U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND

Suppressor Session
20 OCT 2021

Adam M. Jacob

Project Management Engineer

Joint Service Small Arms Program

JS3 IPT

Harmonize Signature Suppression Community

- Test methods and standards
- Service-specific requirements
- S&T efforts
- Data sharing – past and current

Collaborate Across the Joint Services

- Joint S&T requirement development
- Joint S&T project execution
- Collaboration on suppressor efforts across Services

Engage with Industry, Academia, International

- Annual Suppressor Summit
- Participation in NATO WGs
- Site visits
- Participation in conferences and shows
- DOTC, SBIR, etc.

GOAL / VISION

To delivery capability to the Warfighter by collaboratively and efficiently developing **advanced signature suppression technologies, measurement methods,** and **fundamental understanding** of scientific phenomenon behind small arms signature.

AGENDA

Time	Title	Briefer(s)
1305-1315	**STANREC 4785 Suppressor Test Methods**	Dr. Les Flemming (NSWC Crane) and Mr. Adam Jacob (JSSAP)
1315-1325	**Modular Suppressor Test Bed Design of Experiments**	Mr. Dan Cler (DEVCOM AC)
1325-1335	**Suppressor Cleaning**	Mr. Zachary Torigian (DEVCOM AC)
1335-1345	**Intermediate Caliber Virtual-Baffle Suppressor System**	Dr. Phillip Burnside (NSWC Crane)
1345-1355	**Surefire's Advanced Suppressor Program – Blending Experience with Technology to Bring Next Generation Signature Suppression Technology to the Warfighter**	Mr. Barry Dueck (Surefire)
1355-1405	**7.62mm Belt-Fed Suppressor**	Mr. Phillip Haag (Radical Firearms/Radical Defense)
1405-1415	**Maxim Defense M240 Suppressor**	Mr. David Steinbach (Maxim Defense)

U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND
ARMAMENTS CENTER

Modular Suppressor Test Bed Design of Experiments

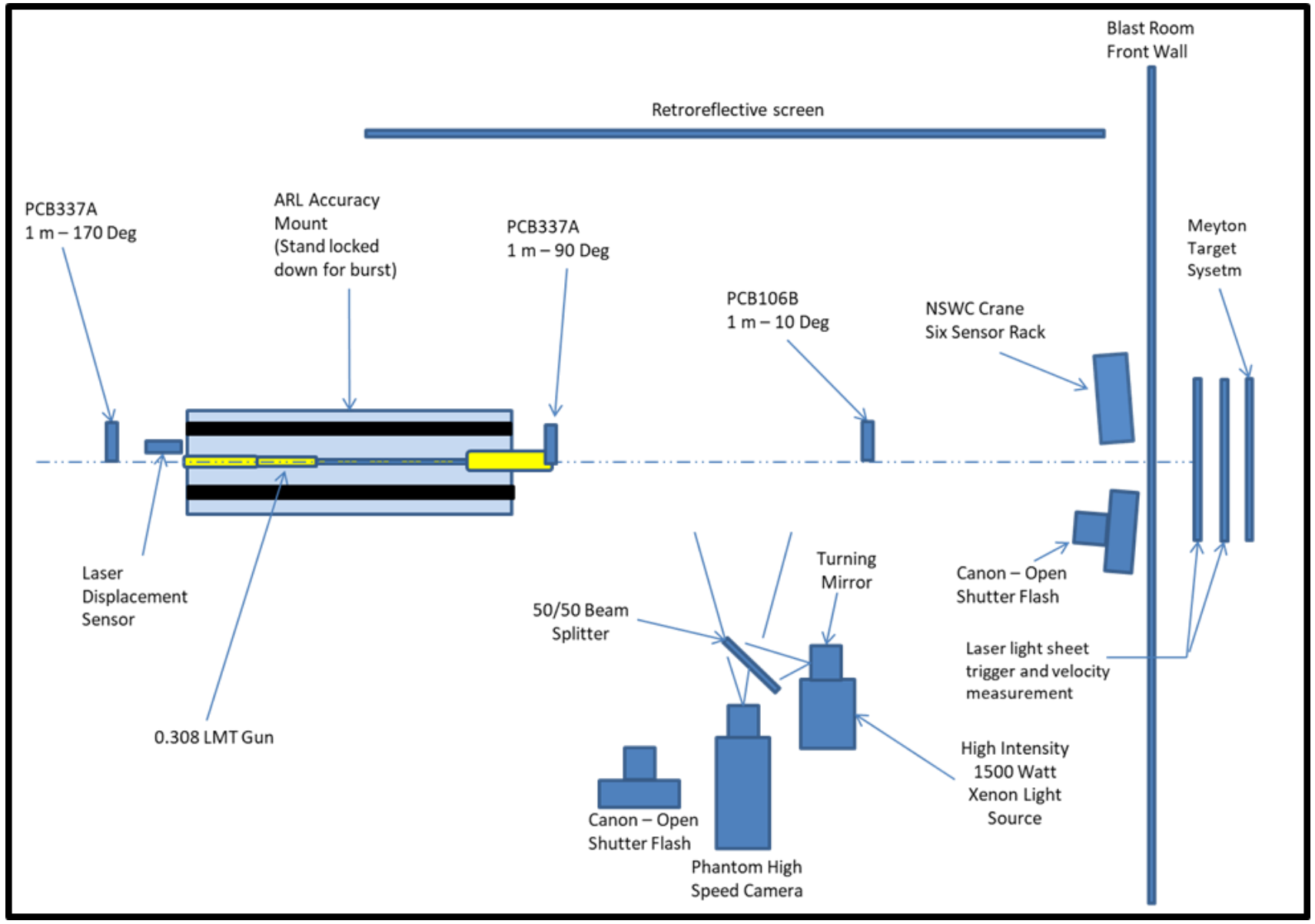
2021 Future Force Capability Conference and Expo, Columbus, GA

Daniel L. Cler, Gregory Oberlin, Eric Binter & Timothy C. Cler

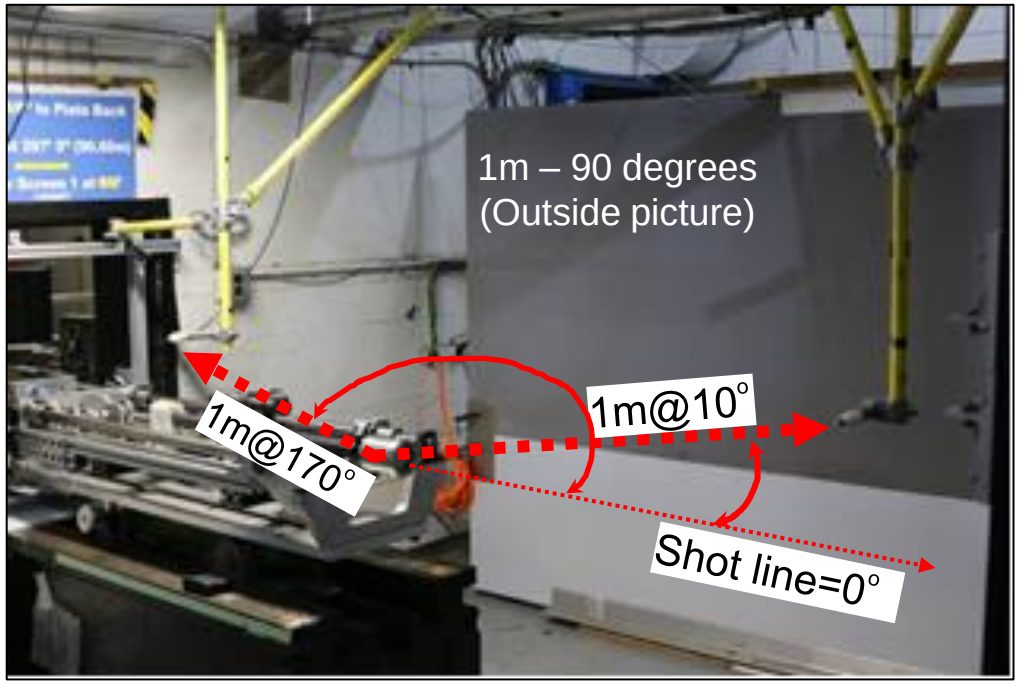
DEVCOM – Armaments Center / DEVCOM – Army Research Lab

