Unconventional Weapon PPE

Blast Overpressure: Testing and Mitigation

Glossary

Too many times, during combat and mostly during training, Blast Overpressure causes injuries, with both short- and long-term effects, and has recently been identified as a serious health threat to US Service Members. As defined by a memo from the office of the Deputy Secretary of Defense, Blast Overpressure is, "*The sudden onset of a pressure wave, above normal atmospheric pressure, which occurs from blast (e.g., explosions and weapons firing events). The pressure wave is caused by the energy released during explosions and weapons firing."* This memo was distributed in August 2024, to Senior Pentagon Leadership, Commanders of the Combatant Commands Defense Agency, and DoD Field Activity Directors in regard to Department of Defense Requirements for Managing Brain Health Risks from Blast Overpressure. The issue has garnered attention from the highest officials within DoD and the services are exploring ways to mitigate this threat to our personnel, including suppression of small arms. For over a decade, RD has been working diligently to overcome the overpressure threat as it relates to small arms usage. Not only has RD's work been successful in reducing exposure to overpressure, but we also continue to lead the industry in the reduction of small arms signature and have developed an overpressure measurement methodology. Consequently, we are now referring to our weapon suppression technology *as Unconventional Weapon Personal Protective Equipment* (PPE). As an added bonus, our work on Blast Overpressure mitigation protects airframes and sensitive electronics and sensors from undue wear and tear as well as from errant readings during operations.

Unconventional Weapon PPE is Personal Protective Equipment defying the convention of not being worn by the operator. Instead, it is installed directly on a weapon, designed to protect the operator, surrounding personnel, and/or sensitive electronics or gear, from harm that can be caused by discharging the weapon due to hazardous sound pressure levels, Blast Overpressure, and/or toxic blowback.

Radical Defense (RD), after spending millions of dollars on research and development on current technology, is seeking a funding vessel and/or a Cooperative Research and Development Agreements (CRADA) from Government to further develop current technology, test methodology, push suppressor innovation, and broaden the use of suppressor technology, with the end goal of fielding RD Unconventional Weapon PPE to protect future generations of warfighters from the hazards presented from discharging weapons during training and combat, mainly Blast Overpressure. Additionally, RD seeks direct involvement with the government in establishing a standard for Blast Overpressure testing in regard to Small Arms and Medium Caliber Systems.

Overpressure, simply put, is an instantaneous increase in air pressure to above atmospheric pressure. During their service, military end users are routinely exposed to overpressure during training as well as in combat. Overpressure events are all-too-often thought of as exposure to Improvised Explosive Devices, explosions from ordinance, artillery, breaching, grenades, etc., but small arms can also trigger overpressure events.

While this isn't often thought of, there are common service weapons, such as the M4, M240 etc., that generate repeated overpressure exposure that can become unsafe over time. The same memo, released by the Deputy Secretary of Defense also states that, *four psi was identified as a health-based safety guideline informed by evolving medical science. This level is different from those anticipated temporary exposure levels developed to protect the public from accidental explosives mishaps in munitions storage and transport that consider mishap probability as detailed in Defense Explosives Safety Regulation 6055.09, "Defense Explosives Safety," January 13, 2019. Additional details regarding the derivation of 4 psi are available in "Interim Recommendation for Blast Overpressure Exposure Safety for Brain Health," located at: https://denix.osd.mil/auth/soh/programs/bop/*

One common service weapon, the US Ordnance M2A1 .50cal Machine Gun, is used heavily in both training and combat environments. In fact, it's more commonly encountered during peacetime due to rigorous training use with a wider range of personnel exposed to its effects. Based on the results of internal testing (with HBM Brüel & Kjær (HBK) - an industry leader in data collection solutions - and Black Box Biometrics (a company that develops sensor technology solutions focusing on measuring concussive forces) this system creates repeated, single exposures on average of 0.2886psi exposure, per shot, measured at the shooter's head. These cumulative pressure events can lead to long term traumatic brain injuries in the warfighter.

RD has an engineering philosophy that a suppressor should have little to no effect on a host weapon system. The suppressor not only reduces signature (sound, flash, ground disturbance, etc.) but it shouldn't cause undue stress to the host system, increase wear and tear, or add to the logistics footprint of the military. This is accomplished by controlling gas flow to smooth out recoil impulse, having little-to-no effect on cyclic rate, and also significantly reducing blowback. The term Blowback is used to refer to excess gas being expelled from the weapon and exposed to the operator's face, consisting of Carbon Monoxide, Hydrogen Cyanide, and Ammonia gasses, which is usually exacerbated by most suppressors by impeding their exit out the end of the barrel; another key performance factor often evaluated on a suppressor. All of these attributes contribute to a suppressor that benefits the weapon operator and cuts down on stoppages, malfunctions, and premature breakages. When designing a device that reduces Blast Overpressure, RD takes into consideration every one of these aspects of the suppressor's performance.

When RD started down a path pursuing blast mitigation with suppressors, test methodologies to capture and quantify Blast Overpressure from a weapon system had to be explored. Attaching a suppressor and validating its ability to reduce a quantified overpressure would be the goal. This essentially to prove a suppressor can be used as a viable, albeit unconventional, piece of PPE. This Unconventional Weapon PPE would be used by service members to reduce weapon signature, increase the lethality of the warfighter, and also prevent traumatic brain injuries due to repeated exposure to Blast Overpressure.

Beginning in 2022, RD began to research, test, and attempt to push the technological envelope of Unconventional Weapon PPE. The goal of which is not only to protect the warfighter, but also to begin a push into the realm of protecting sensitive electronic equipment. Specifically, Blast Attenuation Devices (BAD-30 and BAD-21) have been recently developed to safeguard sensors on Remote Weapon Stations (RWS) and rotary-wing aircraft, at the request of government and military end users.

BAD-30 is designed to be mounted on a Northrop Grumman M230 30mm Chain Gun, engineered to protect valuable, sensitive electronics to maintain the effectiveness of air burst capabilities, and ensure the functionality of other electronically controlled weapons and munitions on the RWS such as rockets, or more traditional belt-fed machine guns. These types of technologies are critical in the ever-evolving space of Counter-Unmanned Aircraft System (C-UAS). The reduced signature afforded to these systems also helps protect these systems from detection by the very drones they are working against.

BAD-21, a suppressor designed for the .50cal FN Herstal GAU-21, is engineered to mitigate damage to critical sensors for the Sikorsky CH-53 helicopter, which RD learned is a massive concern of the Navy while discussing BAD-21 with US Naval Aviation PMA 242 (Direct and Time Sensitive Strike Program). Blast Overpressure from machine guns aboard helicopters can also cause damage to the airframe. Reducing that exposure can prevent undue stress, wear, and tear on the aircraft themselves while also protecting the warfighter.

In September 2022, while testing ground disturbance reduction of our 50FVS suppressor for the M2A1, it was observed by the shooter and test team that the suppressor decreased the felt pressure and concussion while shooting from a ground mount tripod. The RD Test Team filmed a video to demonstrate the ground disturbance of an unsuppressed M2A1 and the reduction of that ground disturbance once suppressed.

While this level of testing is not easily quantifiable, the video evidence was very promising. The unsuppressed weapon generated a very large dust cloud that created roughly 10-feet of visibility in front of the camera, not only giving away a shooter's position, but also completely obscuring the target. Using the RD 50FVS suppressor, the dust cloud was all but eliminated. The shooter and assistant gunner also observed less concussion felt through the ground while firing suppressed versus unsuppressed. This was one of the first tangible indicators to the team that the suppressor was capable of reducing that concussive blast, what RD would later refer to as Blast Overpressure (BOP). Following that test, RD began developing a methodology for testing and quantifying the felt and observed concussive blast.

In January 2023, RD developed a method utilizing crush discs to gather a "Go / No-Go" type of blast pressure reduction metric; either the weapon system popped the disc or it didn't. Each disc demonstrated results in PSI from unsuppressed to suppressed.

During the test, crush discs were placed on posts set in an array around the weapon, on walls, and even on the shooter. Again, this test was very much in an exploratory phase, and the best execution methods weren't clear. Some success was observed with crush discs reacting when close to an unsuppressed muzzle. Beginning with discs that were rated for 25psi, then progressively increased and decreased the disc strengths in 25psi increments until arriving at a disc that would either react or not react given each configuration of the weapon from unsuppressed to suppressed. The discs acting as a "Go / No-Go" gave an idea of what amount of energy the suppressor was capable of reducing.

The test was extremely practical and did yield some interesting results which further validated the use of suppressors to reduce exposure to concussive blast. Unfortunately, the test was not 100% repeatable due to the inconsistency of quality of the crush discs. These mixed results only pushed us to further explore improved test options.

In August 2023, Dewesoft engineers demonstrated their DAQ technology utilizing accelerometers. Testing initially on the M2A1, an accelerometer was attached to the shooter's helmet and a blast microphone fixed on a tripod, moving the tripod to various positions in an effort to find the most ideal location for recording the sound wave.

The weapon was fired from a ground mount tripod with the barrel 24-inches off the ground. Based on suggestions of the engineers, two locations that were evaluated for blast microphone positions were straight behind the weapon and shooter, and the other to right of the weapon ejection port. The distances for the blast microphone varied in 1-foot increments.

While a delta (a difference between two things or values) was captured on the M2A1, other weapon systems proved troublesome to record in the suppressed configuration as the microphone was unable to detect those reduced pressure waves. On the opposite end, there were initial positions for the blast microphones that were actually overloaded when firing .50 BMG unsuppressed.

Essentially, certain weapon configurations were too quiet and others too loud. The method was never finalized due those hardware limitations, and no real standard was established. Shortly after, it was decided to pursue HBK and utilize the current Pulse system already on hand to test its viability.

In March of 2024, while demonstrating at a commercial facing live fire demonstration, RD was contacted by a Black Box Biometrics engineer and Subject Matter Expert (SME) who provided evidence and data in regard to the negative effects of BOP on the warfighter. Eventually reaching out to our contact at HBK to formulate a testing method, RD teamed up with both SMEs from HBK and BlackBox Biometrics to establish distances, offsets, equipment, microphone and sensor positions in relationship to a shooter in the loop, or an actual human doing the firing as opposed to using a fixture, to gather BOP data and establish a delta from unsuppressed to suppressed. Testing was tentatively scheduled for the fourth quarter of 2024 when weather conditions would be ideal for testing.

