PFM DEVICES
THE SOUND OF SCIENCE ™

# Assessing Suppressor Performance Using Auditory Risk Units (ARUs)

NDIA Future Force Capabilities Conference
Fort Worth, TX
30 Sept-3 Oct 2025

448 W. 19th St, #210
Houston, TX 77008
keith.clutter@pfmdevices.com
800.953.2616

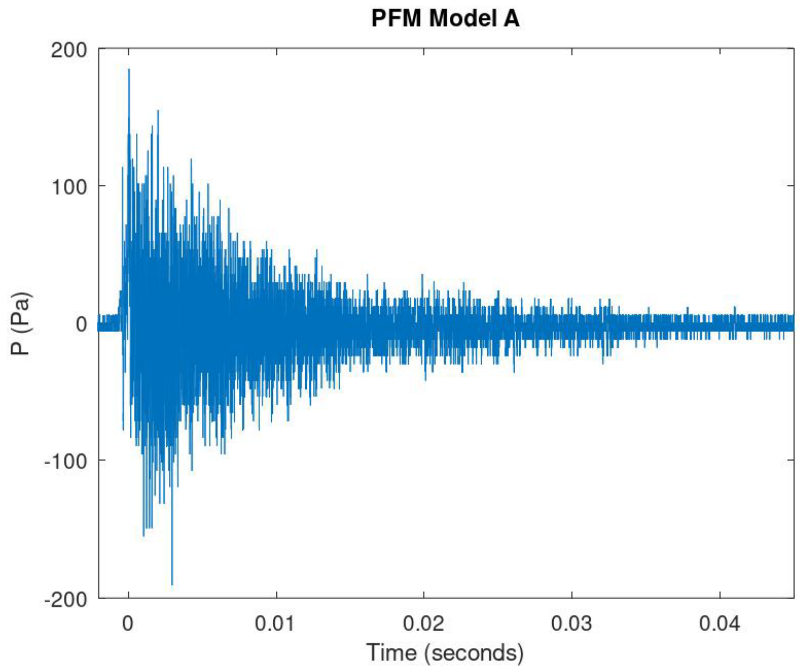
APPROVED FOR PUBLIC RELEASE

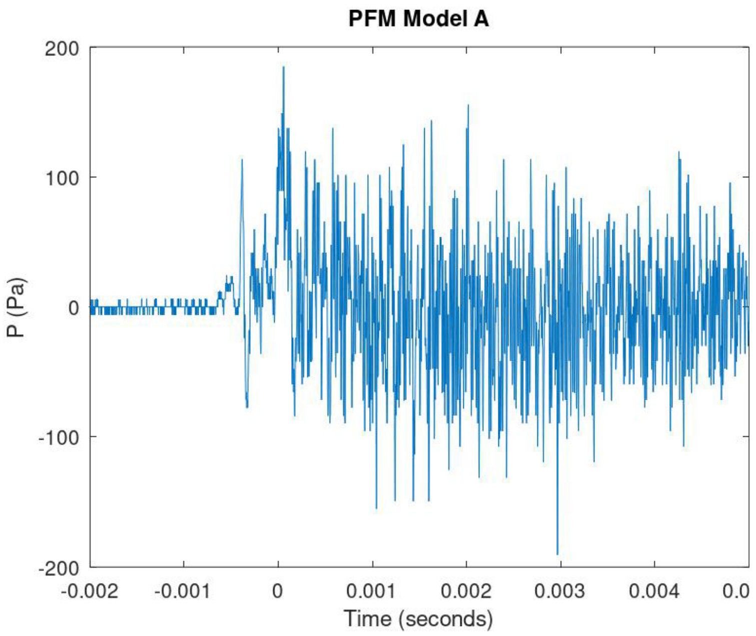
# Introduction

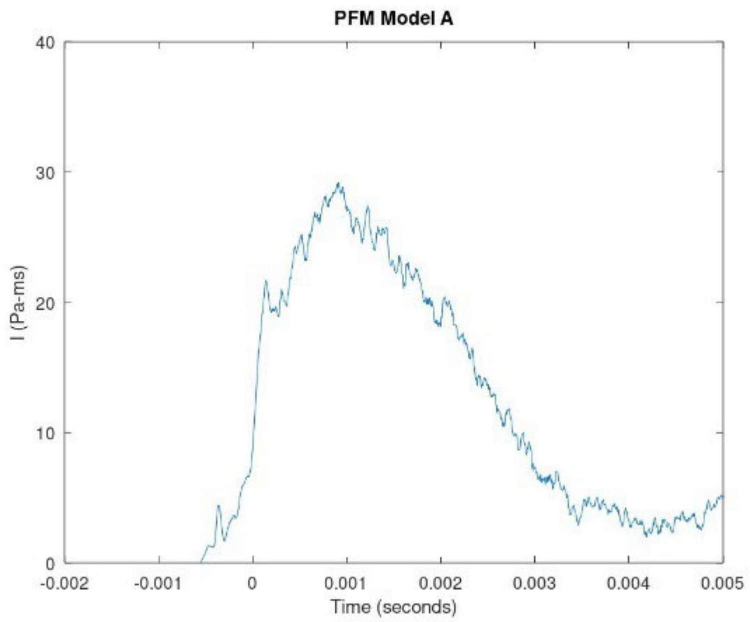
- Objective is to have quantitative & consistent metrics useful in assessing suppressor designs during development
  - Ideal for computational studies, reducing “make-shoot” process & need for qualitative data collection
  - Evaluating use of the Army’s AHAA model as part of process
- Current assessments are mostly made using peak sound level (dB), pressure, impulse and subjective metrics
- Leveraging simulations to quantify relation between design, sound signature & performance (dB, impulse, ARUs)

# Sample Measurement (PFM Model A)

- Measurement made at 1-meter MILSTD location
- AR-15 using 223 Rem, 55 grain, FMJ, 3200 fps
- Current measurements consistent with others