18-21 October 2021

TEST SETUP LAYOUT



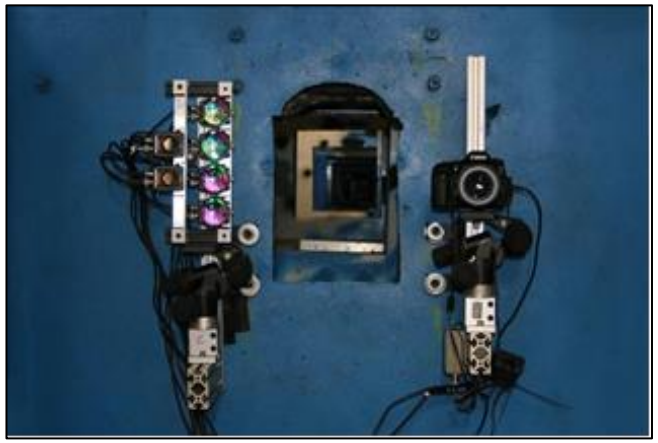
TEST SETUP EQUIPMENT



Sound Gage Layout

Shadowgraph Light Source (L) and Camera (R)

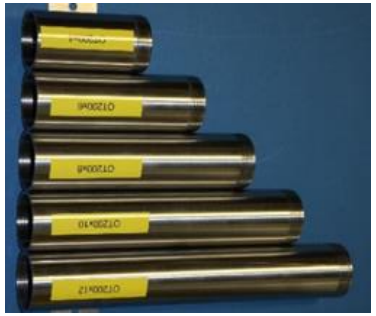
Recoil Mount



Downrange Flash Detectors (L) and Camera (R)

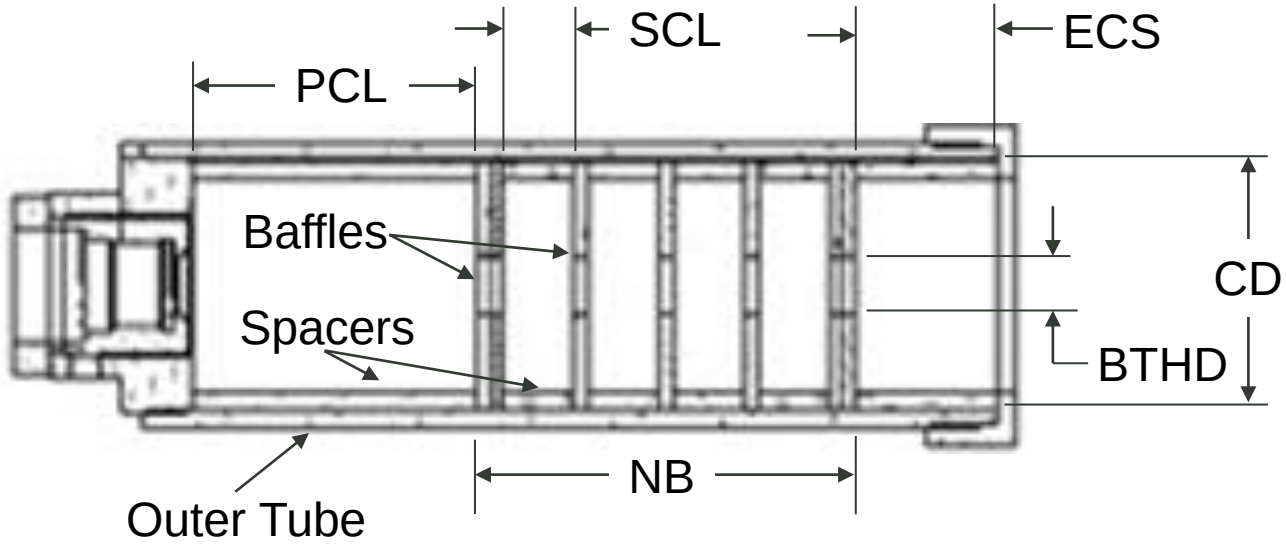
MODULAR SUPPRESSOR TESTBED (MST)