In August 2024, the office of the Deputy Secretary of Defense released a BOP Memo which cemented that RD was on the right track, validating our concerns on this seemingly unthought of metric for suppressor performance. This pushed RD to further develop a repeatable test method. Research began on blast gauges and blast microphone technology, testing multiple systems, to establish a path forward. RD again met with HBK engineer and SME, Scott Hughes, to begin the push to refine testing methods using the current HBK Pulse system to acquire BOP data with existing 4944-A microphones.

In September 2024, RD met with engineers and SMEs of PMA 242 (US Navy Direct and Time Sensitive Strike Program) who were exploring options to reduce BOP exposure of sensors on the CH-53 which were failing due to BOP from the GAU-21, further validating a requirement for blast mitigation on .50cal machine guns, not only to protect the operator, but additionally, to protect the aircraft; in turn protecting all personnel aboard.

In November 2024, using the current methodology developed by RD, HBK, and Black Box Biometrics, testing was executed and BOP deltas gathered using RD's Unconventional Weapon PPE on various small arms weapons systems in common use with modern militaries.

Recording BOP is a new, uncharted endeavor for the weapons industry as a whole, as there is no established industry standard on microphone positions, heights, offsets, etc. As recording BOP is essentially just recording sound pressure wave, it was decided, after discussion with the HBK and Black Box Biometrics engineers, that utilizing the HBK Pulse in conjunction with the Black Box sensors would provide the best results. Setup was similar and directly inspired by the methods used to record sound pressure reduction data.

There are certain challenges to measuring BOP with microphones used for standard sound pressure reduction as opposed to a blast microphone or a blast gauge. The microphones are capable of capturing the full pressure curve of an overpressure event, whereas the blast gauges record the event itself, but only if the pressure event is over a certain, predetermined value. The microphone, additionally, does provide a delta that is easily observed for comparative analysis of unsuppressed to suppressed.

The gauges themselves act as "Go / No-Go" gauge of sorts. Essentially, if it was suspected that an unsuppressed weapon would create a BOP hazard to a shooter, the blast gauge would immediately alert the user of an event, while the microphone, working in conjunction, records the entire event, capturing and assigning a value in Pascal (Pa) or Pounds per Square Inch (PSI).

Example of Microphone and Sensor Placement while recording data for RD GPS on M240B

For the purposes of this white paper, the test layout for the M2A1 will be demonstrated. A shooter behind a (standing) tripod with microphones to the left and right of the muzzle, as well as one on top of the shooter's head. The blast sensors were placed on the same tripods, 9-inches below the microphones, vertically in-line with and pointing towards the muzzle, facing in towards the muzzle. The third sensor was located on the shooter's helmet, facing down range.

The setup for M2A1 microphone and sensor positions were as follows:

- Microphone 4-feet right of muzzle, 5-feet, 9-inches high
- Right Sensor 5-feet high, facing the muzzle
- Microphone 4-feet left of muzzle; 5-feet, 9-inches high
- Left Sensor 5-feet high, facing the muzzle
- Microphone on shooter position, placed on the front of shooter's helmet; 6-feet, 6-inches high (this height will vary per shooter)
- Sensor on shooter position, placed on the front of shooter's helmet; 6-feet, 6-inches high, facing down range (this height will vary per shooter)
- Microphone offsets and distances will vary per weapon setup, per caliber, and per barrel length, as well as the height of the shooter.

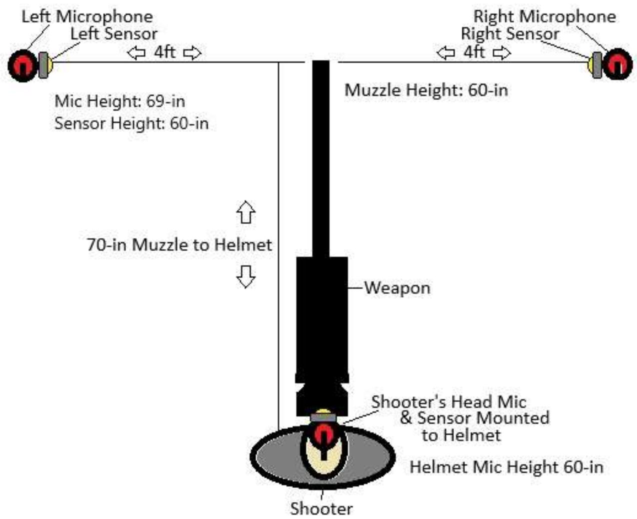


Diagram of Sensor and Microphone Layout for M2A1 .50cal Machine Gun (Top Down View)

Distances for the microphones left and right of the muzzle depended on the weapon and caliber being fired. Microphones would experience “wash out” if too close to certain weapons. In those cases, the microphone positions were moved outward until an acceptable reading was received by the microphone, and unsuppressed sound pressure wave readings matched up with historical data from the same weapon/caliber. Additionally, the height of the microphone and sensor on the shooter’s position will vary per shooter. A defined shooter’s position could easily be established with a third tripod to function as a placeholder for the shooter. For our testing, a microphone and a sensor were mounted on the shooter’s head (Shooter in the Loop).

Each iteration of testing consisted of recording five individual unsuppressed shots, per weapon system, then a suppressor was attached, and five more individual suppressed shots were recorded.

Each shot was fired individually, upon the call of Scott Hughes (HBK), who was recording the data. After five shots, the data was then saved, the system reset, and the next firing iteration would begin.

Depending on the overall length of the weapon combined with the now attached suppressor, the shooter would step back, maintain the muzzle in line with the microphones and blast sensors. The recorded values, for each configuration, would be averaged and then a reduction value was established based on the pressure value in Pa from unsuppressed to suppressed. The blast gauges would be used to verify what the microphones recorded.

When the next weapon was due to be fired, the weapon would be placed on the shooter’s tripod, the shooter then would get into a firing position, and then the distance of the muzzle from the microphones and sensors was verified and adjusted as needed. For each iteration of testing to be successful, each system had to be measured to ensure those distances stay consistent. Each weapon system was tested with a baseline group of unsuppressed fire, and then tested repeatedly with multiple suppressor types, adjusted positioning, and followed the same five round firing schedule.

Some calibers required movement of the microphone to muzzle offsets to record the most optimal data. If a weapon was too close to the microphones, the microphone would peak or wash out. That wash out just meant that too much noise or pressure exceeded the microphone's predetermined pressure range. For example, it was found that the ideal distance from the microphones to collect data for .50 BMG was 4-feet, for 5.56 and 7.62 NATO was 2-feet, .338LM was 4-feet, and even though 7.62 NATO out of a carbine was 2-feet, the M134 Minigun required a distance of 4-feet. Again, all of those measurements were the distance from center of muzzle to the microphone stand, left and right. Those stands held both the microphone and the blast sensor. Each weapon and caliber required the microphone distances to be tested, adjusted, and confirmed before data could be recorded. All of those offsets were recorded to ensure future testing could be replicated.

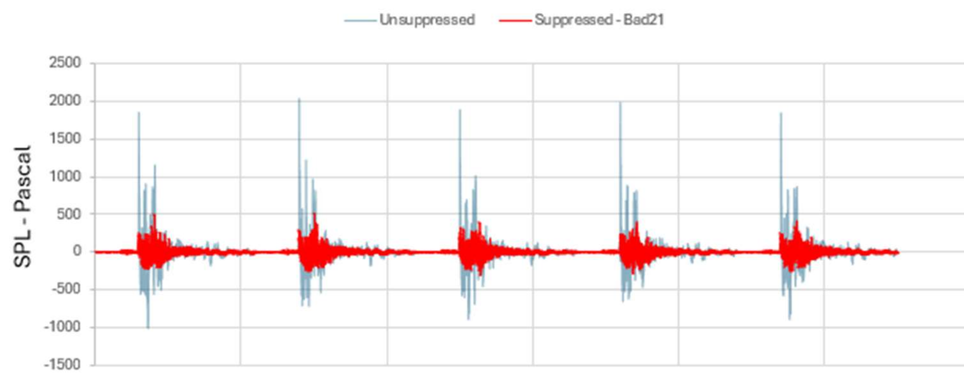
Upon reviewing data while developing the test method, there was a discrepancy discovered between the sensors and microphones. It was determined that the discrepancy was based on the angle of the event in relationship to the microphones versus the sensors. The microphones recorded reflective pressure while the sensors recorded incident pressure. This was simply due to the position of the orifice that absorbed the pressure. Incident pressure was recorded by the sensors which face directly into the blast while the microphones faced straight up, essentially perpendicular to the blast, which recorded reflective pressure. The incident pressure was roughly double that of the reflective pressure, but this relationship remained consistent throughout the test event.

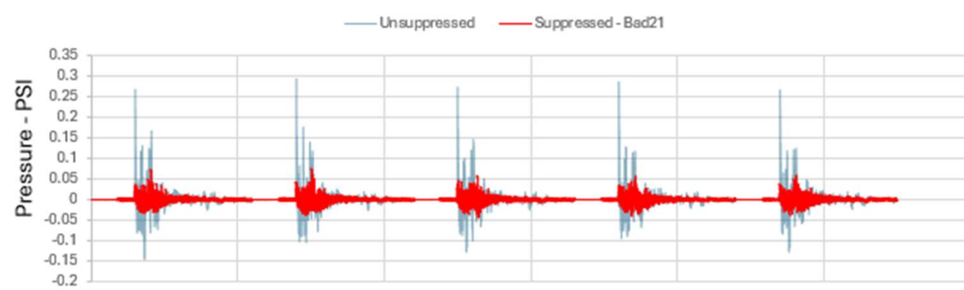
RD is prepared to share its methodology in greater detail upon request.

Using the M2A1 as an example, equipping the BAD-21 suppressor (designed for the GAU-21), BOP was reduced by 77% at the shooter's position. At the microphone positions to the left and right of the muzzle, there was an 88% reduction. In the case of PMA 242, this reduces the BOP to a safe level for both the gunner and the aircraft. Additionally, depending on the position of the weapon during firing, this will also protect the pilots and the crew from dangerous BOP exposure. To the left of the muzzle (which presents a hazard for electronic sensors on the aircraft) yielded a BOP reduction, on average, of 88%. Additionally, the reduction to the right of the weapon was also 88%. Both the left and right offsets during the testing were 4-feet from the muzzle.

