



Troy Acoustics Corporation

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Ft Bragg
SOF Special Forces
Complex –
Ft Bragg, NC

Shooting Range Acoustics Certification of Compliance

W91278-11-N-0001

Prepared by
Troy Acoustics Corporation
28358 Constellation Rd., Suite 640
Santa Clarita, CA 91355
800-987-3306
www.troyacoustics.com

Submitted by Bill Bergiadis and Steve Katz

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Executive Summary

- The Statement of Work called for a "Noise Reduction Coefficient (NRC) of .85 or better in all octave bands from 125 to 8000 Hz" the Troy System™ has an accredited NRC in all octave bands from 125 to 8000 Hz of **0.95**
- Measurements were taken at firing points within the range where shooters will move both transversely and laterally
- Eight channels of high speed data was recorded with four (4) microphones mounted to three (3) shooters and an instructor, and (4) microphones placed in the reverberant field
- The scope called for "the completed range facility to meet or exceed a Reverb Time (RT60) of 1.3 seconds or less in all octave bands from 125 to 8000 Hz, " The Troy treated range has reverberation time of **0.85 seconds** averaged over five (5) microphone positions at key points within the range. Before treatment with the Troy System™ the Reverb Time (RT60) was **4.62 seconds** at the same microphone positions.
- During the testing errant rounds struck one of the baffles. The entrance was clean and there was no ricochet or splash back
- With one (1) shooter, in the prone position, firing six (6) rounds on a SAW 5.56 automatic weapon as measured from the center lane (lane 7) from the 50 meter line, and the same in the post-treated range, psi(t) was reduced from 3,873 psi(t) in the untreated range to 563 psi(t), an improvement of 688 percent (%). The total pressure in psi was reduced from 1,030 psi to 561 psi. The shooters exposure time was reduced from 2.9 seconds to 1.0 second.
- With seven (7) shooters, standing in lanes, 1, 3, 5, 7, 9, 11, 13 firing a single round on a M4 – 5.56 from the 50 meter line, psi(t) was reduced from 10,746 psi(t) to 680 psi(t), an improvement of 1,581 percent (%). The total pressure in psi was reduced from 3,554 psi to 680 psi. The shooters exposure time was reduced from 3.0 seconds to 1.2 seconds.
- Two (2) shooters, prone, in lanes, 5, and 7, firing 6 rounds on a 7.62 M240 automatic weapon from the 25 meter line the psi(t) was reduced from 12,680 psi(t) to 2,673 psi(t), an improvement of 474 percent (%). The total pressure in psi was reduced from 3,456 psi to 1,584 psi. The shooters exposure time was reduced from 3.7 seconds to 1.7 seconds..
- Troy Acoustics certifies that the SOF Special Forces Complex, Ft Bragg, NC complies and exceeds with the specifications and criteria as set forth by USACE

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Report

The following is based on the contractual mandated final testing performed SOF Special Forces Complex at Ft Bragg, NC, on October 26, and October 27, 2011. Pre-testing was performed August 30, and August 31, 2011.

The range is constructed of a concrete slab floor, concrete tilt up walls, with 21 armor steel baffles 8' deep overlapping 6". The bullet trap is armor steel with an overhead steel baffle leading into the bullet trap. There are two (2) sliding armor doors, one on either side of the range located behind the 50 meter firing line on the side walls. There is an acoustical drop ceiling located from the 50 meter line to the rear wall of the range where the range control office is located.

Picture 1 below shows the shooting range a Ft Bragg, NC before treatment with the Troy System™.

Picture 1



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Picture 2 below shows the acoustical treatment consisted of the Troy System attached to the concrete side walls from the leading edge baffle to the rear wall, and including the rear wall. A pocket wall was constructed to provide acoustical treatment at the location of the sliding armor doors, while the doors are in the closed position. There were 21- 8' baffles extending from side wall to side wall. These 21 baffles were treated with the Troy System™ from the point of the acoustical drop ceiling at the 50 meter line to the bullet trap. The acoustical drop ceiling was also replaced with 1" troy board material and 6" of Troy Wool on top of the Troy Board.

Picture 2



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This report represents a "*written guarantee of compliance*" as specified in the Statement of Work (SOW) SOF Special Forces Complex - PURCHASE OF SOUND ATTENUATION SYSTEM FOR SOF INDOOR RANGES at Ft Bragg WA, Ft Bragg CO, Ft Bragg NC, Ft Bragg NC. Solicitation Number: W91278-11-N-0001

Troy Acoustics Corporation certifies that all specifications as set forth in said Statement of Work have been met and exceeded. The SOF Special Forces Complex at Ft Bragg, NC shooting range is fully acoustically compliant as specified and hereby certified for full operation as such.

1 - As per 2.3.1 of Work Statement; the performance specifications shall be met at any possible firing point within the range, shooters will move both transversely and laterally within the range.

The range was measured at the seven (7) meter line, twenty-five (25) meter line, and the fifty (50) meter line. Instrumentation microphones were placed on the top of shooters hearing protection in lanes 3, 5, and 7, a microphone on a stand, ear level that moved with the shooting position was placed in lane 6, and fixed microphones in the center of the range at the twenty-five (25) meter line, and the 50 meter line complying with the requirement reflecting that "shooters will move both transversely and laterally within the range."

2 - As per 2.3.2 the Troy Acoustics Corporation will provide test data from an NAVLAV approved laboratory for Noise Reduction Coefficient (NRC) of .85 or better in all octave bands from 125 to 8000 Hz.

