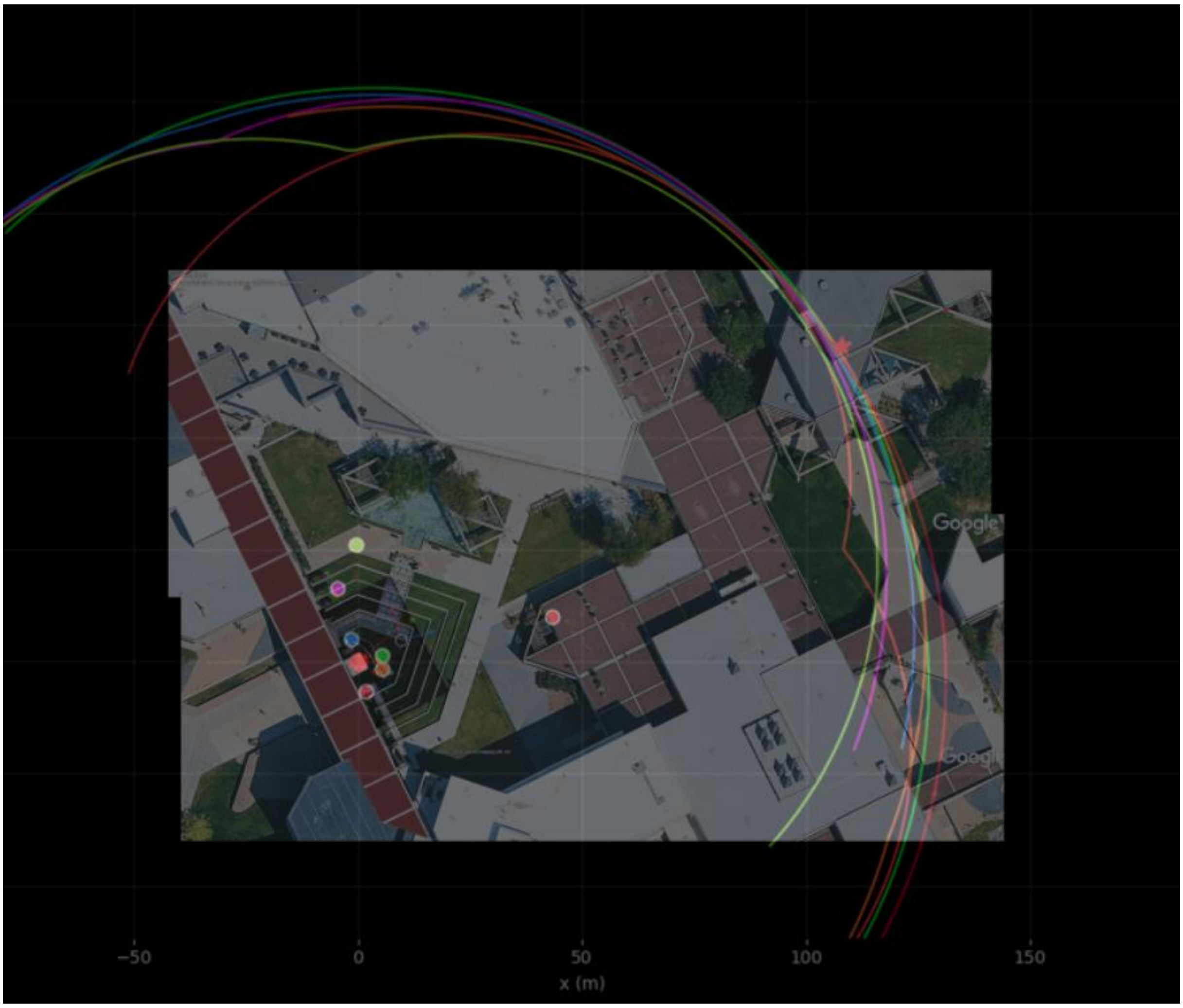
Hypothetical shooter position (360° around Impact)
balcony, vb=1000
field, vb=1000
right, vb=1000
upstairs, vb=1000
close3, vb=1000
left, vb=1000
stairs, vb=1000
balcony
field
right
upstairs
close3
left
stairs
Impact
Shooter Guess
y (m)
x (m)
150
125
100
75
50
25
0
−25
−50
−50
0
50
100
150