Example results for BAD-21, at the shooter's head position, can be seen in the chart below. All subsequent Shooter's Position data from the testing event listed on pages 11-25.

M2A1 – Unsuppressed vs. Suppressed Bad21
Shooter's Position





M2A1 - Shooter's Position Data - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - Bad21		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	160.08	2018.04	0.2927	148.25	516.76	0.0749
2	160.26	2059.99	0.2988	148.24	516.53	0.0749
3	159.64	1917.89	0.2782	145.91	395.07	0.0573
4	160.05	2011.29	0.2917	145.98	398.36	0.0578
5	159.43	1872.91	0.2716	146.35	415.22	0.0602
AVERAGE	159.90	1976.02	0.2866	147.01	448.39	0.0650

REDUCTION[1] **-77.31%**
1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

Additionally, for lower categories of weapon systems such as the 10.3” MK18 (5.56 NATO) and the 13” MK17 (7.62 NATO) both yielded, on average, roughly 0.5 psi at the shooter’s position. This reduction was significant and put the system back into a safe range of operation in terms of BOP exposure.

Left and right microphone offsets for 5.56 and 7.62 carbines were 2-feet left and right of the muzzle. Distance from the muzzle to helmet mounted microphone and blast sensor varied from carbine to carbine and suppressor to suppressor. Each offset was measured and the weapon adjusted accordingly on the shooting tripod to keep the muzzle in line with the microphones and sensors. Microphone and sensor heights remained the same for every test for each weapon and configuration; microphone at 69-inches and blast sensor at 60-inches. Additionally, the muzzle center was confirmed at a 60-inch height for every configuration.

Carbine and rifle testing protocols remained the same. Each weapon would be fired five times unsuppressed, then a suppressor attached and fired five more times for each weapon and suppressor configuration. Data would be collected and averages calculated in order to gather the BOP delta per each configuration.

A Daniel Defense MK18 5.56 carbine with a 10.3-inch barrel, firing M855, our testing showed the unsuppressed weapon produces 0.4606 psi on average, per shot, at the shooter’s head. Five RD suppressors were tested for the MK18. Each of those suppressors yielded significant results. CS5 reduced BOP at the shooter’s head by 63.71%. LS5 reduced BOP at the shooter’s head by 64.31%. GPS5K reduced BOP at the shooter’s head by 60.20%. BLB reduced BOP at the shooter’s head by 64.41%. Finally, CS3 reduced BOP, at the shooter’s head, by 64.32%. The average BOP reduction, across all five suppressors, to the shooter’s head was 63.39%.

An FN (SCAR) MK17 7.62 carbine with a 13-inch barrel, firing M80 Ball, our testing showed the unsuppressed weapon produces .5365 psi on average, per shot, at the shooter’s head. Four RD suppressors were tested for the MK17. GPS7K reduced BOP at the shooter’s head by 70.86%. LS3 reduced BOP at the shooter’s head by 89.81%. SASS reduced BOP at the shooter’s head by 91.49%. CS3 reduced BOP at the shooter’s head by 83.97%. The average BOP reduction, across all four suppressors, to the shooter’s head was 84.03%.

A US Ordnance M240B, firing 7.62 M80 Ball, our testing showed the unsuppressed weapon produces 0.3328psi on average, per shot, at the shooter's head. Three RD suppressors were tested for the M240, the GPS, GPS7K, and the FVS. Each of those suppressors yielded significant results. GPS reduced BOP at the shooter's head by 82%. GPS7K reduced BOP at the shooter's head by 75%. And the FVS reduced BOP at the shooter's head by 82%. The average BOP reduction, across all three suppressors, to the shooter's head was 80.16%.

A US Ordnance M2A1, firing M33 Ball, our testing showed the unsuppressed weapon produces 0.286psi on average, per shot, at the shooter's head. Three RD suppressors were tested for the M2A1, the FVS, GPS, and the BAD-21. Each of those suppressors yielded significant results. FVS reduced BOP at the shooter's head by 76%, GPS reduced BOP at the shooter's head by 75%, and the BAD-21 reduced BOP at the shooter's head by 77%. The average BOP reduction, across all three suppressors, to the shooter's head was 76%.

Reduction of BOP not only protects the service member on the battlefield but also increases their quality of life and long-term health well after serving. RD has spent years refining suppressor design, engineering improvements of suppressor performance, and pursuing test methodologies with proven partners. Capitalizing on these relationships, an effective test method has been established. This methodology gathers a delta from unsuppressed to suppressed weapons to demonstrate just how effectively RD suppressors reduce BOP. In addition to demonstrating the ability to increase a warfighter's lethality and reduce weapon signature, acting as a force multiplier, RD suppressors also perform as a valuable piece of Personal Protective Equipment. The engineering philosophy of RD along with industry leading testing and evaluation, exhibits the potential of suppressors to significantly reduce BOP exposure to operators, sensitive electronics, and equipment.

A breakdown of the test equipment and software used during the BOP testing is as follows:

Data Acquisition Hardware
LAN-XI Type 3052, 3-channel, high-frequency module (DC to 102.4kHz), sampling rate up to 262 kS/s.
Type 4944-A, ¼” pressure-field microphones.
BlackBox Biometrics “Blast Gauge” system.
Data Acquisition Software
PULSE LabShop, Ver. 28, release date June 2024.
Time-capture analyzer and PL Program (convert Pa to PSI) utilized to record impulse pressure data

Weapons Utilized during Testing:

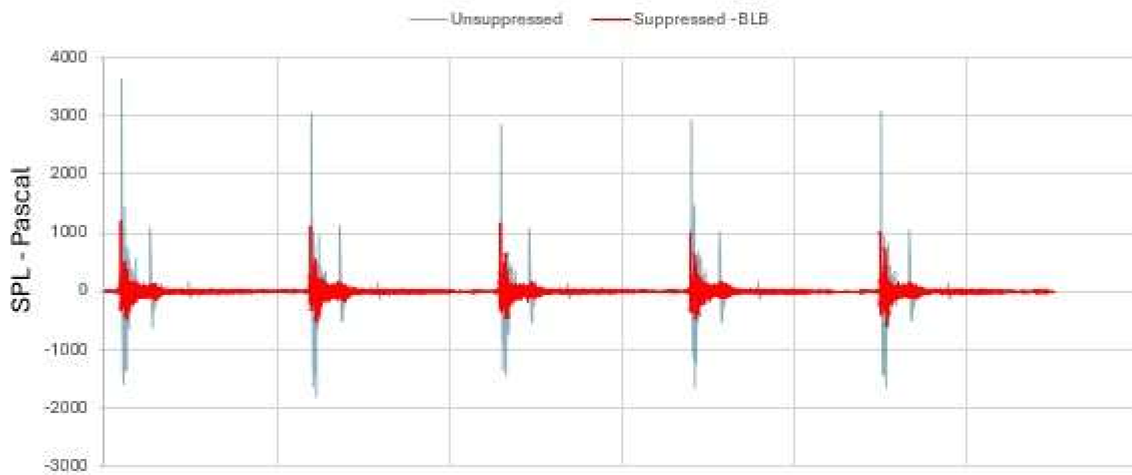
Daniel Defense MK18 5.56 10.3-inch Barrel