Outer Tubes



Spacers

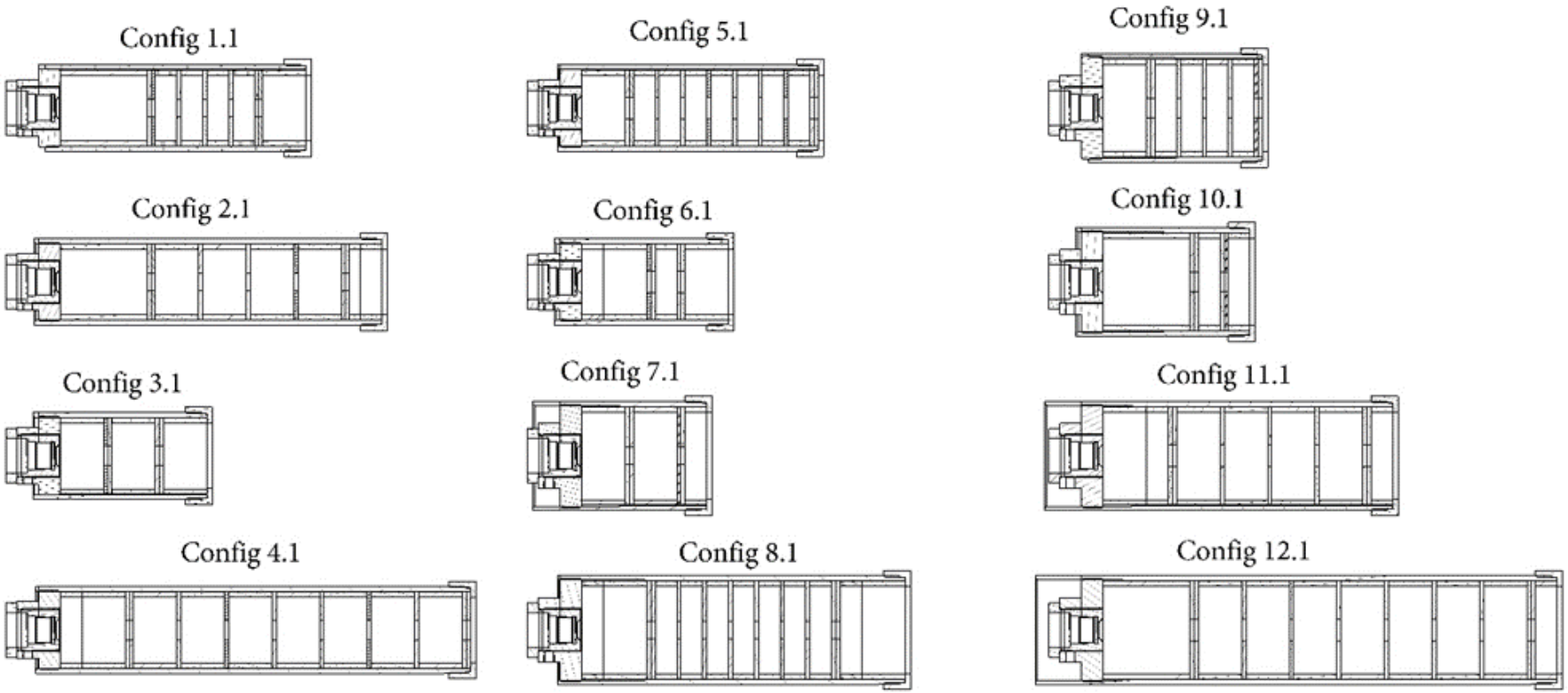
Baffles



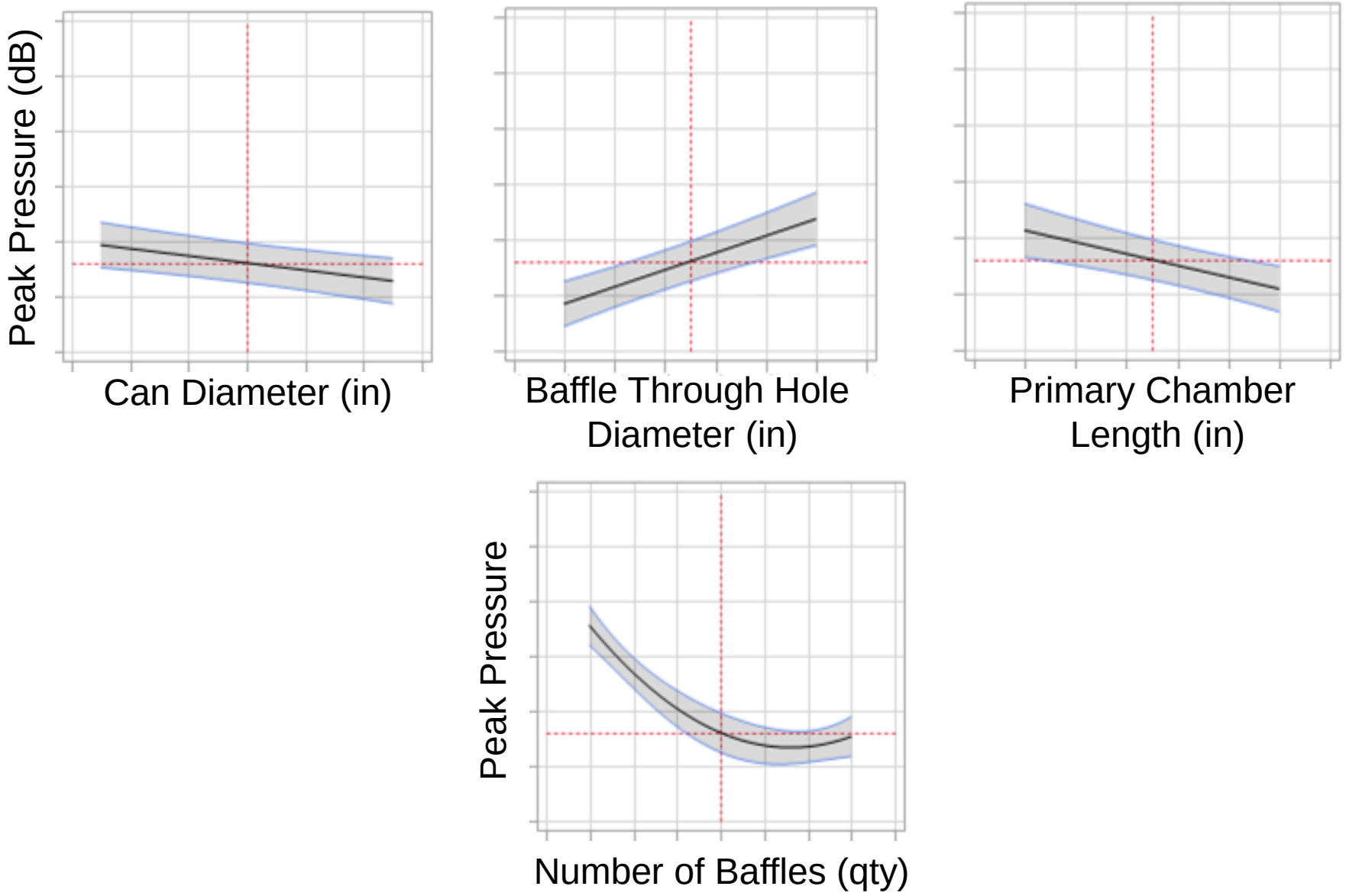
PCL = Primary Chamber Length
SCL = Secondary Chamber Length
ECS = End Cap Spacer Length
BTHD = Baffle Through Hole Diameter
CD = Can Diameter
NB = Number of Baffles

DOE SUPPRESSOR CONFIGURATIONS

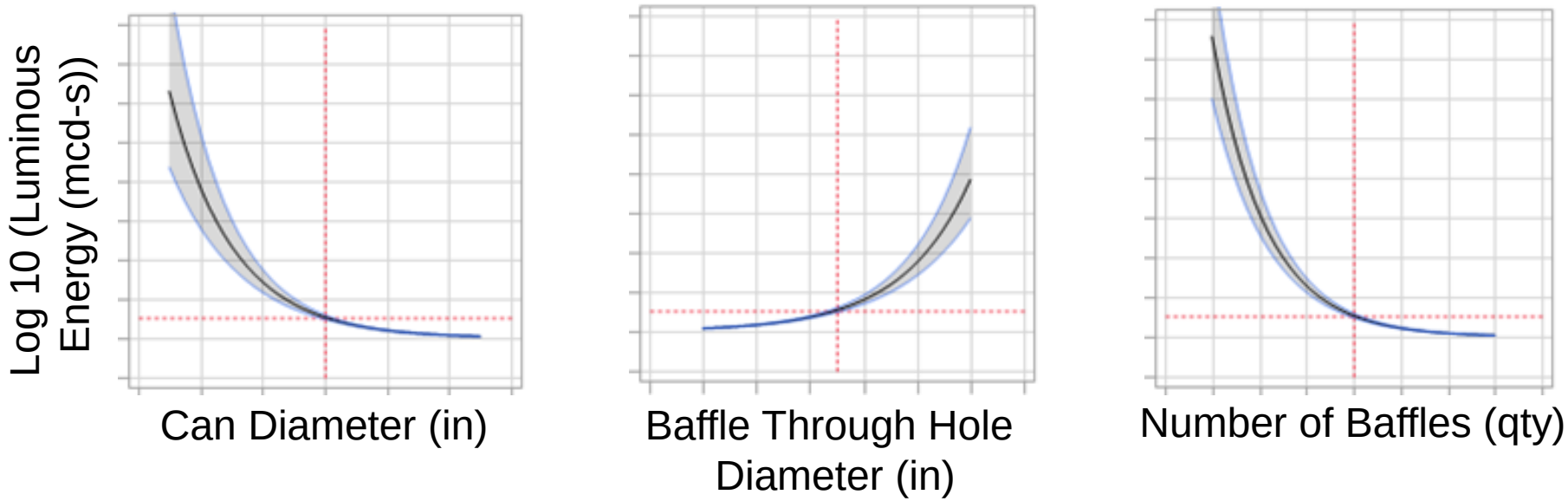
Twelve Design of Experiments (DOE) modular suppressor configurations selected based on D-Optimality criteria for fit of a 2nd order least squares fit model with a maximum of 9-10 terms in the model.