Overlays

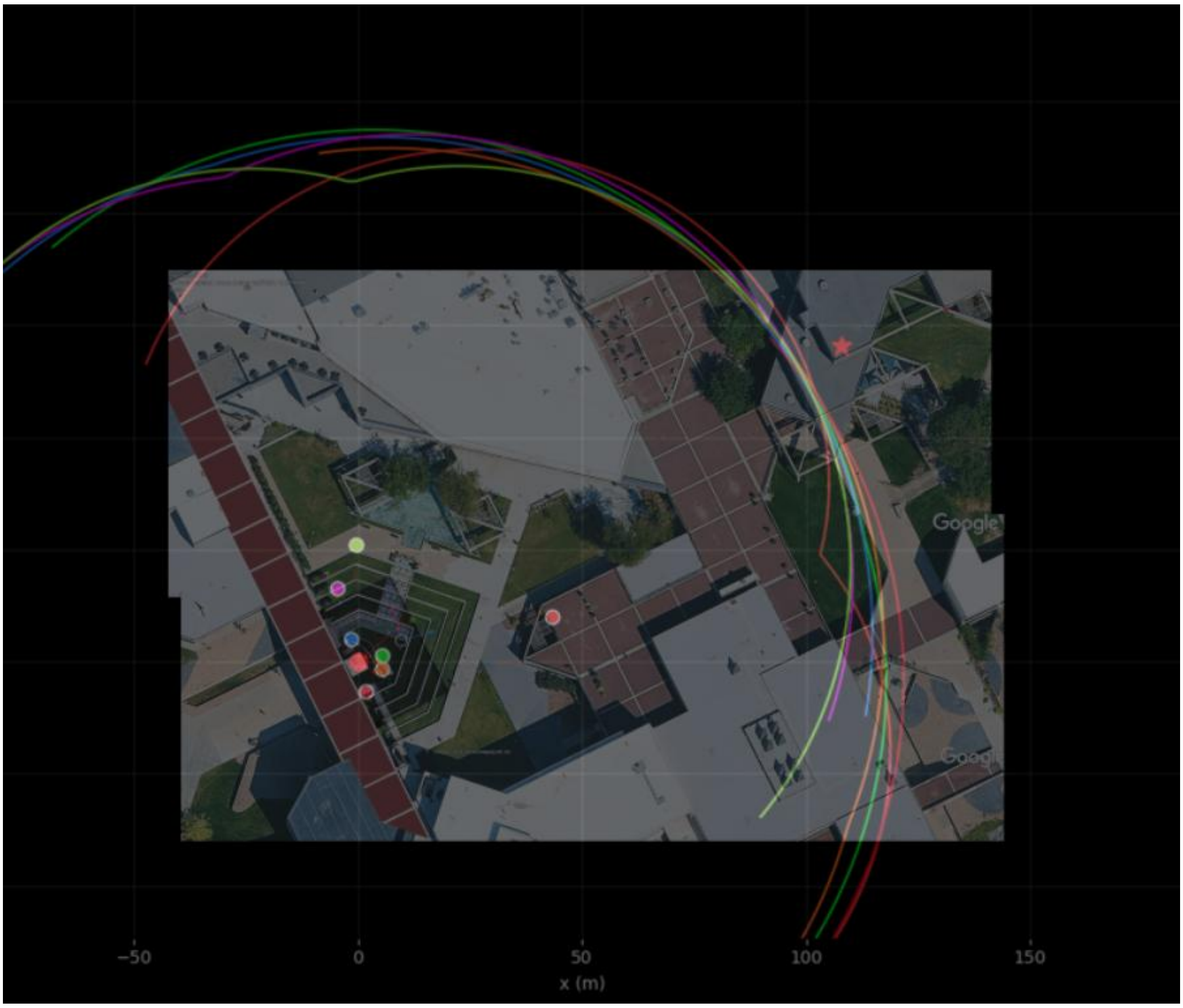
V_b 700m/s

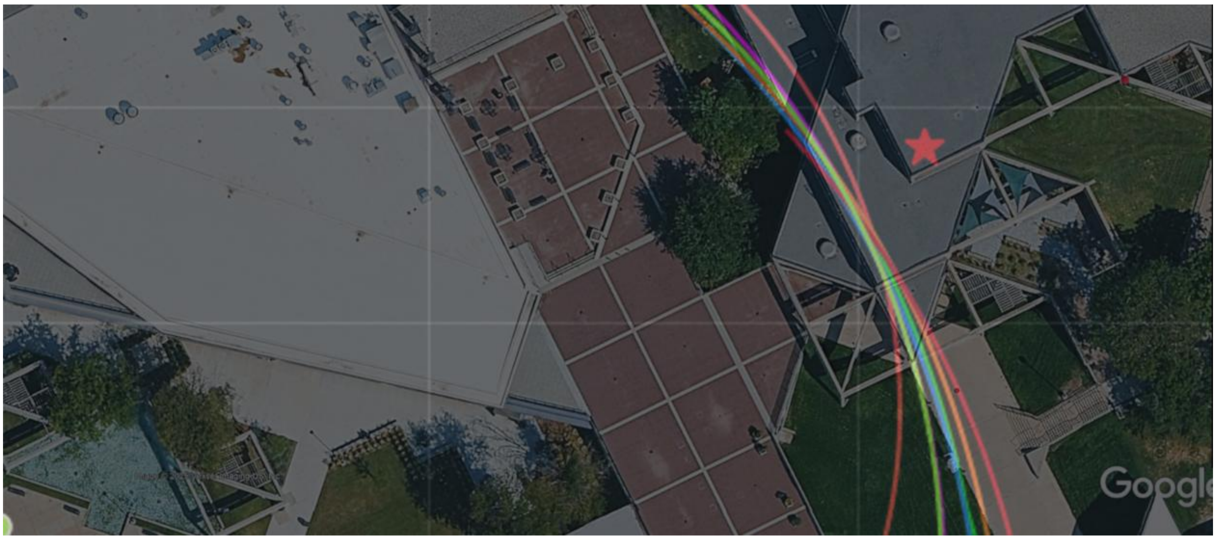


V_b 800m/s

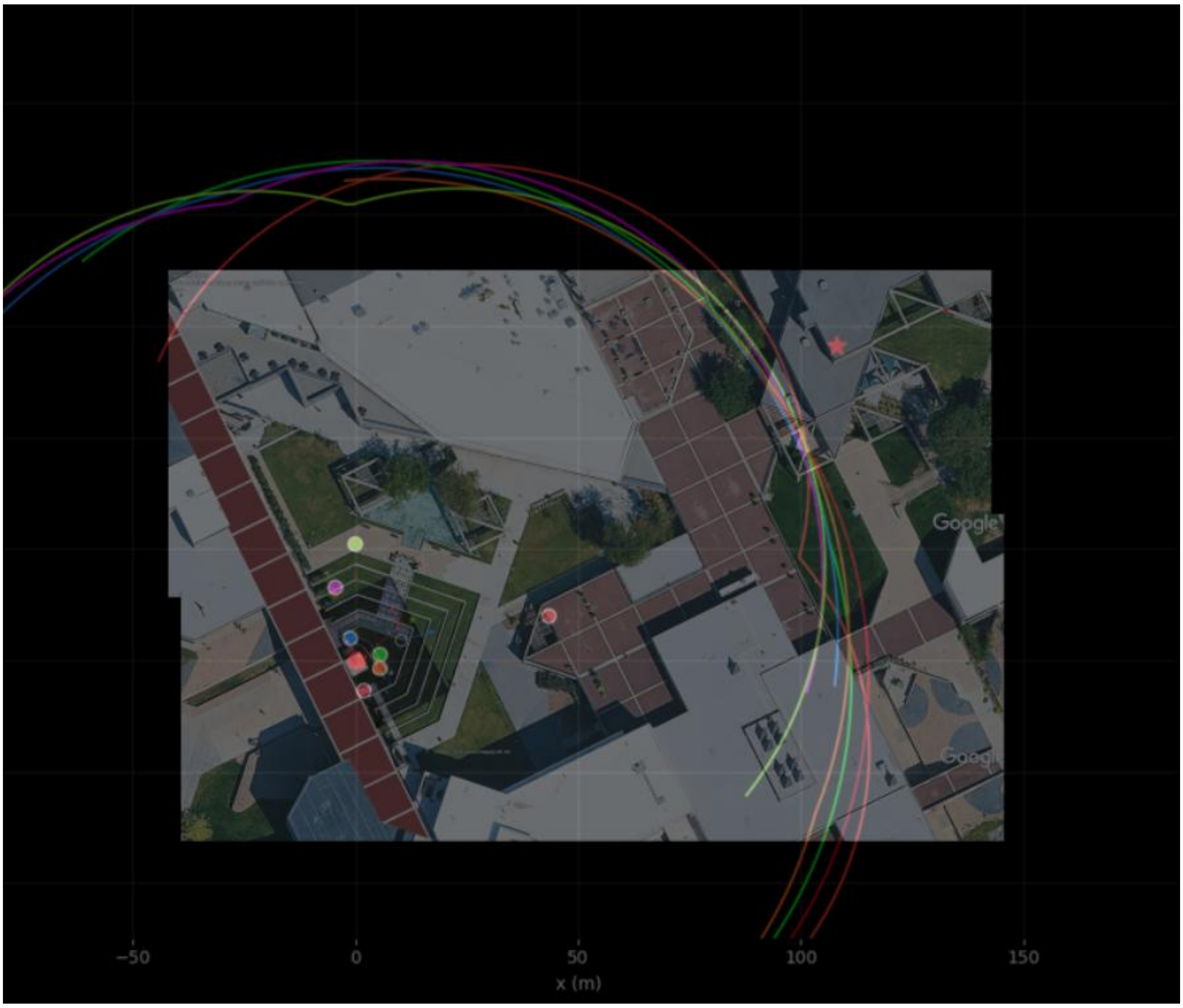


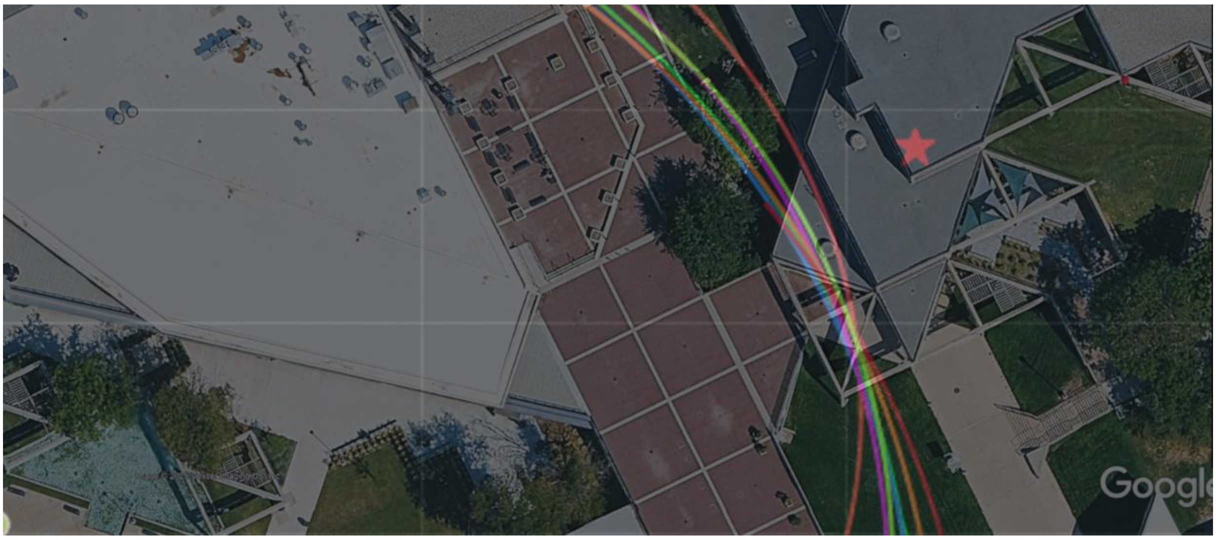
V_b 900m/s





V_b 1000m/s





Implication

First of all, we can safely rule out any theory of a shot from close range, from the side, or from behind.

Furthermore, we must bear in mind that in this calculation, a few milliseconds can shift the result.

In this respect, the roof on which a suspicious person was spotted is very well located in the narrow area that is not excluded by any microphone as a "blind spot" and in which the lines for the calculated shooter positions intersect or converge at a bullet velocity of about v_b=800m/s.

However, it must also be said that the result converges more strongly at v_b=900m/s, indicating a location a few meters to the southwest of that roof. As far as can be judged from a distance, a shot from a window at this location would have been possible.