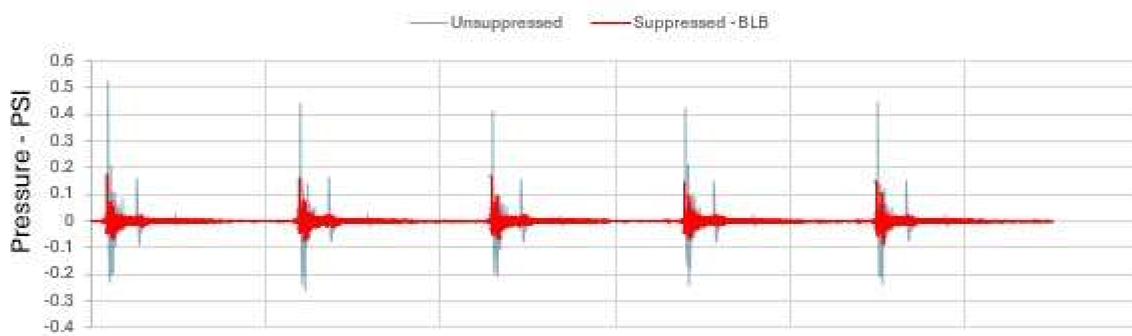
FN SCAR MK17 7.62 13-inch Barrel

US Ordnance M2A1 50cal Machine Gun

US Ordnance M240B 7.62 Machine Gun

MK18 – Unsuppressed vs. Suppressed BLB
Shooter's Position





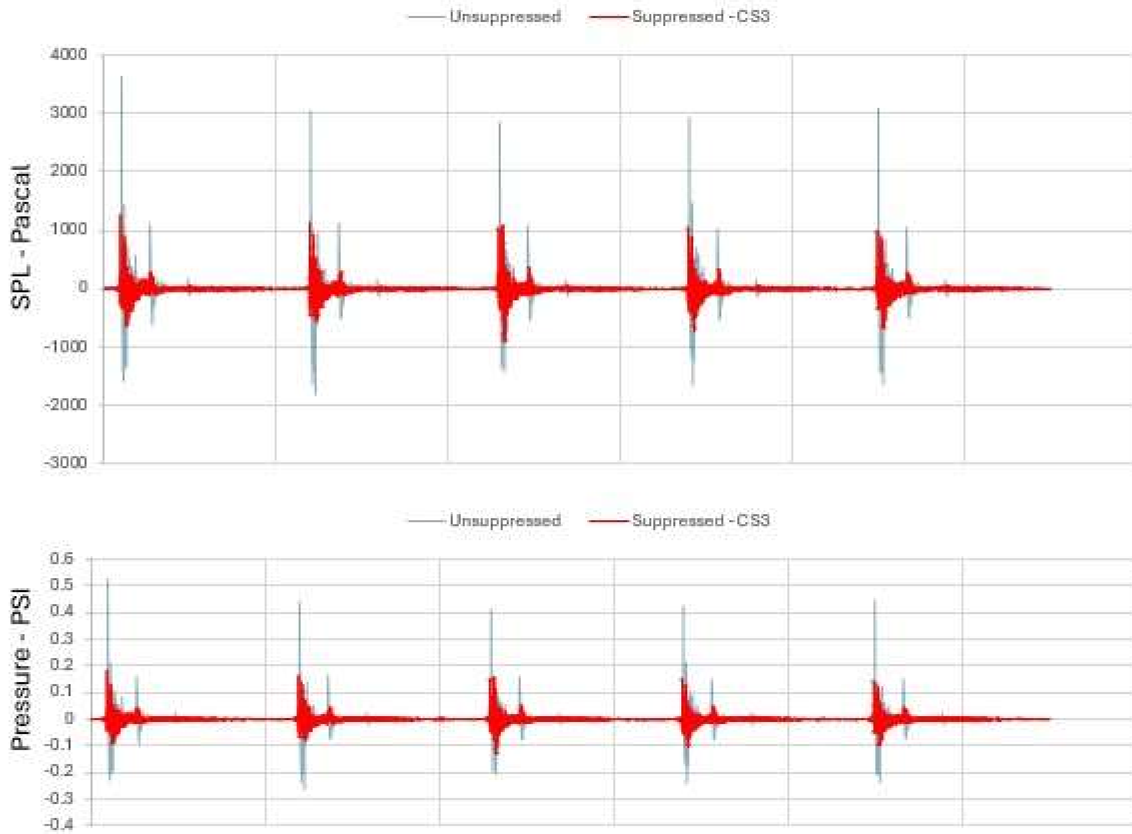
Mk18 - Shooter's Position - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - BLB		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.48	3760.01	0.5453	155.73	1223.94	0.1775
2	163.89	3129.65	0.4539	155.18	1147.87	0.1665
3	163.06	2843.89	0.4125	155.61	1206.42	0.1750
4	163.71	3066.43	0.4447	154.15	1020.17	0.1480
5	163.74	3077.53	0.4464	154.42	1052.05	0.1526
AVERAGE	164.02	3175.50	0.4606	155.04	1130.09	0.1639

REDUCTION[1] **-64.41%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

MK18 – Unsuppressed vs. Suppressed CS3
Shooter's Position



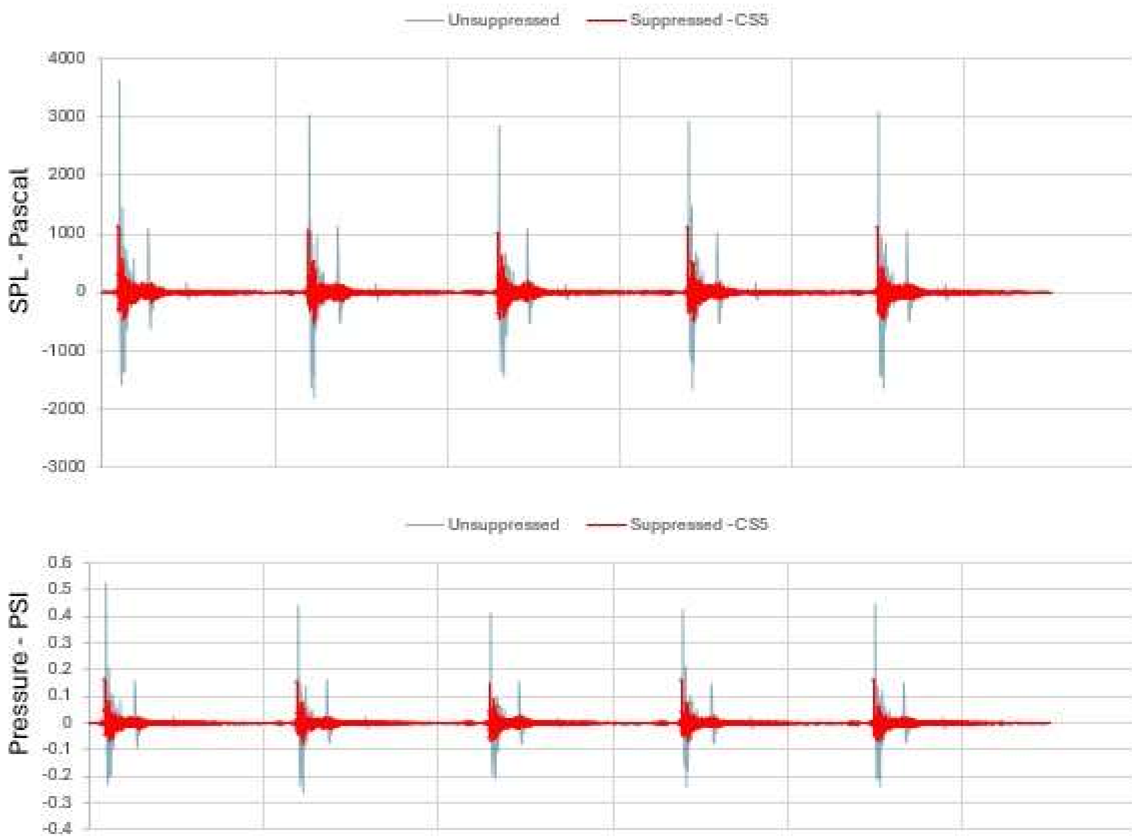
Mk18 - Shooter's Position - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - CS3		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.48	3760.01	0.5453	156.29	1304.41	0.1892
2	163.89	3129.65	0.4539	155.11	1139.20	0.1652
3	163.06	2843.89	0.4125	154.77	1095.91	0.1589
4	163.71	3066.43	0.4447	154.45	1055.83	0.1531
5	163.74	3077.53	0.4464	154.57	1070.50	0.1553
AVERAGE	164.02	3175.50	0.4606	155.07	1133.17	0.1644

REDUCTION[1] **-64.32%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

Mk18 – Unsuppressed vs. Suppressed CS5
Shooter's Position

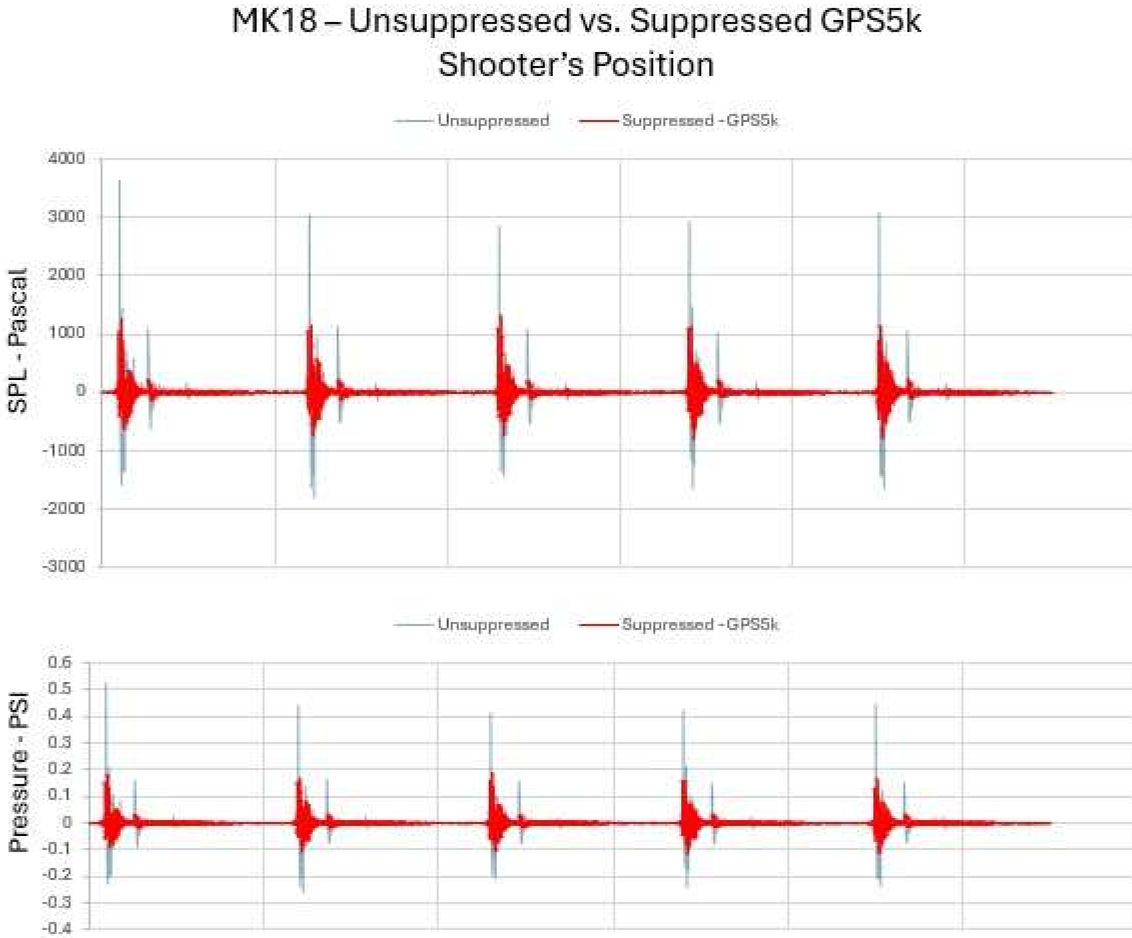


Mk18 - Shooter's Position - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - CS5		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.48	3760.01	0.5453	155.18	1148.30	0.1665
2	163.89	3129.65	0.4539	154.71	1087.93	0.1578
3	163.06	2843.89	0.4125	155.00	1125.27	0.1632
4	163.71	3066.43	0.4447	155.50	1191.28	0.1728
5	163.74	3077.53	0.4464	155.63	1209.73	0.1755
AVERAGE	164.02	3175.50	0.4606	155.21	1152.50	0.1672

REDUCTION[1] **-63.71%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.