Troy Acoustics certifies that the Reduction Coefficient (NRC) of SOF Special Forces Complex at Ft Bragg, NC, in all octave bands from 125 to 8000 Hz is 0.95. Documentation from a NAVLAV approved laboratory is included below.

3 - As per 2.3.3 Troy will guarantee the completed range facility to meet or exceed a Reverb Time (RT60) of 1.3 seconds or less in all octave bands from 125 to 8000 Hz.

Chart 1 - below shows a Reverberation Time (RT60) of 4.62 seconds in all octave bands from 50 Hz to 20,000 Hz before treatment of the Ft Bragg, NC shooting range with the Troy System™, and a **Reverb Time (RT60) of 0.85** seconds in all octave bands from 50 Hz to 20,000 Hz after treatment of the Ft Bragg, NC shooting range with the Troy System™. The Reverberation Time (RT60) was arrived at by averaging microphone positions at the seven (7) meter, 25 meter, and 50 meter lines with a single shooter firing a single shot M4, 5.56 round at the seven, 25, and 50 meter lines, respectively. This complies with standard reverberation time measurement procedure.

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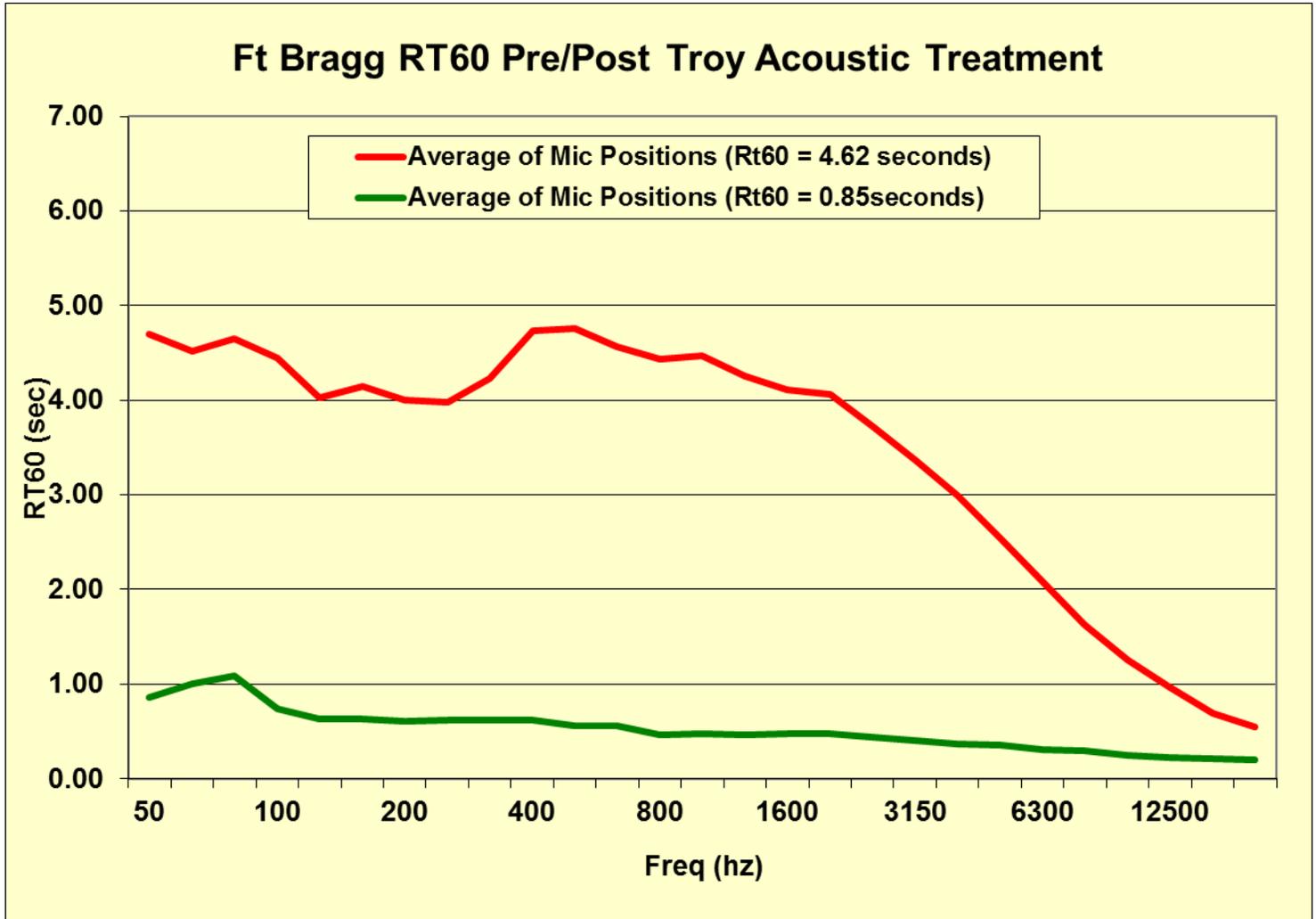
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The reduction of the Reverberation Time (RT60) from 4.62 seconds to 0.85 seconds is a considerable reduction of the impulse overblast energy within the range and is well below the 1.3 second Reverberation Time (RT60) as put forth in the statement of work.

Chart 1



4. As per 2.3.4. Troy Acoustics Corporation shall provide a written guarantee of compliance with both the NRC and RT60 requirements (after post installation testing). The written guarantee of compliance is based upon the installation of the Troy System™ by Troy Acoustics Corporation or a contractor certified and approved by Troy Acoustics Corporation.

This document complies with the above.

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5. Per 2.3.5. The Troy System™ shall maintain the required acoustical performance without degradation of the acoustical integrity due to bullet splash back. Troy Acoustics Corporation will provide documentation showing approval of the Troy System™ for Anti-Splatter & ricochet as per testing performed by USAF.