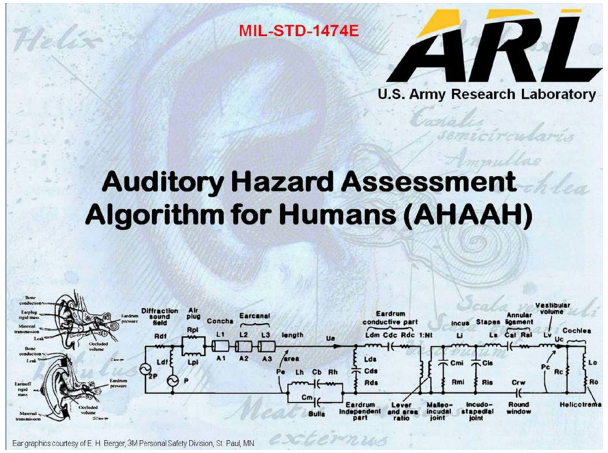


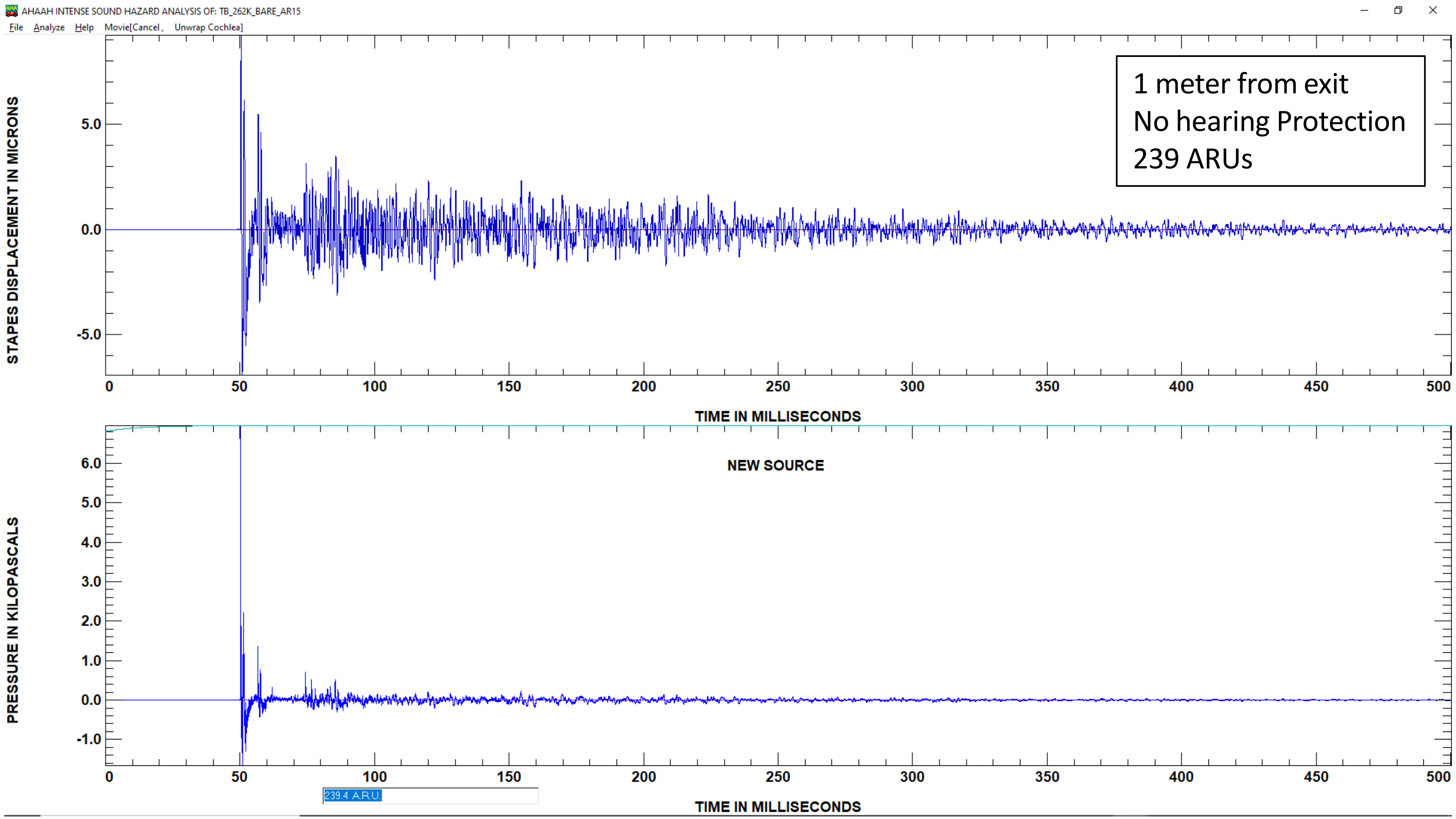
# AHAA

- Model of the ear used to evaluate hazards to hearing
- 95$^{th}$ percentile (most susceptible) human ear
- Outputs auditory rusk units (ARUs) which are physically related to damage
- Max allowable “dose” 500 ARUs / 24 hrs
- Allows for hearing protection to be considered
- Provides “Warned” & “Unwarned” ratings
- ARUs shown here are “Warned” ratings, no hearing protection & for pressure signature measured 1 meter from exit (MILSTD location)
- Objective – have a metric to assess designs in addition to dB & impulse that correlates to “qualitative” metric




ARL-TR-6748, Dec 2013

# Bare Muzzle ARU Measurement



# Ratings of Commercial Suppressors

- Pressure signature taken from Thunder Beast Arms testing**
- Ratings from Pew Science* (muzzle) site also shown