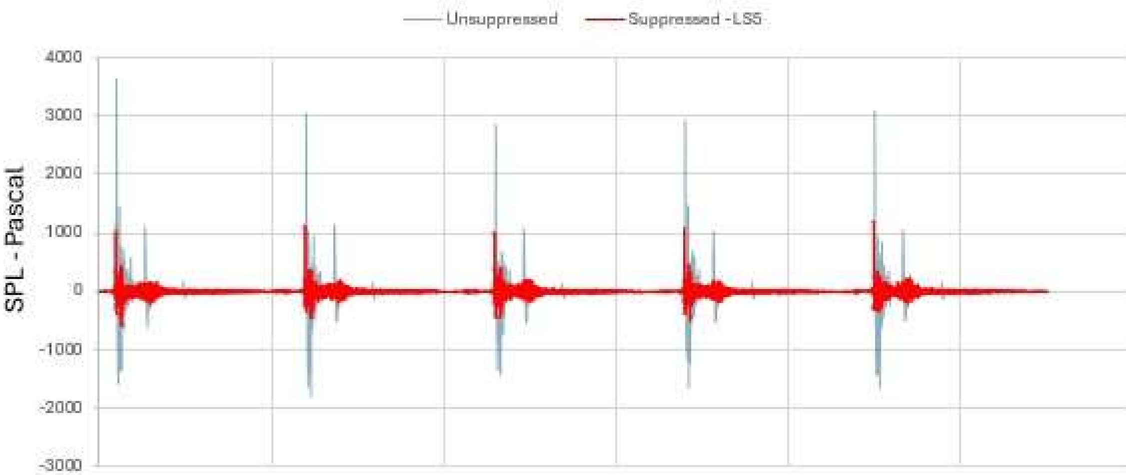
Mk18 - Shooter's Position - 20 Nov. 2024

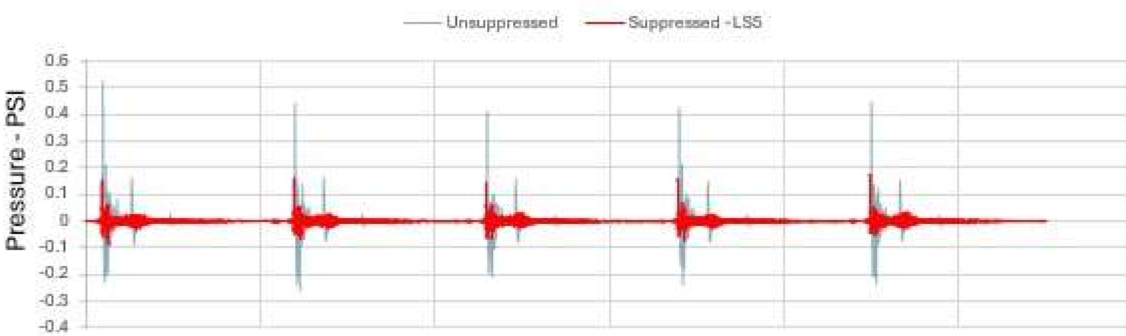
Shot #	Unsuppressed			Suppressed - GPS5k		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.48	3760.01	0.5453	156.43	1326.08	0.1923
2	163.89	3129.65	0.4539	155.61	1206.96	0.1751
3	163.06	2843.89	0.4125	156.83	1388.99	0.2015
4	163.71	3066.43	0.4447	155.44	1183.63	0.1717
5	163.74	3077.53	0.4464	155.66	1213.83	0.1761
AVERAGE	164.02	3175.50	0.4606	156.01	1263.90	0.1833

REDUCTION[1] **-60.20%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

MK18 – Unsuppressed vs. Suppressed LS5
Shooter's Position





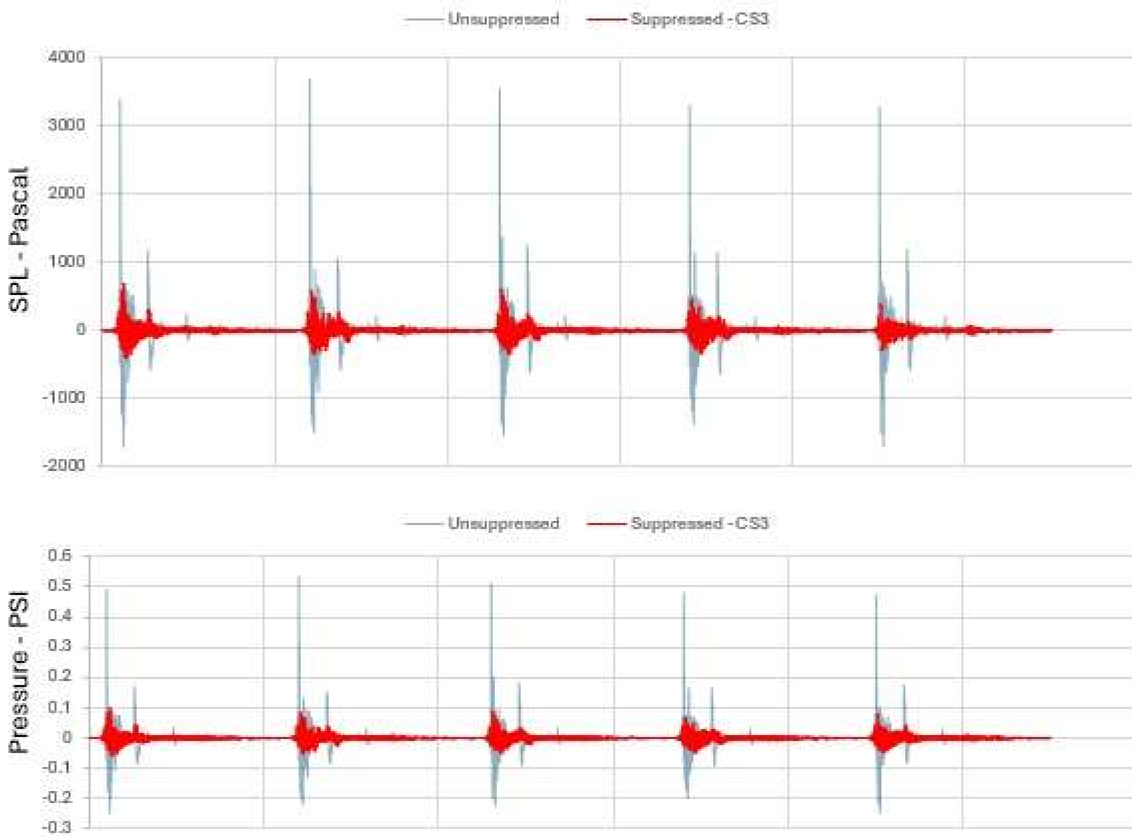
Mk18 - Shooter's Position - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - LS5		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.48	3760.01	0.5453	154.90	1112.24	0.1613
2	163.89	3129.65	0.4539	155.06	1132.98	0.1643
3	163.06	2843.89	0.4125	154.59	1072.35	0.1555
4	163.71	3066.43	0.4447	154.97	1120.30	0.1625
5	163.74	3077.53	0.4464	155.77	1229.38	0.1783
AVERAGE	164.02	3175.50	0.4606	155.07	1133.45	0.1644

REDUCTION[1] **-64.31%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

MK17 – Unsuppressed vs. Suppressed CS3
Shooter's Position



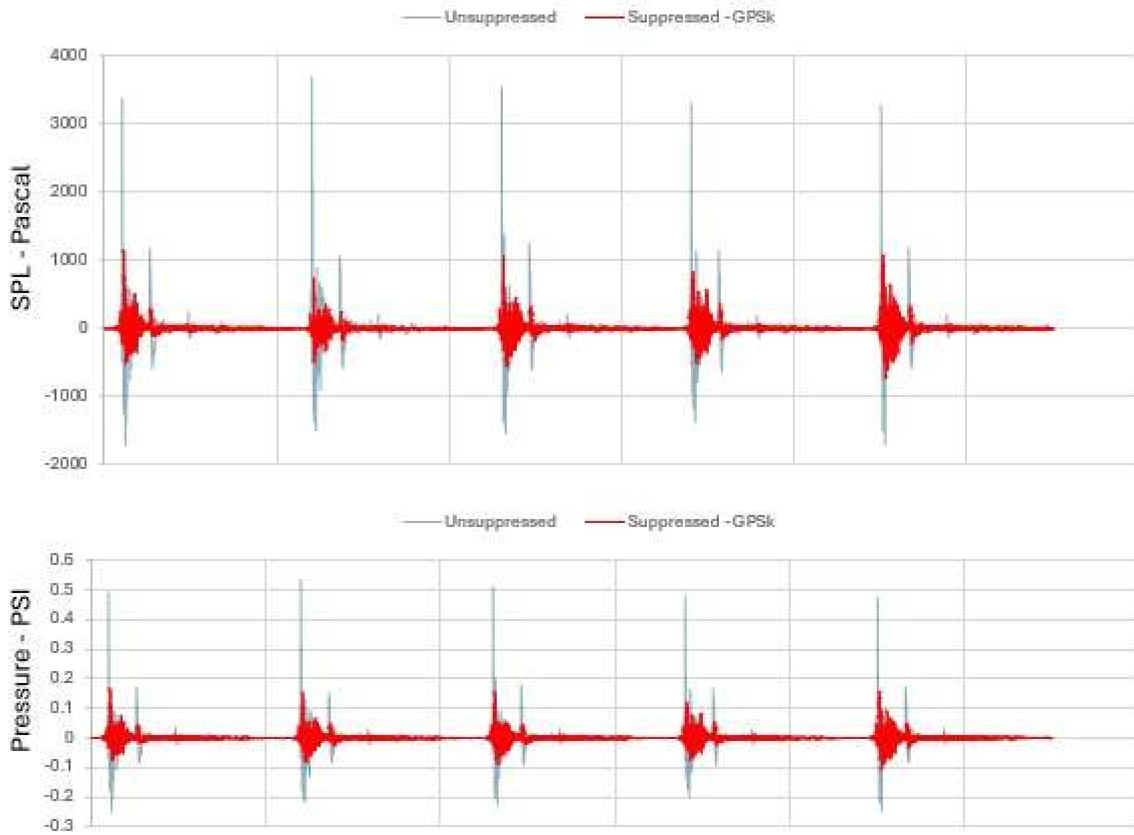
Mk17 - Shooter's Position - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - CS3		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.38	3716.24	0.5390	150.97	707.52	0.1026
2	165.82	3908.38	0.5669	149.17	574.91	0.0834
3	165.62	3817.78	0.5537	150.18	645.55	0.0936
4	164.94	3531.60	0.5122	147.44	471.24	0.0683
5	164.92	3522.58	0.5109	149.04	566.42	0.0822
AVERAGE	165.34	3699.32	0.5365	149.44	593.13	0.0860