A copy of the USAF report on Anti-Splatter & Ricochet is being submitted under separate cover.

6. As per 2.3.6. Troy Acoustics Corporation shall provide testing of the installed system as verification that the system meets the performance requirements. Troy shall submit a testing plan that will include the experience and qualifications of personnel performing the test and analyzing the results for this site.

The standard course of fire as specified by Range Specialist; SFC Joseph A Iampaglia was modified as to the weapons available at Ft Bragg, NC at the time. A copy of the pre and post-testing course of fire is available on request.

7. As per 2.4.6. The Supplier shall provide testing of the installed system as verification that the system meets the performance requirements. The Supplier shall submit a testing plan to be approved by the Government prior to system testing. The testing plan shall include the experience and qualifications of personnel performing the test and analyzing the results. The Government will provide all weaponry support required for testing of the system. The test agency shall provide documentation with recommended firing operations restrictions for each weapon type under slow, rapid, and automatic firing conditions, to include recommended firing operations for suppressed weapons. The test results shall be submitted to the Government prior to acceptance of the installed system.

A testing plan was submitted to the Government (attached) appended and approved by Range Specialist; SFC Joseph A Iampaglia (amended course of fire available on request). This plan was followed at Ft. Bragg subject to availability as to weapons and ammunition.

Section 2.1 of the RFP states: *Existing Conditions. The existing facility design has resulted in unsafe conditions and unacceptable firing restrictions due to inadequate reverberation control.*

As shown in *Chart 1*, the treatment of this range with the Troy Sound Absorption and Noise Abatement System has reduced the reverberation time from 4.62 seconds to 0.85 seconds for an improvement of 544%.

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Pressure Time

The one existing military impulse noise standard MIL-STD-1474D¹ only refers to hearing conservation criterion. Treating a shooting range with the Troy System™ has the considerable benefit of protecting the whole person. The reduction of pressure on the body can be measured in Pressure Time

Troy Acoustics is pioneering the use of **Pound-Force per Square Inch (psi)** and **Pound-Force per Square Inch Time (psi(t))²** to evaluate shooting ranges and gauge the amount of improvement from sound absorption/noise abatement treatment.

- Psi(t) gives an actual representation of the total energy generated within the range
- Psi(t) gives an accurate representation of the effect of multiple shooters firing multiple rounds
- Psi(t) gives an accurate representation of automatic and semiautomatic fire, single or multiple shooters
- Psi(t) can be used to compare any range whether acoustically treated or not
- psi(t) is an excellent way to compare an, indoor or outdoor acoustically untreated range to an acoustically treated range to gauge performance and improvement
- Psi(t) clearly expresses the effect on the total human physiology not just hearing
- Exposure to impulse blast overpressure besides hearing loss is linked to: hypertension, heart disease, anxiety, headaches, judgment impairment, sleep disturbance, and other physiological conditions

Figure 1 below shows in the pre-treated Ft Bragg shooting range with one (1) shooter, in the prone position in lane 7, firing six (6) rounds on a SAW 5.56 automatic weapon as measured from the center lane (lane 7) from the 50 meter line, and the same in the post-treated range³. Psi(t) was reduced from 3,873 psi(t) in the untreated range to 563 psi(t), an improvement of 688 percent (%). The total pressure in psi was reduced from 1,030 psi to 561 psi. The shooters exposure time was reduced from 2.9 seconds to 1.0 second. The left hand scale is SPL (dB re 20uPA)) verses Time in seconds.

¹ Revision offered 12 February 1997

² psi(t) is the integer of the area under the peak pressure curve (in Pa) times the total event duration in seconds with the formula $\text{psi}(t) = Z_n \left(\int f(x) dx (\text{sec}) \right)$

³ The pressure sensor used was a 1/4" Troy designed Personal Mounted Microphone (PMM) (PCB Model 377a12) attached to the top of the shooters hard hearing protection. Worn by the shooter in lane 7