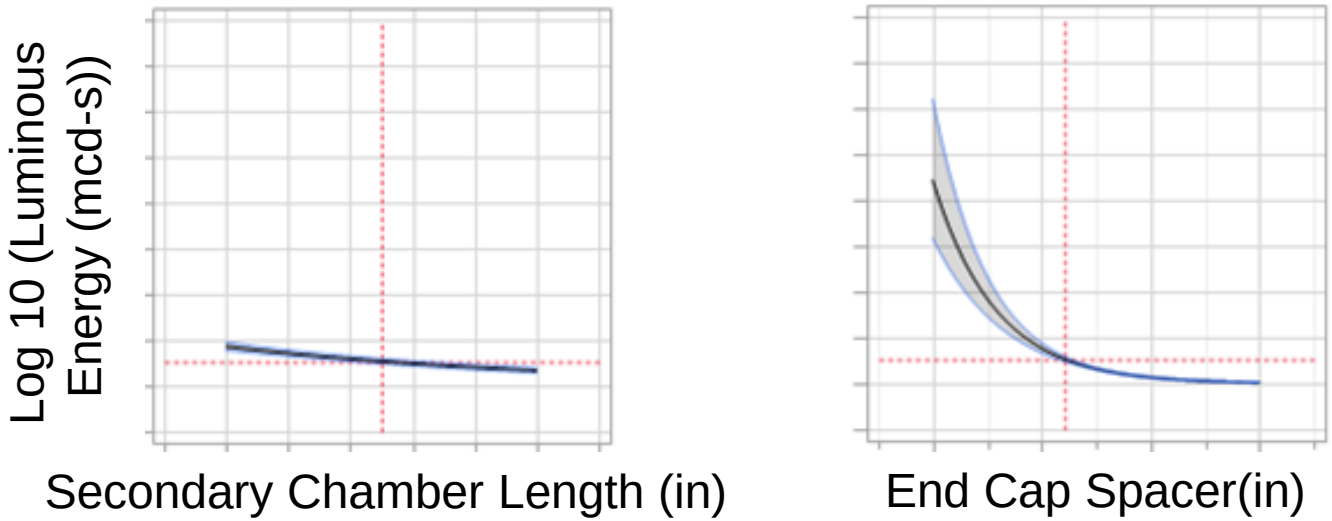


LEAST SQUARES FIT OF DOE RESULTS
PRESSURE @ 1M-170 DEG VS DOE DESIGN PARAMETERS



LEAST SQUARES FIT OF DOE RESULTS
LUMINOUS ENERGY VS DOE DESIGN PARAMETERS



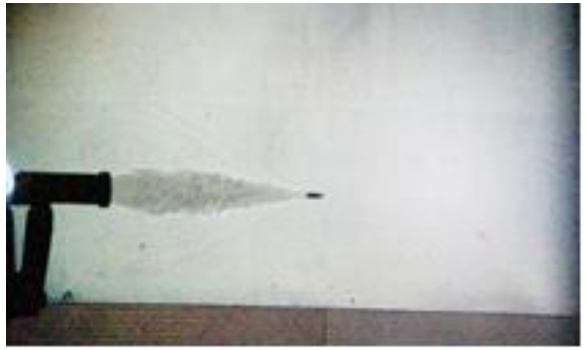


SHADOWGRAPH – CONFIG 1.1

T=0 μs

T=200 μs

T=400 μs



T=600 μs

T=800 μs

T=1000 μs

CONCLUSIONS

- The Modular Suppressor Testbed (MST):
  - Utilizes 6 unique design variables
  - Provides an endless amount of different configurations for testing
  - Can verify simulated performances by testing simple suppressor geometries

- The MST was used to create high quality least squares fit models of sound, flash and impulse responses across a limited design space using only twelve suppressor configurations.

- The least squares fit models can be used to design suppressors and optimize performance with simple least square fit models.

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SUPPRESSOR CLEANING STUDY

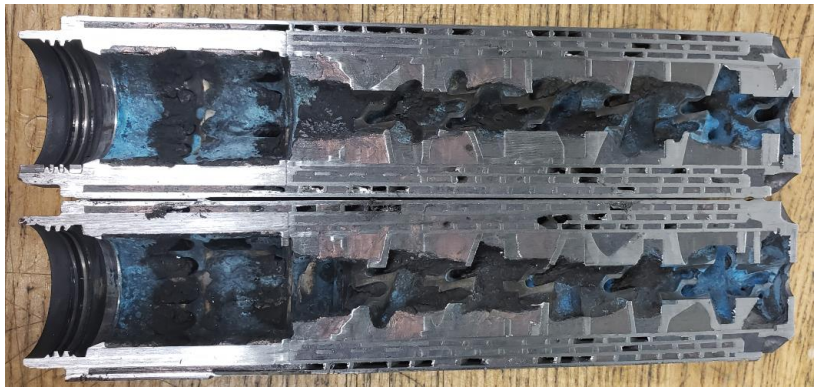
Project Problem / Background

- Built up fouling deposits are decreasing performance and causing premature replacement of suppressors.
- No current process / procedure is established to effectively clean suppressors and restore performance.

The accumulation of fouling in the form of carbon, copper and lead results in:

- Significant Weight Increase
- Degradation of Sound Reduction
- Degradation of Flash Suppression
- Degradation in Dispersion/ Point of Impact Shift
- Difficulty of install/ removal
- Misalignment promoting Baffle Strikes
- Increased exposer to Toxic Vapor

M110 Suppressor



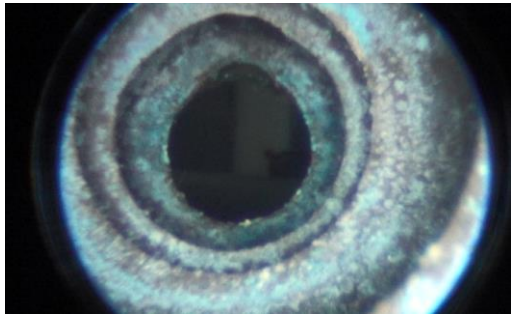
Fouled M110 Suppressor Cross Section

SUPPRESSOR CLEANING STUDY

Project Problem / Background Cont.

- Current cleaning efforts (Brushes, soaking, ultrasonic bath) prove to be costly, time consuming and ultimately ineffective due to the variety and complexity of modern sealed suppressors

- These factors have caused the DOD to prematurely classify suppressors as unserviceable, costing the US Government $$.
- Suppressors are expensive and often times are equally or more expensive than the weapon they are mounted too.



US ARMY SUPPRESSOR PREVALENCE

Next Generation Squad Weapon (NGSW) Suppressed Weapons

The NGSW is still under competition

M2010 ESR

M110 SASS

M110A1 CSASS

SUPPRESSOR CLEANING STUDY

Objective:

Research, develop and test processes to remove the buildup of carbon and metal oxides that are deposited on internal suppressor surfaces. Analyze commercially available systems to enhance development and knowledge in search of a field-able solution that will efficiently clean a wide variety of suppressors to maintain peak capabilities and maximize service life.

Warfighter Benefits / Operational Payoff:

- Eliminates Premature Replacement = Saves $$
- Extends Service Life of Suppressor
- Maintains Peak Capabilities and Performance
- Decreased weight on end of muzzle
- Maintainable signature reduction
- Decrease exposure to Toxic vapors

Need for Solution:

- Demand for a cleaning procedure will increase as suppressed weapons become more prevalent. Ex. (Army, Marine Corp, Special Ops, etc.)

Project Manager Soldier Lethality (PM SL) Innovative Designs & Engineering Assessment (IDEA) Program

BLUF: PM SL, is seeking information on new, innovative, enabling technologies that can generate new capabilities or provide enhanced capabilities to the Army's portfolio of small and medium caliber weapons, optics, binoculars, remote weapons stations, suppressors, powered rails, barrel life enhancements, externally powered systems, recoilless rifles, Next Generation Squad Weapons (NGSW) weapons, fire control, and ammunition.

The IDEA program is:

- An opportunity for Industry to submit innovative ideas and technologies for the USG to assess. Assessments may be conducted at vendor or government facilities.
- A one-on-one pitch to the USG showcasing their technology for a potential for non-competitive award under 10 U.S.C, § 2373 - Procurement for Experimental Purposes.
- Renewable on a quarterly basis.

The IDEA program is <u>NOT</u>:

- Intended to be a developmental program
- A USG in-house proposal
- A competitive contract

https://sam.gov/opp/ced1e1c4bcbc4e329b781c66cbd74d3e/view

PMSL will leverage enabling IDEA technologies to quickly provide Soldier capabilities and enhancements.

COMMERCIAL MACHINES

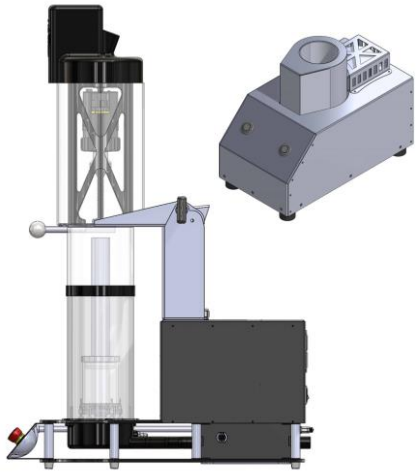
1. OTIS Technology - OSCR (Otis Suppressor Cleaner and Reclaimer)

OSCR-6

The cleaner operates by circulating a proprietary cleaning solution through the suppressor at a high temperature and pressure. Available as a single or six suppressor machine

The OSCR, according to OTIS, consistently removes up to 95% of fouling buildup.

2. TDA Research – Sealed Suppressor Cleaner and Drier



TDA SSC&D

The dual system utilizes an ultrasonic horn that enters inside the suppressor to mechanically break up and release carbon and metal fouling and then dries the suppressor. Currently a single suppressor machine with a six suppressor attachment.

According to TDA, the system will cut accumulation rate by a third, reduce premature failures, ‘carbon welding’ and baffle strikes, improving service life.

Development was funded by the USMC SBIR program (M67854-18-C-6514).