REDUCTION[1] **-83.97%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

MK17 – Unsuppressed vs. Suppressed GPS7K Shooter's Position



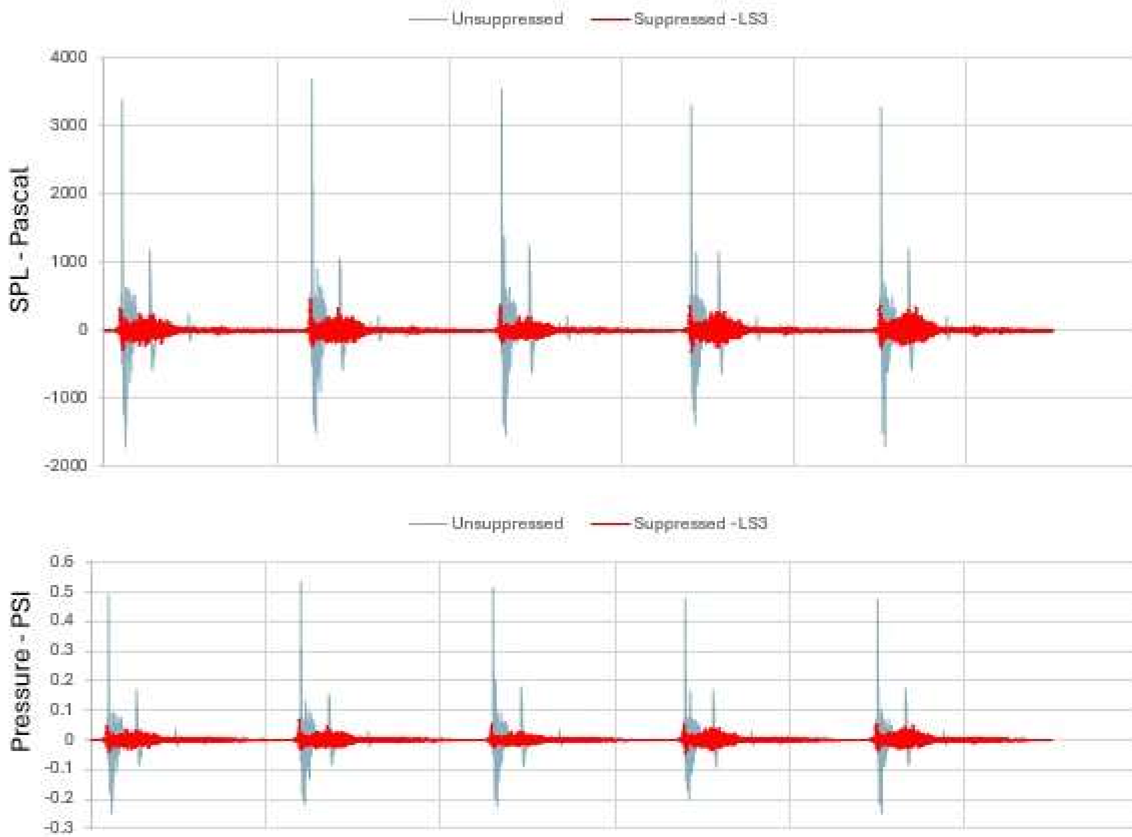
Mk17 - Shooter's Position - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - GPSk		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.38	3716.24	0.5390	155.17	1147.10	0.1664
2	165.82	3908.38	0.5669	154.56	1069.58	0.1551
3	165.62	3817.78	0.5537	154.95	1118.35	0.1622
4	164.94	3531.60	0.5122	152.59	852.12	0.1236
5	164.92	3522.58	0.5109	155.58	1202.16	0.1744
AVERAGE	165.34	3699.32	0.5365	154.63	1077.86	0.1563

REDUCTION[1] **-70.86%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

MK17 – Unsuppressed vs. Suppressed LS3
Shooter's Position

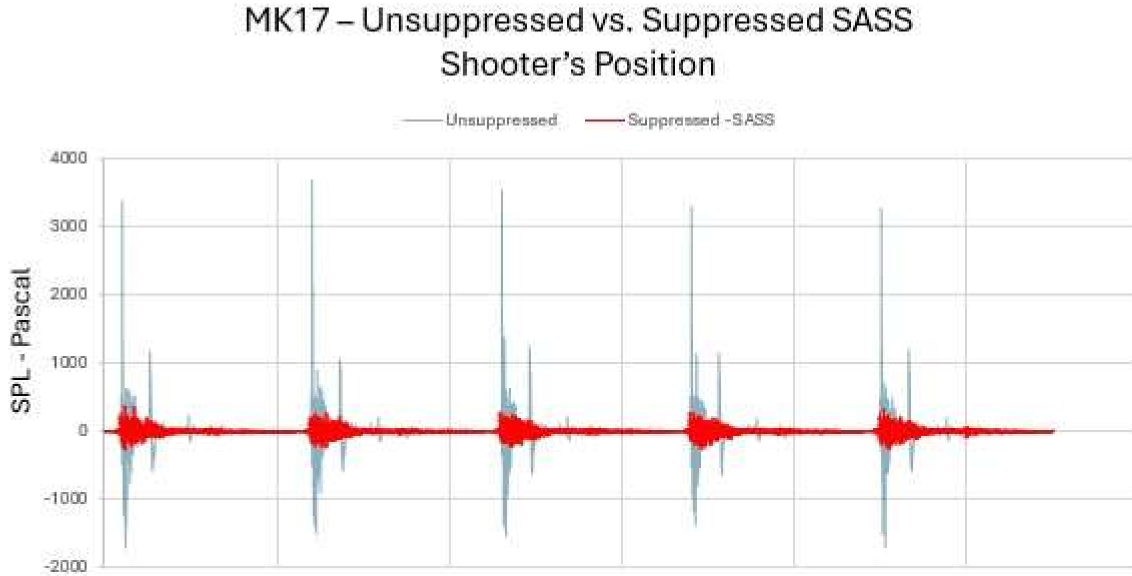


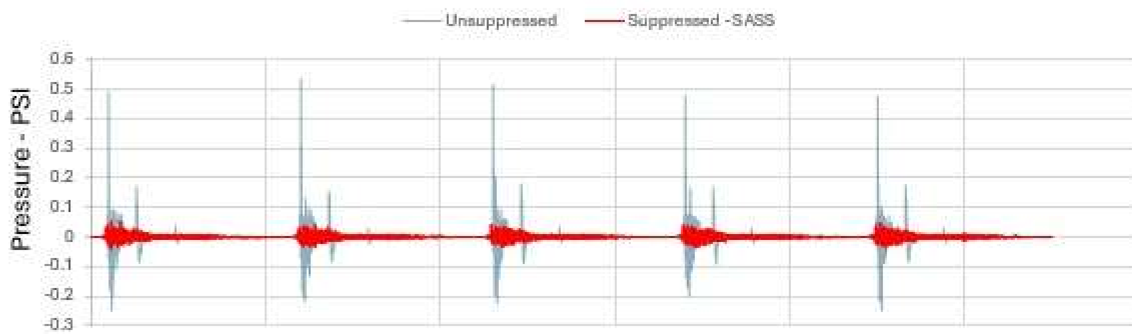
Mk17 - Shooter's Position - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - LS3		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.38	3716.24	0.5390	144.57	338.44	0.0491
2	165.82	3908.38	0.5669	147.27	461.68	0.0670
3	165.62	3817.78	0.5537	145.03	357.08	0.0518
4	164.94	3531.60	0.5122	145.15	361.79	0.0525
5	164.92	3522.58	0.5109	145.25	366.08	0.0531
AVERAGE	165.34	3699.32	0.5365	145.51	377.02	0.0547

REDUCTION[1] -89.81%

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.





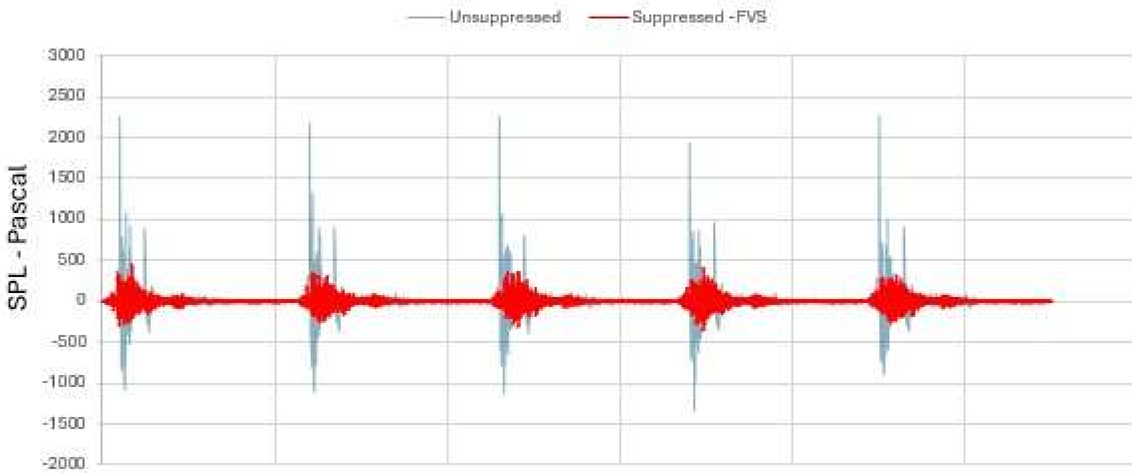
Mk17 - Shooter's Position - 20 Nov. 2024

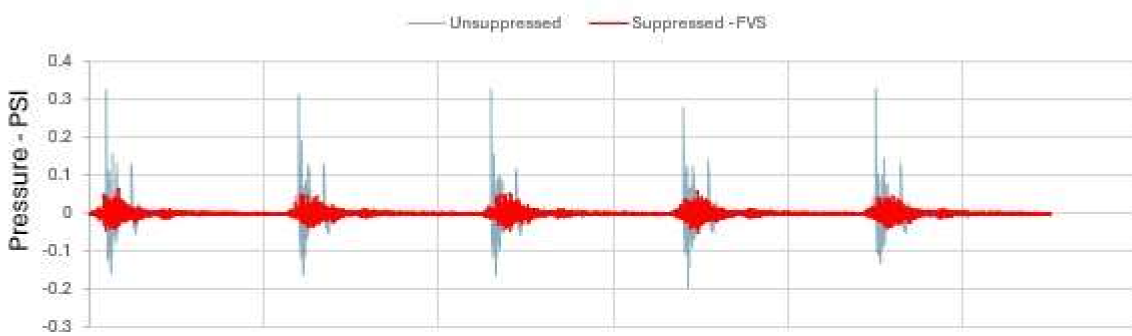
Shot #	Unsuppressed			Suppressed - SASS		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	165.38	3716.24	0.5390	145.51	377.02	0.0547
2	165.82	3908.38	0.5669	143.73	307.17	0.0446
3	165.62	3817.78	0.5537	142.91	279.59	0.0406
4	164.94	3531.60	0.5122	142.65	271.39	0.0394
5	164.92	3522.58	0.5109	144.59	339.09	0.0492
AVERAGE	165.34	3699.32	0.5365	143.94	314.85	0.0457