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Figure 1

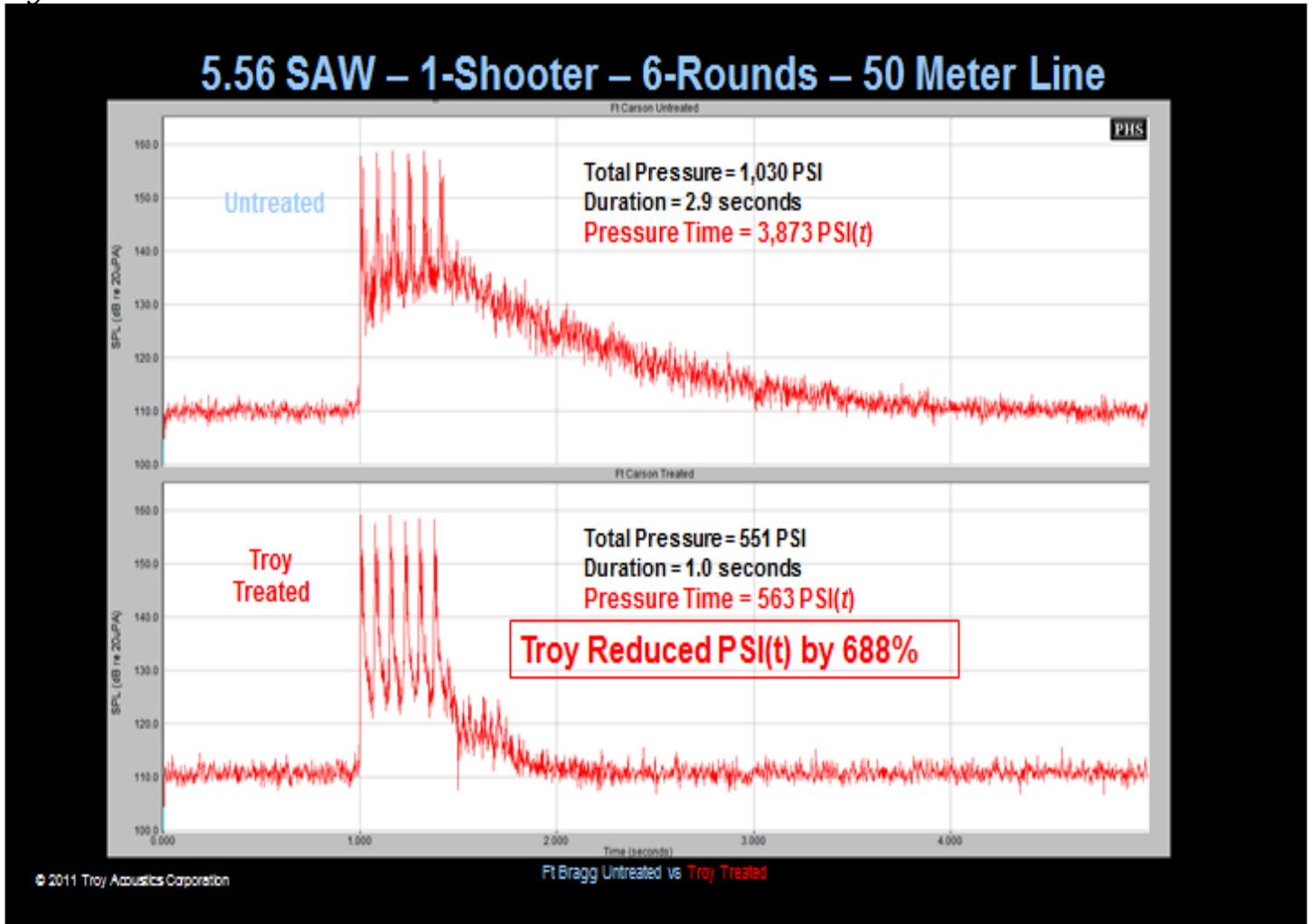


Figure 2 below shows seven (7) shooters, standing in lanes, 1, 3, 5, 7, 9, 11, 13 firing a single round on a M4 – 5.56 from the 7 meter line⁴. Psi(t) was reduced from 10,746 psi(t) to 680 psi(t), an improvement of 1,581 percent (%). The total pressure in psi was reduced from 3,554 psi to 680 psi. The shooters exposure time was reduced from 3.0 seconds to 1.2 seconds. As part of the testing procedure Troy Acoustics gives a countdown to the shooters to aid them to fire as synchronized as possible.

⁴ The pressure sensor used was a ¼” Troy designed Personal Mounted Microphone (PMM) (PCB Model 377a12) attached to the top of the shooters hard hearing protection. Worn by the shooter in lane 7