OTIS TECHNOLOGIES

OTIS TECHNOLOGY

OSCR | OSCR-6 OSCR-1

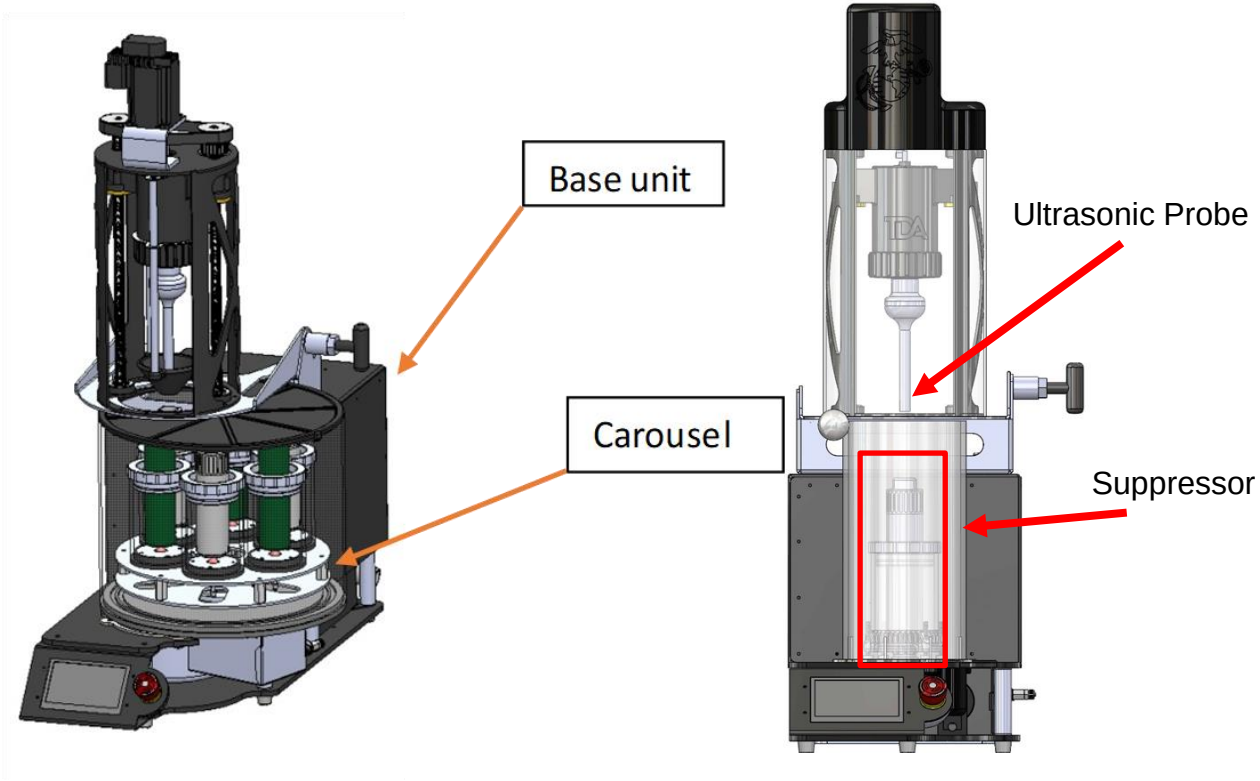
OTIS SUPPRESSOR CLEANER AND RECLAIMER

The OSCR is available in large unit that will clean 6 suppressors simultaneously, and a single, table top, unit that can clean one suppressor at a time.

Primary Cleaning Method:

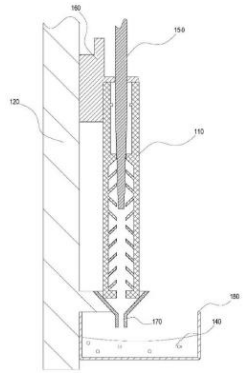
- Circulation of High Temperature and High Pressure proprietary cleaning solution.
- Suppressors are directly threaded onto cleaning nozzles.

TDA RESEARCH

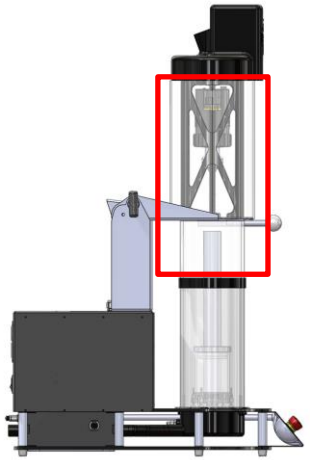


Primary Cleaning Method:

- Ultrasonic probe that utilized high frequency pressure (sound) waves to agitate liquid and create cavitation bubbles to mechanically remove “scrub” contaminates.
- Proprietary cleaning solution primarily consisting of water. This prevents solubilizing of deposited metals leading to hazardous waste (Cu and Pb Oxides)
- Corrosion inhibitors prevent oxidation



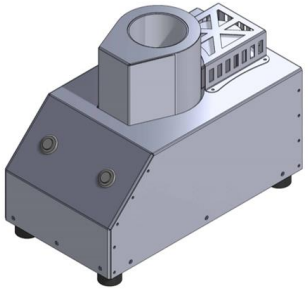
TDA RESEARCH ADDITIONAL COMPONENTS



Height Extension:

- Allows up to a 14” Suppressor

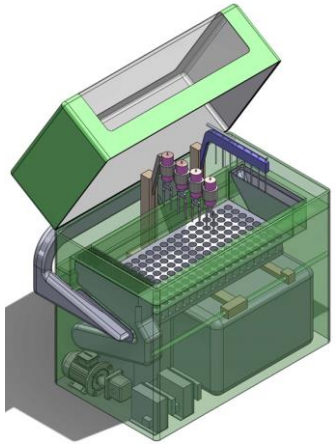
Dryer:



Features:

- Recirculating air flow means external contact surfaces are always cool to the touch
- Automated heat up and cool down cycle times
- Hot air temperature up to ~500°F during dry out portion
- Suppressor emerges dry and cool to the touch within 10 minutes of cycle start (suppressor is ~100°F when complete)

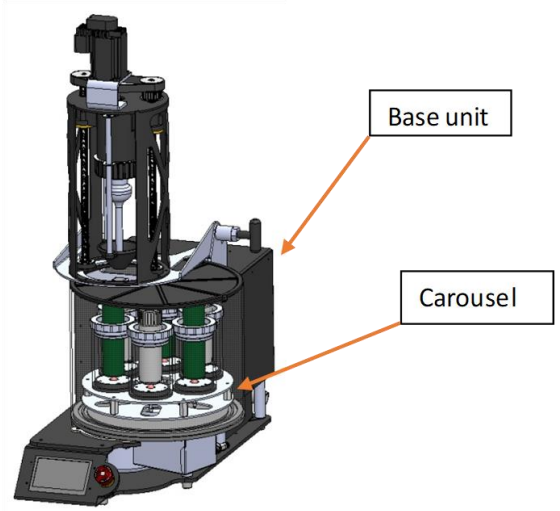
Unit Level Cleaner Concept:



Features:

- Larger floor based unit can clean up to 144 suppressors in a single run
- Integrated wash, rinse and drying cycles within the same unit
- Multiple ultrasonic tips can clean a full row of suppressor at one time (up to 8 per row)
- Self contained and sealed unit prevents contamination from exiting the unit
- Automated robotic arms used to wash and rinse all suppressors
- Wash basin automatically drained and then dried with integrated resistive blower

Multi-Suppressor Cleaner Attachment :



Features:

- Completely encapsulated cleaning cylinder prevents splash out and cuts down on noise from cleaning process
- 2 Quick connects to enable the accessory (1 fill line and power to the motor drive)
- 6 cylinder automated rotating drive to clean 6 suppressors without swapping
- Swap out of the accessory only requires 4 bolts on the main platform
- Alignment of each cylinder is automated with a lever switch within the motor housing
- Cylinders can be adapted with different size holders to clean various suppressor in the same run

Patents Pending

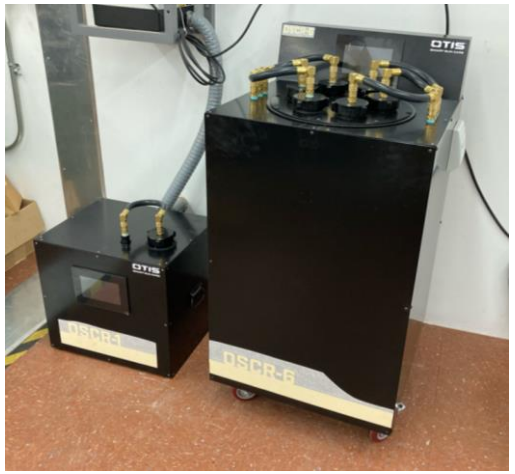
PERFORMANCE EVALUATION

An engineering evaluation will be conducted on each machine. 12 suppressors with identical round counts and firing cadence will be cleaned to determine system performance.