REDUCTION[1] **-91.49%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

M240 – Unsuppressed vs. Suppressed FVS
Shooter's Position





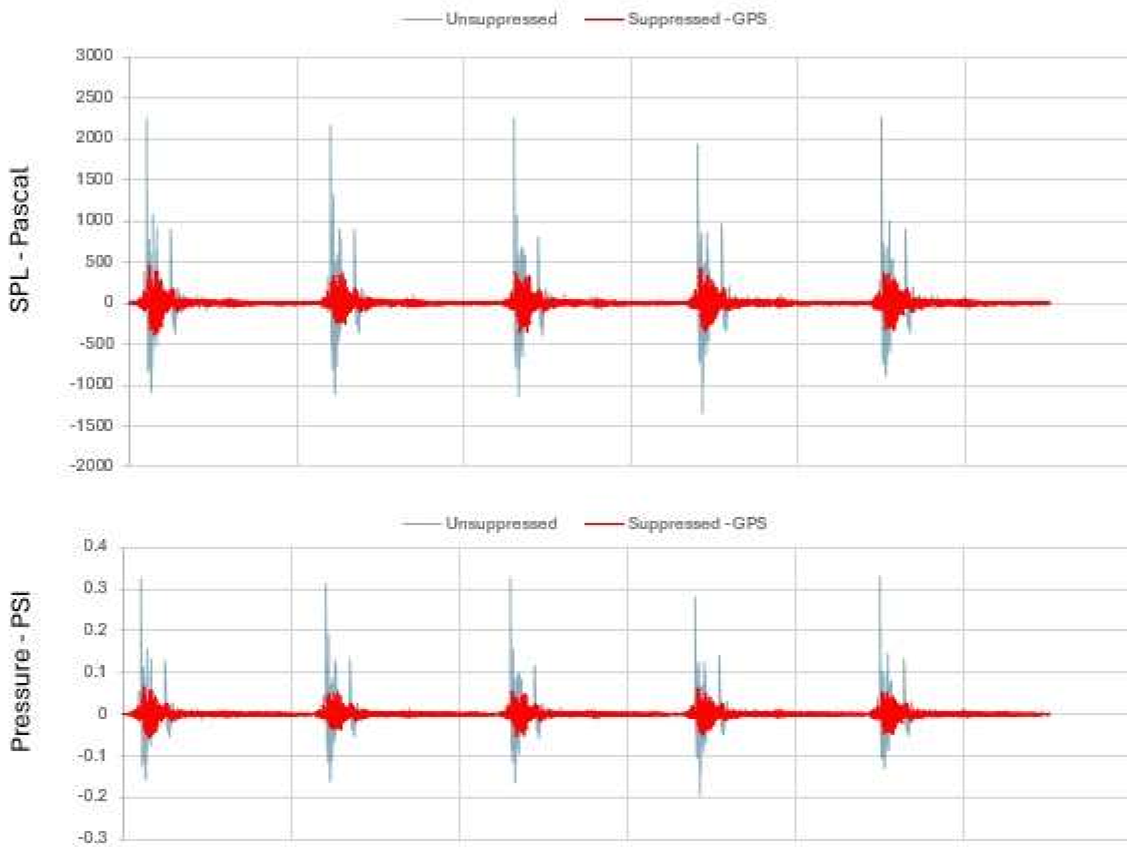
M240 - Shooter's Position - 21 Nov. 2024

Shot #	Unsuppressed			Suppressed - FVS		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	161.19	2293.48	0.3326	147.15	455.60	0.0661
2	161.50	2375.83	0.3446	145.44	374.02	0.0542
3	161.10	2270.68	0.3293	145.74	387.21	0.0562
4	160.48	2114.01	0.3066	146.37	416.61	0.0604
5	161.65	2417.43	0.3506	145.29	367.60	0.0533
AVERAGE	161.19	2294.29	0.3328	146.03	400.21	0.0580

REDUCTION[1] **-82.56%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

M240 – Unsuppressed vs. Suppressed GPS Shooter's Position



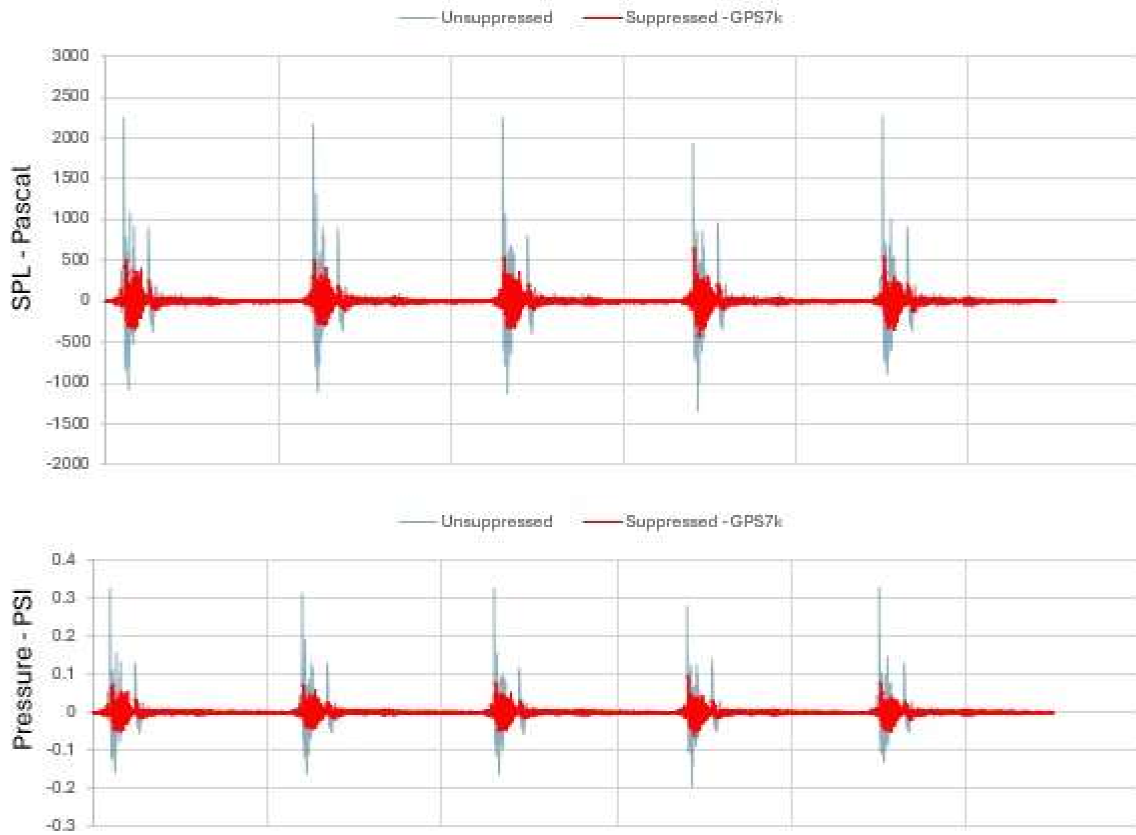
M240 - Shooter's Position - 21 Nov. 2024

Shot #	Unsuppressed			Suppressed - GPS		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	161.19	2293.48	0.3326	147.32	464.54	0.0674
2	161.50	2375.83	0.3446	145.65	383.51	0.0556
3	161.10	2270.68	0.3293	145.95	396.74	0.0575
4	160.48	2114.01	0.3066	146.59	427.16	0.0620
5	161.65	2417.43	0.3506	145.44	374.06	0.0543
AVERAGE	161.19	2294.29	0.3328	146.22	409.20	0.0593

REDUCTION[1] -82.16%

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

M240 – Unsuppressed vs. Suppressed GPS7k Shooter's Position



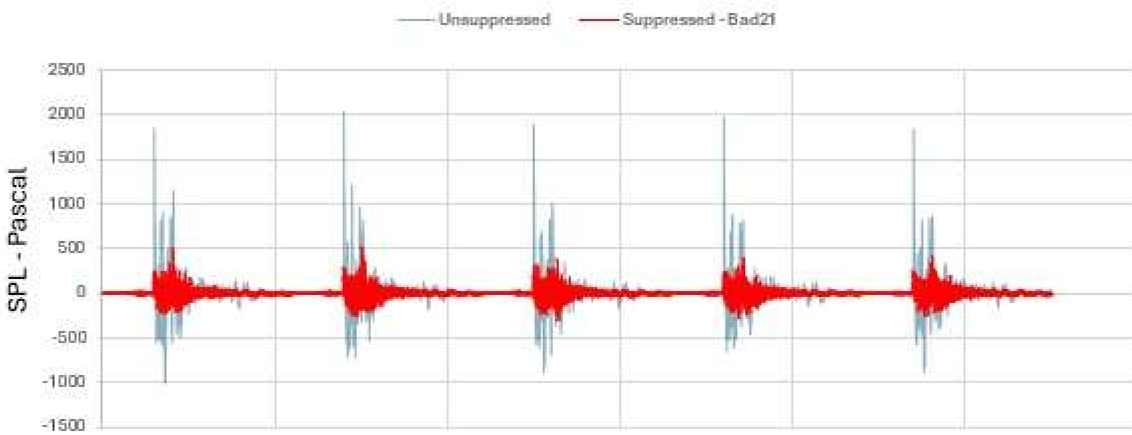
M240 - Shooter's Position - 21 Nov. 2024