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Figure 2

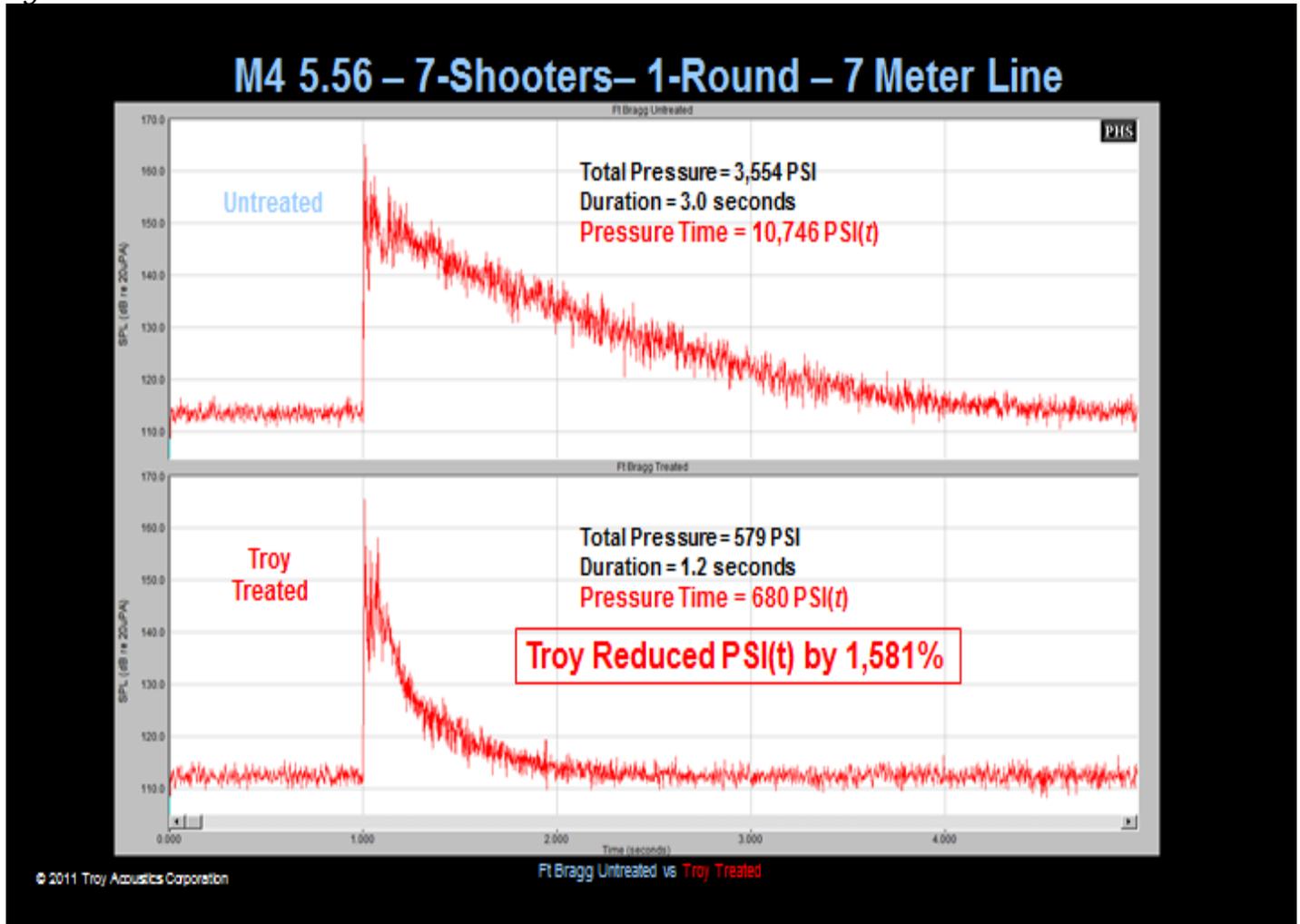


Figure 3 below shows two (2) shooters, prone, in lanes, 5, and 7, firing 6 rounds on a 7.62 M240 automatic weapon from the 25 meter line⁵. Psi(t) was reduced from 12,680 psi(t) to 2,673 psi(t), an improvement of 474 percent (%). The total pressure in psi was reduced from 3,456 psi to 1,584 psi. The shooters exposure time was reduced from 3.7 seconds to 1.7 seconds.

⁵ The pressure sensor used was a 1/4" Troy designed Personal Mounted Microphone (PMM) (PCB Model 377a12) attached to the top of the shooters hard hearing protection. Worn by the shooter in lane 7

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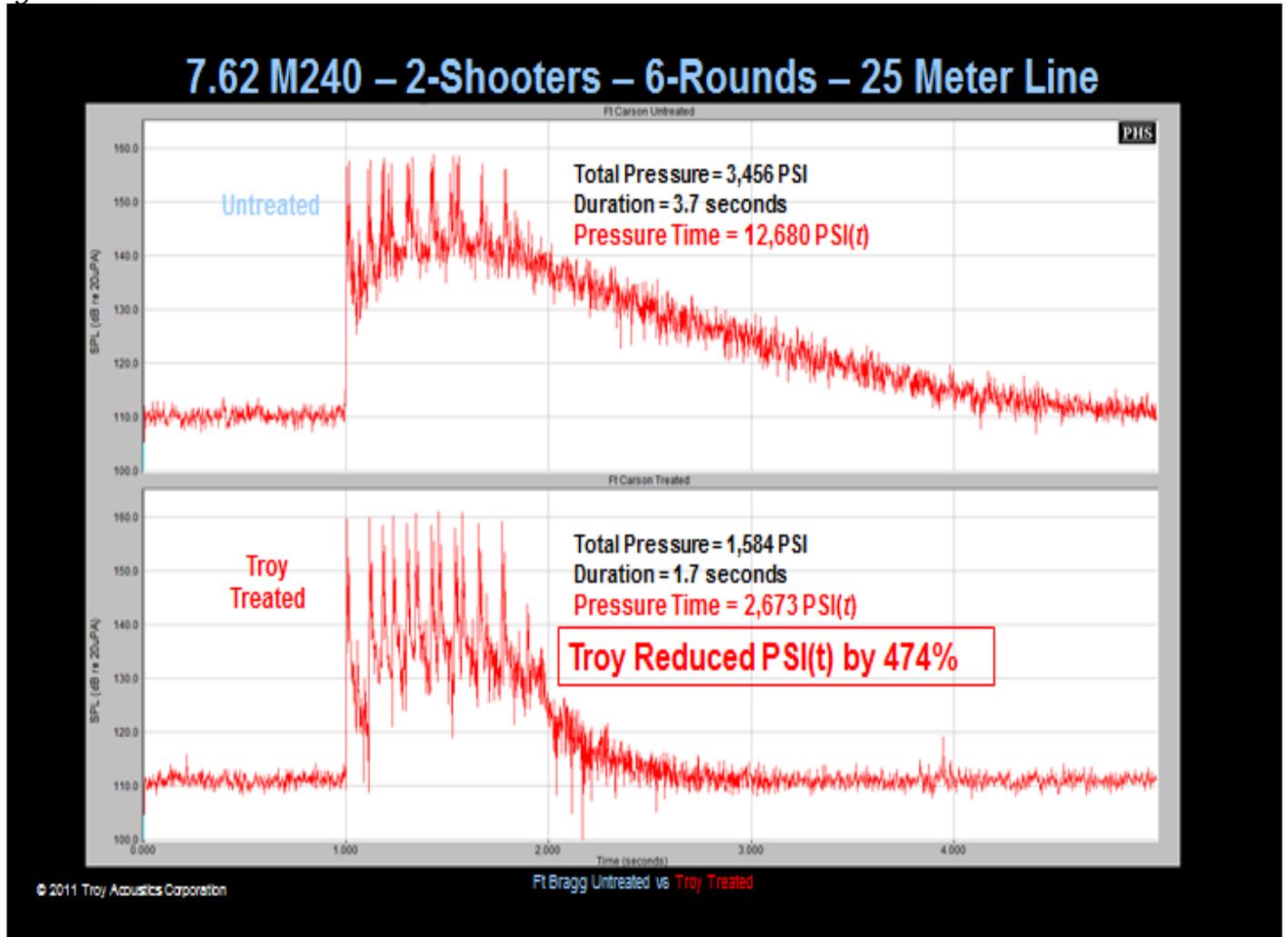
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Figure 3



Testing Methodology

Troy Acoustics has conceived and developed a comprehensive measuring methodology, and post analysis package specifically designed and configured for testing and evaluating indoor and outdoor shooting ranges.