The machines will be utilized for specialized testing/ modifications for further data collection and suggested improvements.

Additional suppressor cleaning experiments will aid in determining the most efficient, and cost effective method of cleaning.

Fired vs Cleaned Suppressor TDA



Suppressor Cleaning Machines

The machines will be tested for durability and simulated operational use to obtain further data while supporting other programs such as NGSW.

Data obtained will reflect machines reliability and performance under repeated use.

Fired, unfired weights, makes, models, caliber etc. will be logged for each suppressor cleaned.

SUMMARY

Maintenance is a critical aspect to preservation of a well performing weapon system. The US Military is rapidly incorporating suppressors to increase operational capabilities. An effective and efficient suppressor cleaning method will benefit the war fighter and the DoD as a whole.

Should cleaning suppressors prove to reduce cost over replacing, the Army would pursue a cleaning strategy through full and open competition.

Suppressed Carbine

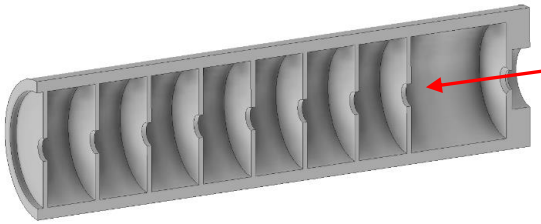
NSWC Crane Division – Suppressor D.O.E.

Presented by: Phillip Burnside, PhD

NAVSEA
WARFARE CENTERS
CRANE

Simple Compressor D.O.E.

Simple Suppressor from ARL



Taking Black Art to Science

- Currently suppressors are designed using the trial and error process
- With the development of the ALE3D4i Computational Fluid Dynamics (CFD) by Lawrence Livermore National Labs, a new and validated tool can be used to simulate the affects of firing a round through a suppressor which allows multiple designs to be evaluated each day
- We can now use applied science to optimize a suppressor based on predicted performance for the given weapon system

Design of Experiments: Simple Suppressor

Inputs

- Can diameter
- Primary chamber length
- Secondary chamber length
- Number of chambers
- Baffle hole size

Key Performance Parameters

- Gas temperature in front of suppressor
- Pressure at bolt
- Sound
- Gas temperature inside the suppressor

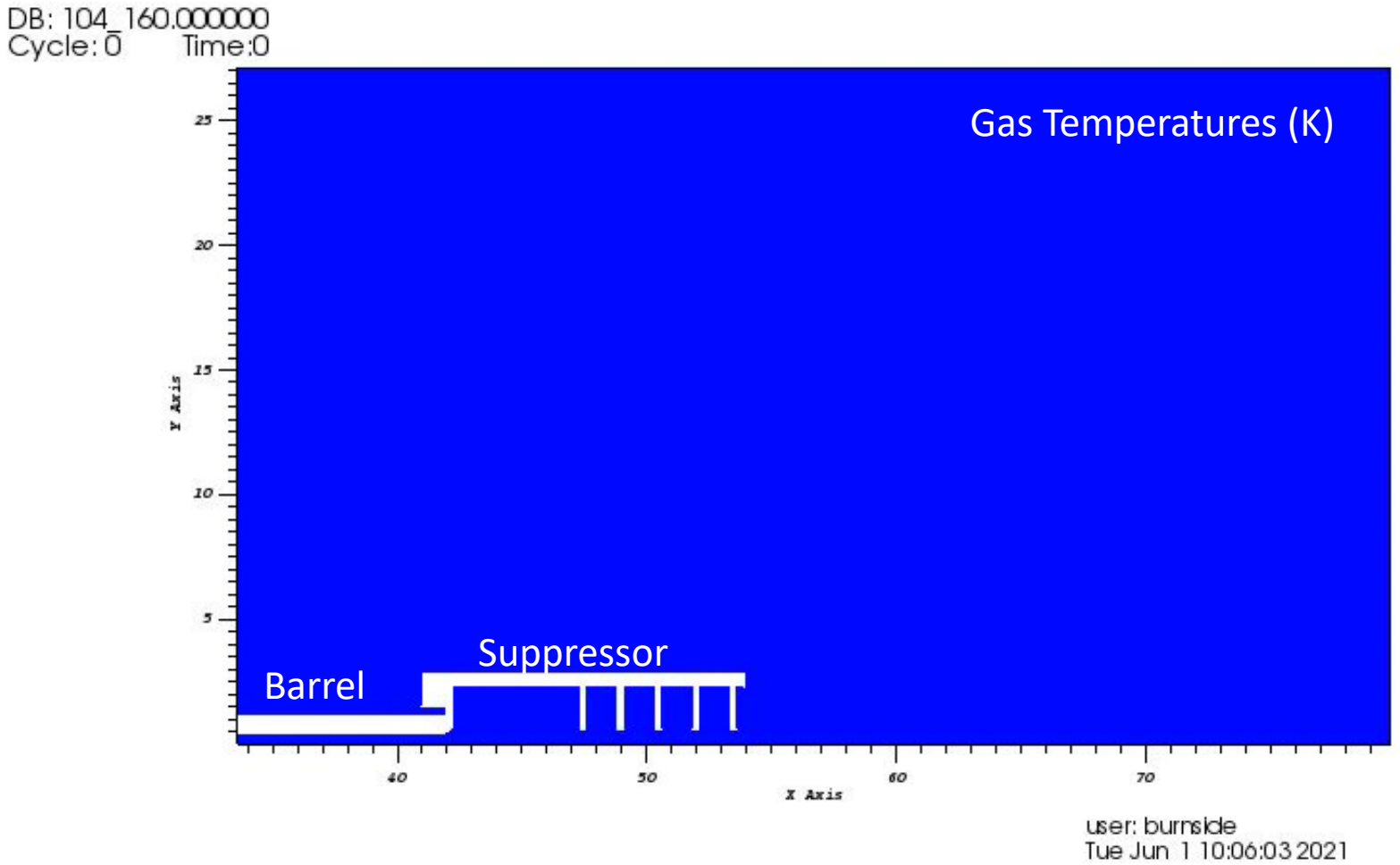
case	Can Diameter (in)	Baffle Hole Diameter (in)	Primary Chamber Length (in)	Number of Baffles	Secondary Chamber Length (in)	Overall Length (in)	Microphone Position in X (cm)	Inside Suppressor Supy2 (cm)
Baseline								
1	1.75	0.35	1	2	0.5	1.800	3.62	1.60
2	1.75	0.35	1	5	0.5	3.300	7.43	1.60
3	1.75	0.35	1	8	0.5	4.800	11.24	1.60
4	1.75	0.35	1	2	1	2.300	4.89	1.60
5	1.75	0.35	1	5	1	5.300	12.51	1.60
6	1.75	0.35	1	8	1	8.300	20.13	1.60
7	1.75	0.4	1	2	0.5	1.800	3.62	1.60
8	1.75	0.4	1	5	0.5	3.300	7.43	1.60
⋮								
161	2.75	0.45	2	5	1	6.300	15.05	2.87
162	2.75	0.45	2	8	1	9.300	22.67	2.87

Requirements for an MK48 Suppressor

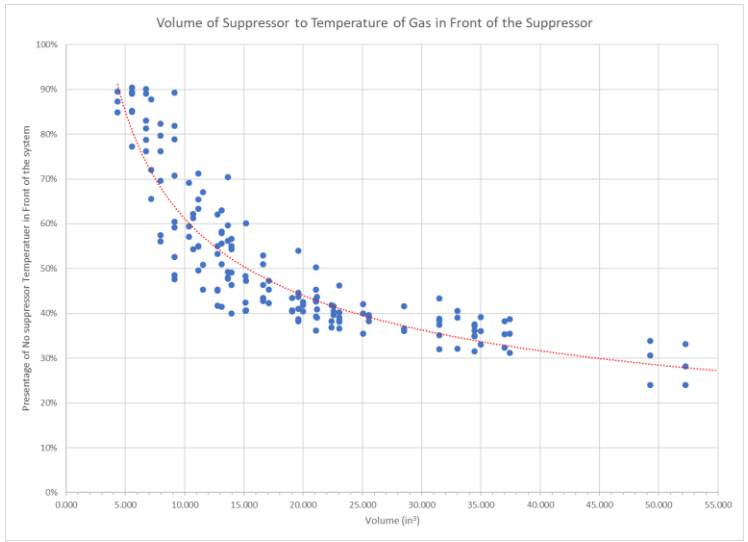
Key Performance Parameters in order of importance to the warfighter:

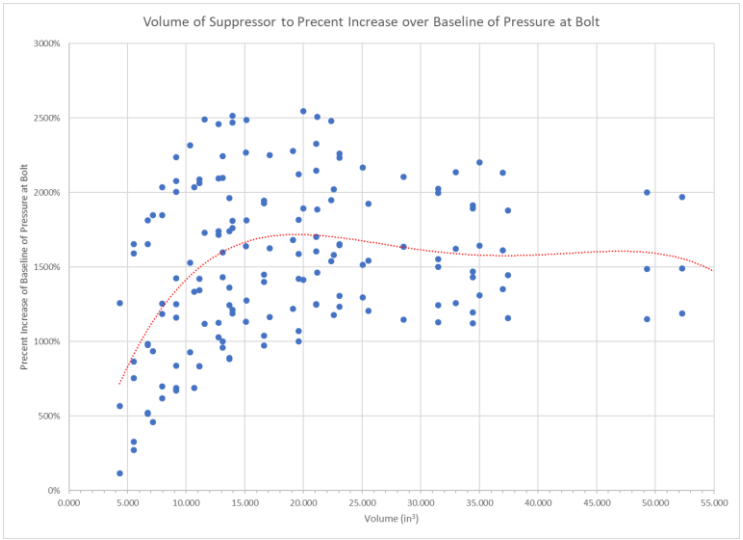
1. Flash in front of suppressor
2. Blow-back at bolt on opening
3. Sound level at one meter to side of weapon

Example of Design of Experiments Simulation



Design of Experiments Results

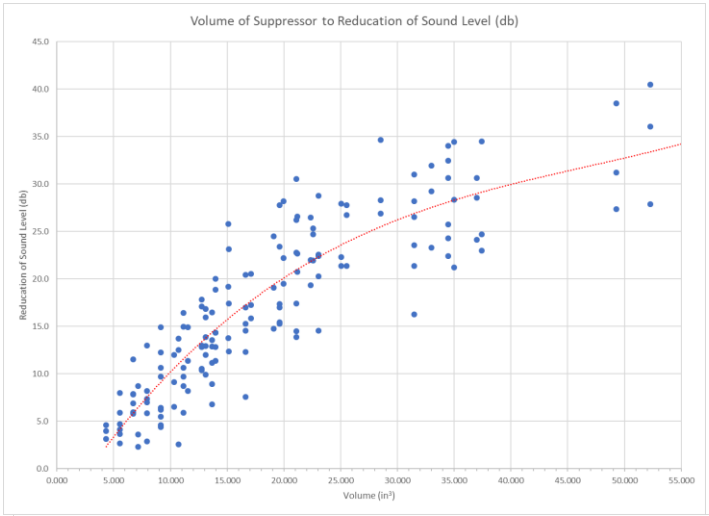


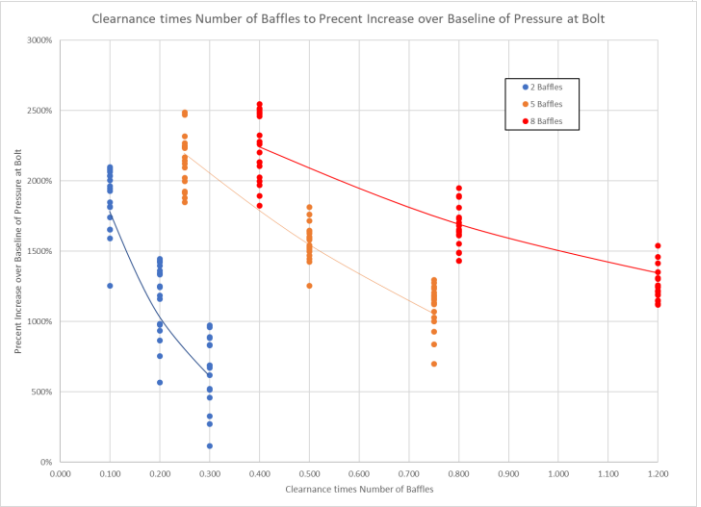


- Utilizing temperature in front of the suppressor allows comparison of flash vs the volume:
  - the relationship is nonlinear; and
  - the relationship is also significantly affected by other features of the suppressor.
- The relationship with volume to back pressure at the bolt also has these same two factors.

Design of Experiments Results

- The relationship of volume to peak sound also exhibits a nonlinear relationship.
- The data can be sliced many different ways, but the relationships between the various features of the suppressor are always interacting in a nonlinear manner.
- This means optimization is based on a ranked set of Key Performance Parameters (KPP)



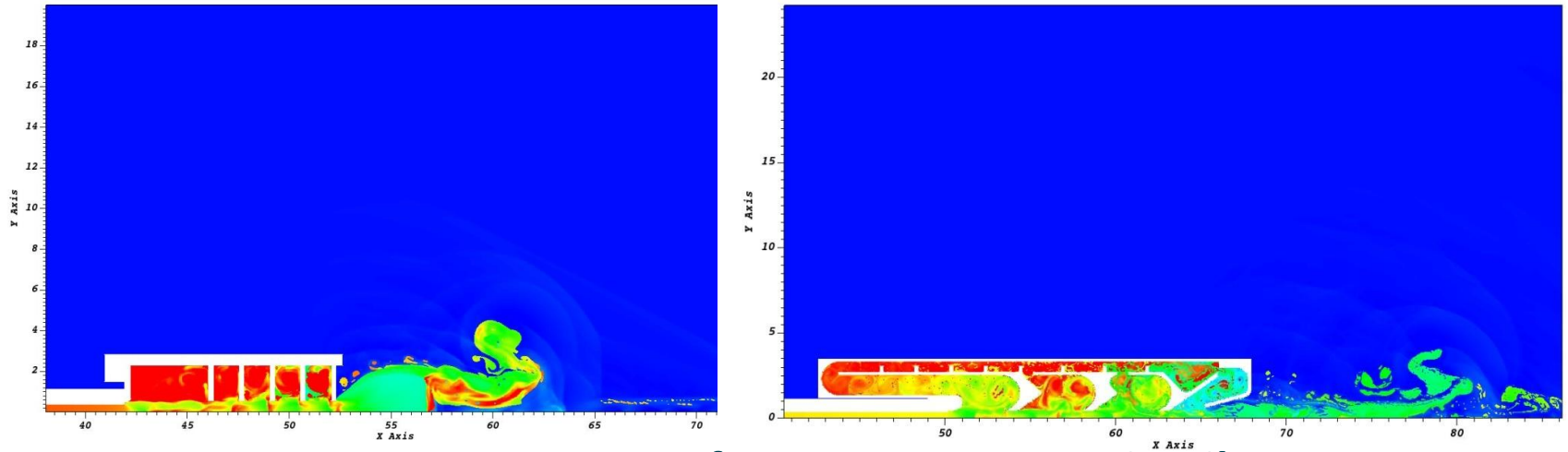


Comparison of Suppressors

- CFD ALE3D4I code was used to test concepts to come to an optimized design.
- By looking at small changes, a new, more efficient NSWC Crane design was developed.