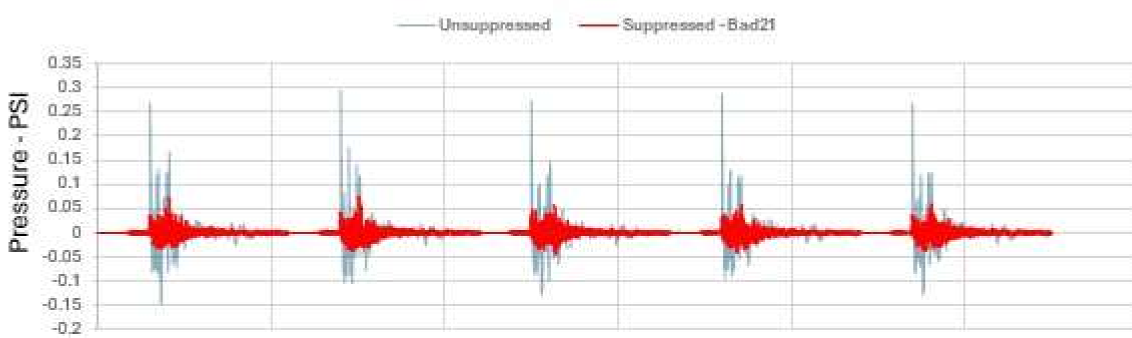
Shot #	Unsuppressed SPL - dB	Unsuppressed SPL - Pa	Unsuppressed Pressure - PSI	Suppressed - GPS7k SPL - dB	Suppressed - GPS7k SPL - Pa	Suppressed - GPS7k Pressure - PSI
1	161.19	2293.48	0.3326	148.11	508.53	0.0738
2	161.50	2375.83	0.3446	148.05	505.00	0.0732
3	161.10	2270.68	0.3293	148.66	542.15	0.0786
4	160.48	2114.01	0.3066	150.57	675.66	0.0980
5	161.65	2417.43	0.3506	148.77	548.68	0.0796
AVERAGE	161.19	2294.29	0.3328	148.88	556.00	0.0806

REDUCTION[1] -75.77%

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

M2A1 – Unsuppressed vs. Suppressed Bad21
Shooter's Position





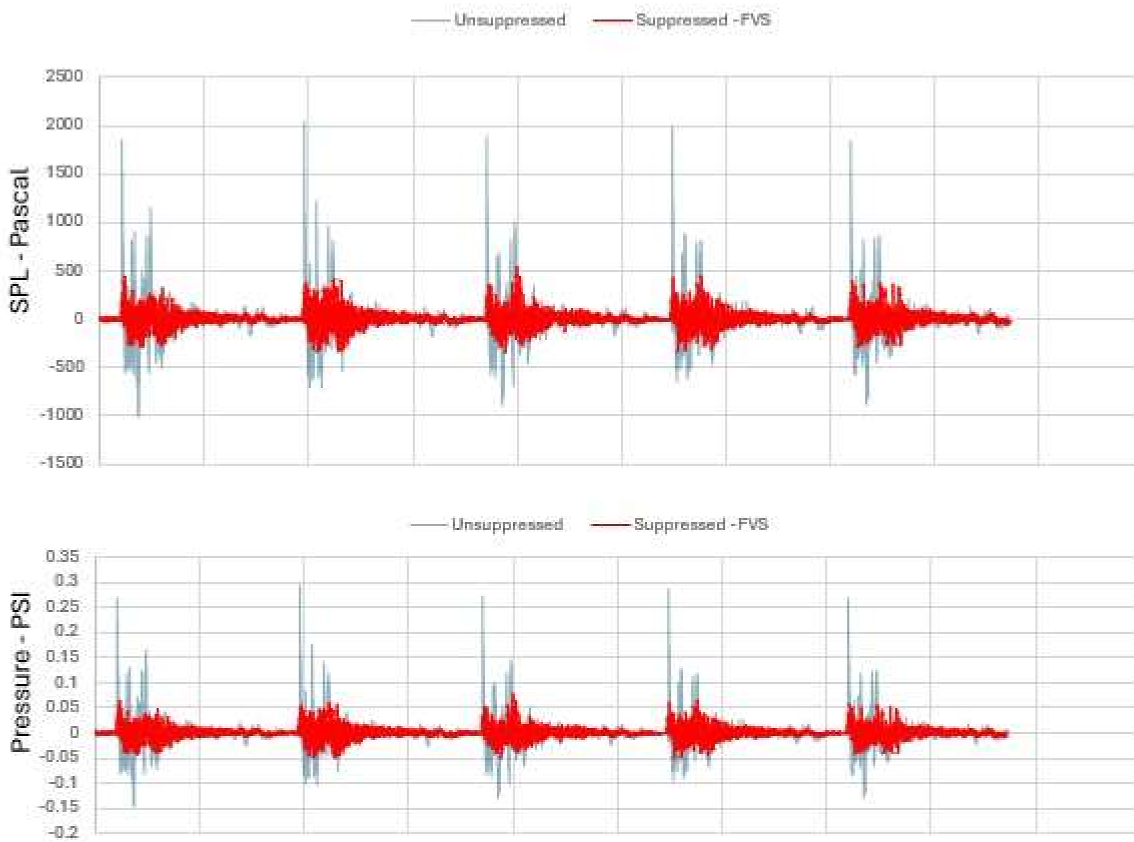
M2A1 - Shooter's Position Data - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - Bad21		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	160.08	2018.04	0.2927	148.25	516.76	0.0749
2	160.26	2059.99	0.2988	148.24	516.53	0.0749
3	159.64	1917.89	0.2782	145.91	395.07	0.0573
4	160.05	2011.29	0.2917	145.98	398.36	0.0578
5	159.43	1872.91	0.2716	146.35	415.22	0.0602
AVERAGE	159.90	1976.02	0.2866	147.01	448.39	0.0650

REDUCTION[1] **-77.31%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

M2A1 – Unsuppressed vs. Suppressed FVS
Shooter's Position



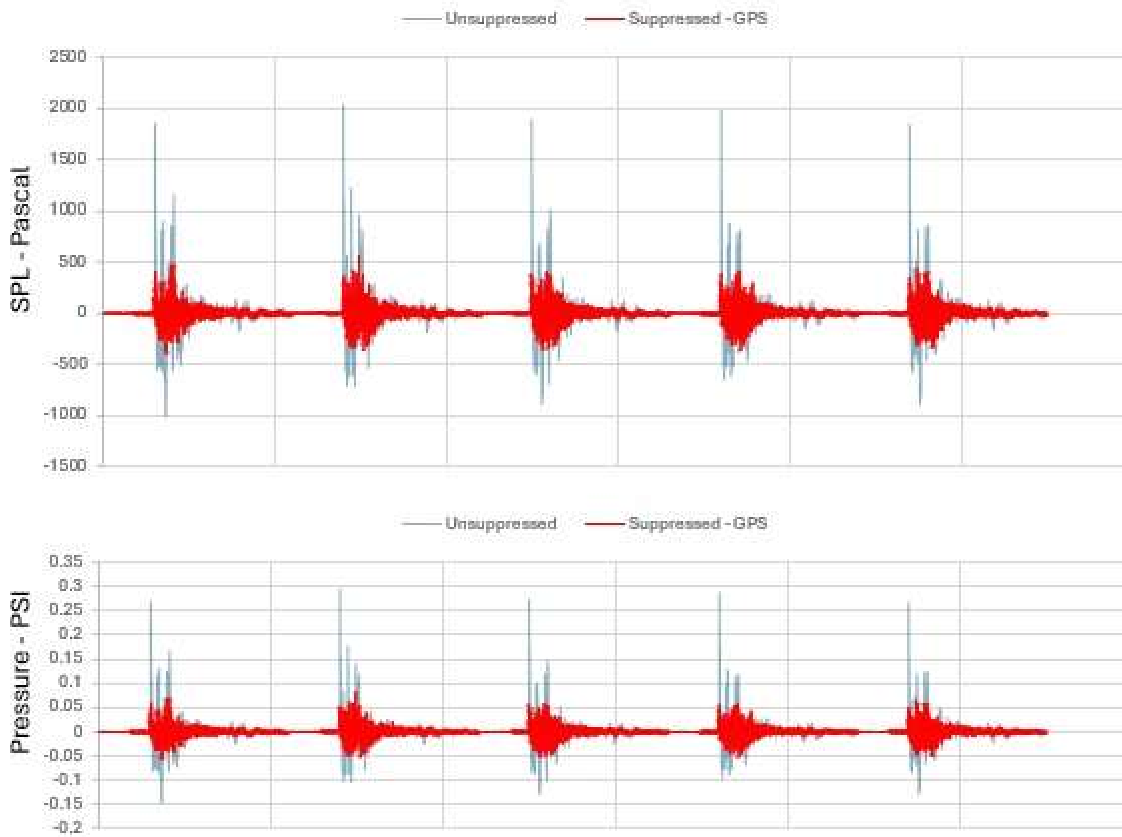
M2A1 - Shooter's Position Data - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - FVS		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	160.08	2018.04	0.2927	147.26	461.44	0.0669
2	160.26	2059.99	0.2988	146.47	421.28	0.0611
3	159.64	1917.89	0.2782	148.71	545.19	0.0791
4	160.05	2011.29	0.2917	147.10	452.78	0.0657
5	159.43	1872.91	0.2716	146.30	413.25	0.0599
AVERAGE	159.90	1976.02	0.2866	147.21	458.79	0.0665

REDUCTION[1] **-76.78%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.

M2A1 – Unsuppressed vs. Suppressed GPS
Shooter's Position



M2A1 - Shooter's Position Data - 20 Nov. 2024

Shot #	Unsuppressed			Suppressed - GPS		
	SPL - dB	SPL - Pa	Pressure - PSI	SPL - dB	SPL - Pa	Pressure - PSI
1	160.08	2018.04	0.2927	147.77	489.29	0.0710
2	160.26	2059.99	0.2988	149.40	590.12	0.0856
3	159.64	1917.89	0.2782	146.15	406.08	0.0589
4	160.05	2011.29	0.2917	146.29	412.36	0.0598
5	159.43	1872.91	0.2716	147.89	496.08	0.0720
AVERAGE	159.90	1976.02	0.2866	147.58	478.79	0.0694

REDUCTION[1] **-75.77%**

1) The reduction percentage is based on the reduced amplitude of the average values of the unsuppressed and suppressed data.