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The Troy range measuring package consists of:

- 8 - PCB 1/4" pressure, prepolarized condenser microphone typical sensitivity= 0.25 mV/Pa (± 3 dB), 4 Hz to 20 kHz (± 2 dB). with a dynamic range of 178dB dB re 20 μ Pa⁶
- 2 - PCB Pressure Transducer, Pressure Sensor ICP® microphone, 300 mV/psi, resolution 0.0001 psi (+91 dB) range 8.3 psi⁷
- 2 - PCB 483C05 8-channel, line-powered, ICP® sensor unity gain, Signal Conditioners⁸
- 1 - Larson Davis CAL250 Precision Acoustic Calibrator, Output level: 114 dB, Output frequency: 251.2 Hz⁹
- 1 - B&K (Bruel & Kjaer) 4222 laboratory standard Pistonphone Output level: 124 dB, Output frequency: 250 Hz
- 10 - Microtech Gefell 1/2" Messmikrofonvorverstärker MV 203 / MV 204 mounting clamps custom modified with shock and vibration reducing 1/8" open cell neoprene foam
- Lynx Studio Technology: Aurora 16, 192k, 24 bit, 16 channel analog to digital (a/d) and digital to analog (d/a) converter –with the 16 channel, 192k LT-MADI Buss with digital Lightpipe I/O option¹⁰
- 1 - HDSPe ExpressCard MADIface, 192k 250 MB/s transfer rate per direction digital interface¹¹
- LT-ADK/1Q AR/1600 custom laptop computer w/ Intel - Core i5 520M 2.4GHz Dual Core w/HT 3Meg Cache mobile processor, Mushkin 2Gig DDR3 1333 Sodimm 9-9-9-24 memory, and Microsoft - Windows 7 Home Premium 64-bit
- REAPER 192k digital audio workstation software¹²

The Troy Post-Processing package consists of:

- SpectraPLUS¹³ - FFT Spectrum Dual channel 24 bit sampling precision and sampling rates above 192kHz Analyzer w/modules including:
 - Custom Psi and Psi(t) measuring modules¹⁴
 - Narrowband FFT sizes up to 1,048,576 points, and Octave scaling to 1/96.
 - Real Time Mode, Spectrum, Time Series, and Phase displays, Triggering, Markers, Overlays, Averaging, Peak Hold, Decimation, Mic Compensation, A, B, C Spectral Weighting..

⁶ http://www.pcb.com/spec_sheet.asp?model=377A12&item_id=9272

⁷ http://www.pcb.com/spec_sheet.asp?model=106B&item_id=11065

⁸ http://www.pcb.com/spec_sheet.asp?model=483C05&item_id=11533

⁹ http://www.larsondavis.com/Downloads/LD_CAL250_0209_Lowres.pdf

¹⁰ http://www.lynxstudio.com/product_detail.asp?i=1

¹¹ http://www.rme-audio.de/en_products_hdspe_madiface.php

¹² <http://www.reaper.fm/>

¹³ <http://www.spectraplus.com/>

¹⁴ Troy Acoustics offers to any qualified researchers and military and industry researchers using the SpectraPLUS platform use of this custom module

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- Real and Complex Transfer Functions, Coherence, Average, Cross Spectrum and cross channel delay compensation.
- Recorder and Post Processing modes - allows direct hard disk recording and playback.
- Post processing mode provides comprehensive analysis from WAV files. Includes Digital Filtering capability
- Spectrogram View - displays the spectrum versus time in grayscale or color format for advanced joint time-frequency analysis.
- 3-D Surface View - displays the spectrum versus time in a 3-Dimensional perspective format
- Independent channel calibration and scaling for left and right channels with separate views for each.
- Calibration conversions from Acceleration to Velocity or Displacement; Power Spectral Density scaling option for accurate noise measurements.
- Reverberation Time (RT60) utility features bar graph of reverberation time versus frequency band, 3-D Surface plot of the decay versus frequency and individual decay plots versus time. Delay Finder measures delay between two channels in milliseconds, feet or meters.
- Equivalent Noise (Leq) utility provides comprehensive noise level calculations for LeqT, Leq, Lpk, Lsel, Lmax, Lmin, L10, L50, and L90.

Figure 4 below shows the microphones used and their positions and placements. The same serial number microphones have been used for pre and post testing of all SOCOM ranges except for Eglin AFB where mic 6 was placed in the center of the range 37.5 feet from the firing line. Sensors 9 and 10 were introduced at Ft Bragg and Ft Bragg for pre and post testing. Their purpose is to better understand the pressure on vulnerable parts of the body. A pressure sensor as opposed to a microphone can be directed at the source without concern for overload or distortion.