Simple Design

Crane Optimized Design



Gas Temperature from a 7.62mm Projectile

Results Summary

	Priority 1	Priority 2	Priority 3
CASE	**Percent of Peak Mean Temperature in Front of Suppressor (F)**	**Percent Increase over Baseline of Pressure at Bolt**	**Reduction of the Peak DB Sound @ 1m**
Baseline	**N/A**	**N/A**	**N/A**
Simple Case 12 (tested)	**39%**	**1156%**	**15.2**
LLNL Bypass Design	**30%**	**418%**	**18.7**
Crane Optimized Design	**19%**	**54%**	**31.0**

Lower value = reduced gas temperature and thereby reduce flash

Lower value = minimize blow-back

Higher value = more reduction in the sound level

RADICAL DEFENSE
MODERN DEFENSE SOLUTIONS

ISO 9001:2015 Compliant Company
CAGE: 8RC72 DUNS: 043893696

M240 fvs machine gun suppressor

Approved for
Public Release

NDIA

RADICAL DEFENSE
MODERN DEFENSE SOLUTIONS
ISO 9001:2015 Compliant Company
CAGE: 8RC72 DUNS: 043893696

Background

- Stated need for a suppressor to handle sustained fire on belt fed machine gun
- Largest challenges are controlling heat and back pressure
- Utilized technology developed during SURG program (Suppressed Upper Receiver Group)
- Applied knowledge of superalloy use in firearms
- Employed additive manufacturing for non-traditional geometries and structural integrity

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CAGE: 8RC72 DUNS: 043893696

Your Current Problems

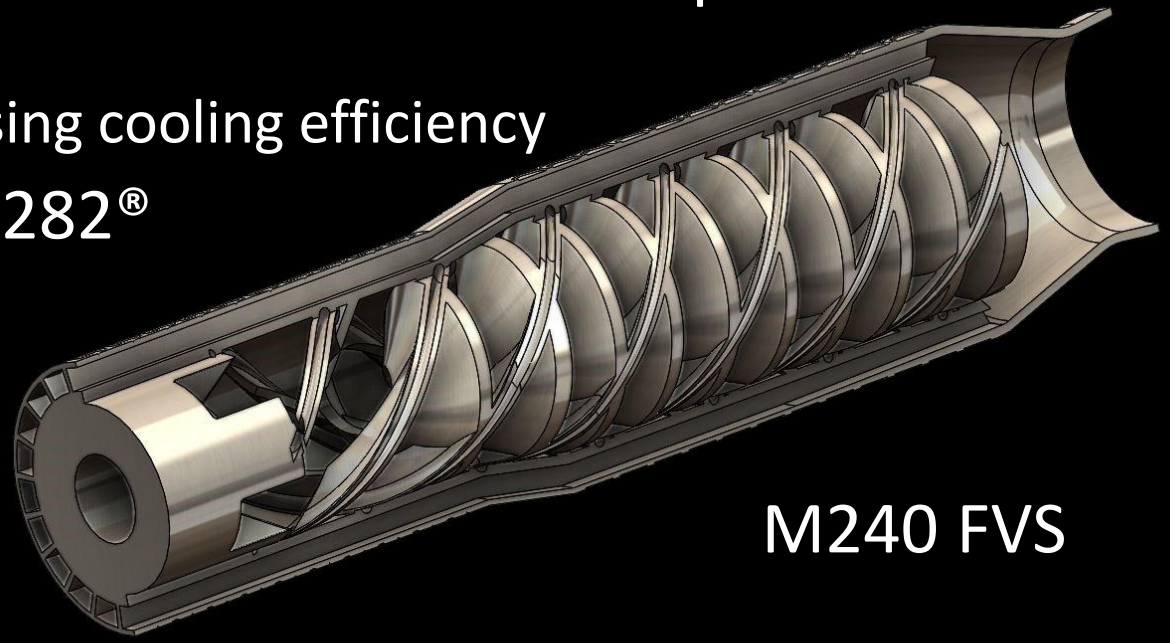
- Suppressors overheat to the point of catastrophic failure
- Use of common commercial materials such as titanium, 17-4, cobalt, or Inconel, are not durable enough for the subjected environment
- Use of standard manufacturing and assembly, such as welding and threading or press fitting, creates structural weak points
- High temperatures for long durations increase signature and interfere with Thermal/IR optics functionality
- Backpressure created by common suppressor designs causes cyclic rate issues and increases MRBS (Mean Rounds Between Stoppages)

NDIA

RADICAL DEFENSE
MODERN DEFENSE SOLUTIONS
ISO 9001:2015 Compliant Company
CAGE: 8RC72 DUNS: 043893696

The Radical Solution

- Venturi-based cooling
- Heat sink cooling channels
- Backpressure reduction from Venturi assist nozzles and spiral baffle design
  - Reduces backpressure while increasing cooling efficiency
- Nickel based super alloy - Haynes 282®
- 3D-printed monolithic structure
- Alpha-shield Elite coating
  - Reduces Thermal and IR signatures
  - Withstands extreme temperatures



M240 FVS

Approved for
Public Release

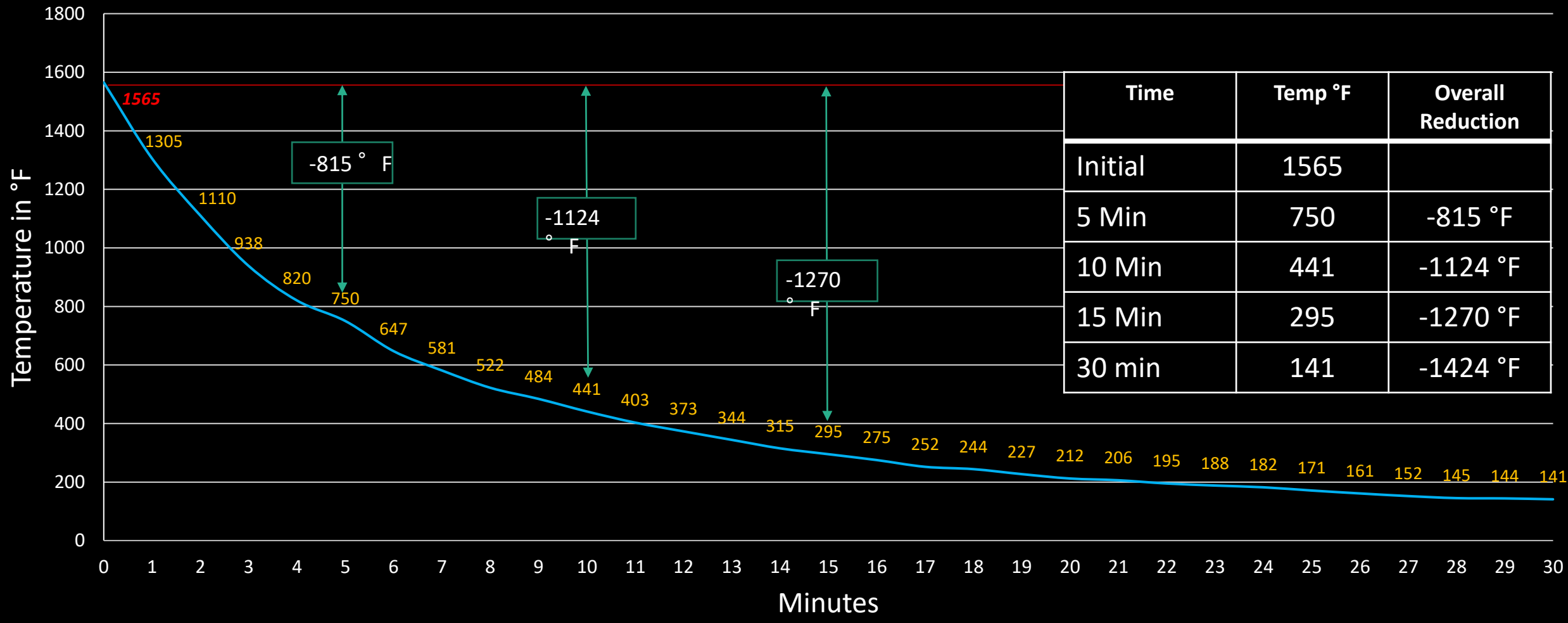
NDIA

Approved for Public Release

Technical Data

RADICAL DEFENSE
MODERN DEFENSE SOLUTIONS
ISO 9001:2015 Compliant Company
CAGE: 8RC72 DUNS: 043893696

Thermal Test Data 240 FVS
Post 600rd "Mad Minute"



Time	Temp °F	Overall Reduction
Initial	1565	
5 Min	750	-815 °F
10 Min	441	-1124 °F
15 Min	295	-1270 °F
30 min	141	-1424 °F

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Points of Performance

- Rapid cooling
- Reduces 28 dB over an unsuppressed weapon
- Coating does not degrade under extreme heat
- Decreases ground signature disturbance
- Improves accuracy
- Moderates flash
- Monolithic super structure does not deform under heavy rates of fire
- Mitigates Thermal/IR signature
- Controls negative effect of backpressure

Contact Information

- Available in 5.56x45 mm for M249 SAW and.338 Norma Magnum for LMMG
- POC: Phillip Haag, Dir. Research & Development

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