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Figure 4

Track	Type	Manf	Model	Sn#	Position	Placement	Height	Facing
1	1/4 Pressure	PCB	377A12	118631	Shooter Lane 7	worn by shooter	n/a	Up
2	1/4 Pressure	PCB	377A12	118628	Shooter Lane 5	worn by shooter	n/a	Up
3	1/4 Pressure	PCB	377A12	118625	Shooter Lane 3	worn by shooter	n/a	Up
4	1/4 Pressure	PCB	377A12	118626	Instructor Lane 5	worn by instructor	n/a	Up
5	1/4 Pressure	PCB	377A12	118624	on stand see drawing	between L-7/8 75' from FL	5'3"(1.6m)	Up
6	1/4 Pressure	PCB	377A12	126570	on stand see drawing	Center of lane 6 ¹⁵	5'3"(1.6m)	Up
7	1/4 Pressure	PCB	377A12	109030	on stand see drawing	between L-7/8 Firing Line	5'3"(1.6m)	Up
8	1/4 Pressure	PCB	377A12	126571	on stand see drawing	between L-9/10 3' from R Wall	5'3"(1.6m)	Up
9	Sensor	PCB	106B	12635	Shooter Lane 7	Lane 7 shooter's left temple	n/a	out
10	Sensor	PCB	106B	12648	Shooter Lane 7	Lane 7 shooter's sternum (xiphoid process)	n/a	out
-								
-								
16					slate	Moves with shooters		

Figure 5 shows the pressure microphone placement for microphones 1 – 8. The red X's are microphones mounted on the shooters or instructors hard hearing protection. The pinkish dots are fixed mic positions except for mic 6 which is moved with the shooters.

¹⁵ Microphone 6 moves with the shooters position re 7, 25, and 50 meter lines

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Figure 5

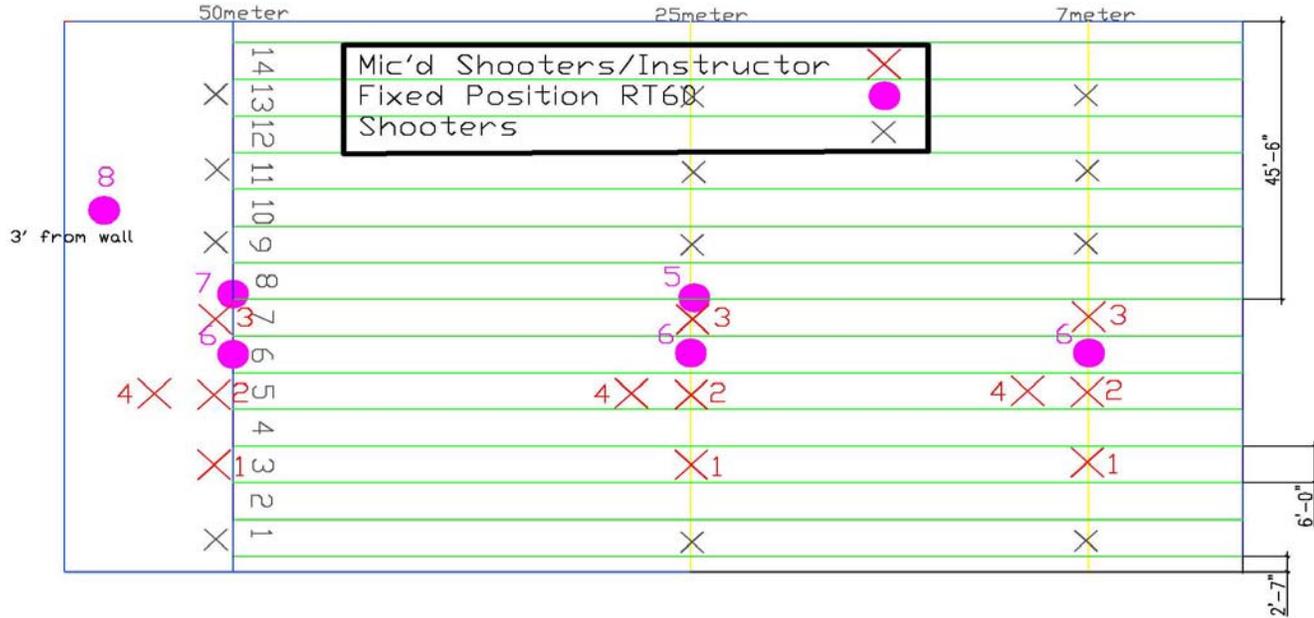


Figure 6 and Figure 7 below show the Personal Mounted Microphones (PMM's) in action.

Figure 6



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Figure 7



Figure 8 below shows the Troy Acoustics custom 16 channel recording channel. This photo shows only one (1) PCB signal conditioner currently there are two (2) of these units.



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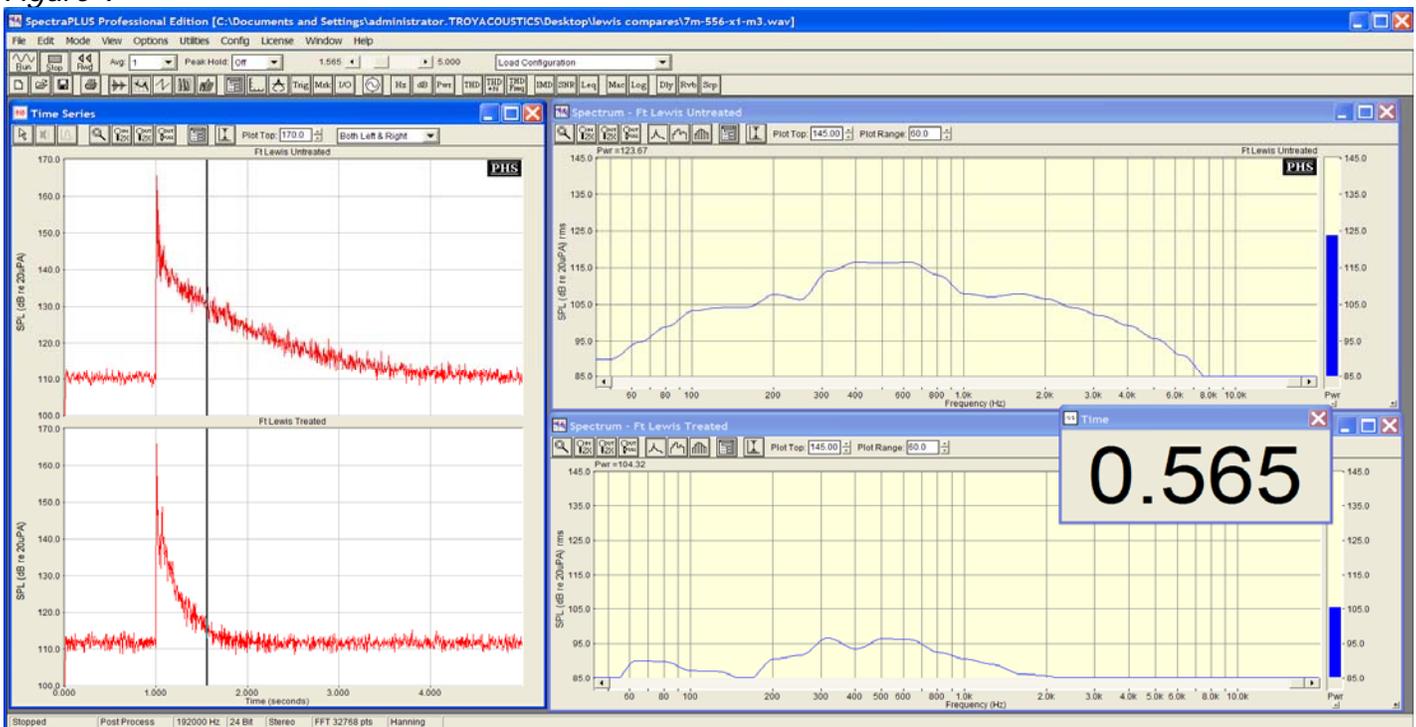
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Figure 9 below shows the SpectraPLUS software used for post-analysis. The time series on the left compares a single shooter in the center lane (lane 7), at the 7m line, firing one round on a 5.56 rifle. The right hand trace compares the spectrum at a period of time defined by the black line in the time series. It is at .565 seconds from the initial impulse. One can see on the untreated rang (top trace in both windows) that the total power at this time is 123.67 SPL rms while the treated power 104.32 SPL. It can be seen in the time series that the Troy treated range has almost fully decayed and the untreated range does not fully decay until three-seconds from the initial impulse.

Figure 9



Troy Acoustics' Commitment to Excellence

- Integrity and professionalism in all that we do – adhere to the rules and standards of our industry
- Be innovative – advance the art and science of noise measurement and acoustic treatment
- Provide our customers with the highest performance for the best value
- Be proud of our accomplishments and stand behind our work
- Protect And Serve Those Who Protect and Serve Us All

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Experience and Qualifications

As per 2.4.6 experience and qualifications of personnel performing the test and analyzing the results.

Stephen Katz

The testing was designed and facilitated, and this report was written by Stephen Katz, Vice President Applied Research & Technology, Troy Acoustics. Mr. Katz's experience and qualifications include:

Director, Applied Research and Technology, Troy Acoustics

...Won an Academy Award for the co-development of Dolby Stereo. He has over thirty feature film credits including, *Star Wars*, *Close Encounters of the Third Kind*, and *Altered States*.

...He was a recording engineer for Jimi Hendrix, Chuck Berry, Ike and Tina Turner, Barry Manilow, the St. Louis Symphony, etc.

...Designed and built recording studios for Dolly Parton and Porter Wagner, Pete Drake, the original Cherokee Ranch (Steely Dan, *ajá*), Tom T. Hall, Sea Saint Recording (Allen Toussaint), Grand Funk Railroad, etc.

...Founding partner Eventide Electronics, one of the first manufacturers of professional digital audio equipment including digital delay lines, auto-locators, and pitch changers. Eventides' first project was to design a 2.5 second digital delay line for NASA to be used for astronaut training in preparation for the first moon landing.

Mr. Katz is the Director of the Center for Entertainment Industry Data and Research (CEIDR).

Has authored, been featured, and published reports, papers and articles. His research has been covered by CNN, The New York Times, NPR, The Wall Street Journal to name a few. Mr. Katz was invited by the Harvard Club to debate a former Prime Minister of Canada.

Member: Acoustical Society of America (ASA), Audio Engineering Society (AES), Society of Motion Picture and Television Engineers (SMPTE)

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William (Bill) Bergiadis

Supervising the testing was William (Bill) Bergiadis, Chief Executive Officer Troy Acoustics:

- Inventor and patent holder of the Troy System™ sound wall design
- Has provided acoustical consulting and design/engineering services for: City of Los Angeles, LAPD, NYPD, Santa Monica Police Department, City of Pasadena, Pasadena, Police Department, Chula Vista Police Department, FBI, NASA Ames, US Navy, WPAFB, US, Secret Service, Lawrence Livermore National Laboratory, Lawrence Berkeley Nation, City of Manhattan Beach Fire Department, the City of West Hollywood, City of Thousand Oaks and many various private Fortune 500 Companies.
- Established more sophisticated criteria for shooting range acoustic performance

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This report is respectively submitted by Stephen Katz and Bill Bergiadis.

Bill Bergiadis, CEO Troy Acoustics Corporation

Steve Katz, Vice President Applied Research and Technology

Date

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