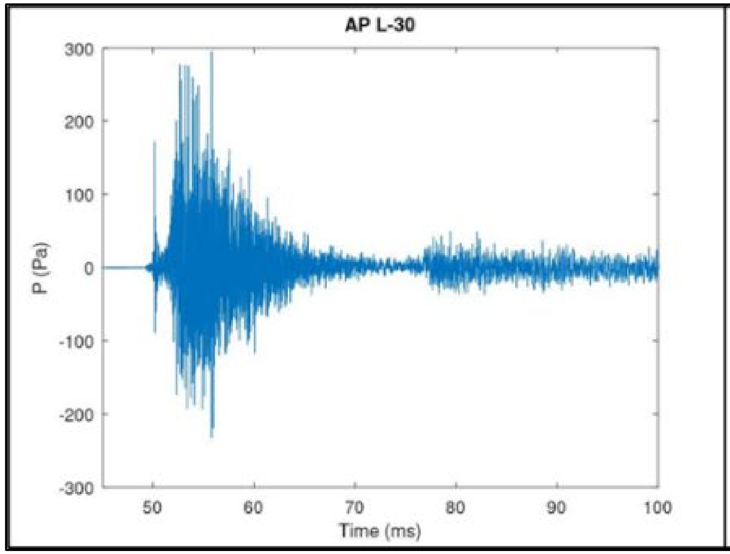
| Manufacturer | Model | Sound (db) | Peak P (Pa) | Impulse (Pa-ms) | Pew Science* Ranking | ARUs‡ |
|---|---|---|---|---|---|---|
| Energetic Armament | ARX | 154 | 991 | 161 | 21.5 | 65 |
| Aero Precision | Lahar-30 | 143 | 295 | 25 | 29.5 | 12.9 |
| HUXWRX | FLOW 556Ti | 145 | 363 | 37 | 41.1 | 16.4 |
| PTR | Vent 3 | 139 | 184 | 42 | 42.6 | 15.8 |
| Silencer Central | Banish 223 | 140 | 196 | 30 | | 12.9 |
| Sig Sauer | SLX 556 | 149 | 548 | 72 | | 30.1 |

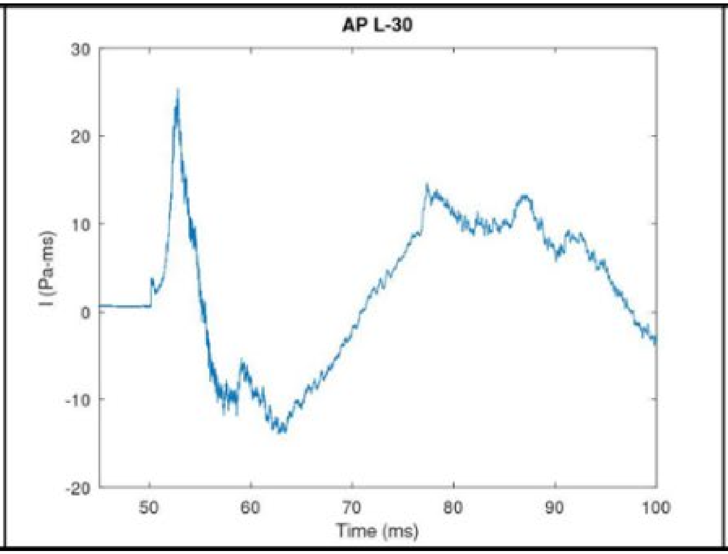
Highlighted on next slide

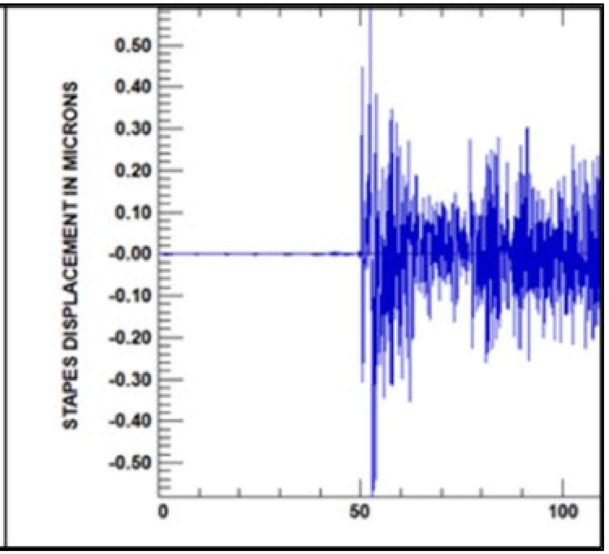
*www.pewscience.com – higher is better
‡ lower is better
**https://thunderbeastarms.com/sound/summit2023 & summit2024

# Sample Commercial Suppressors & Response

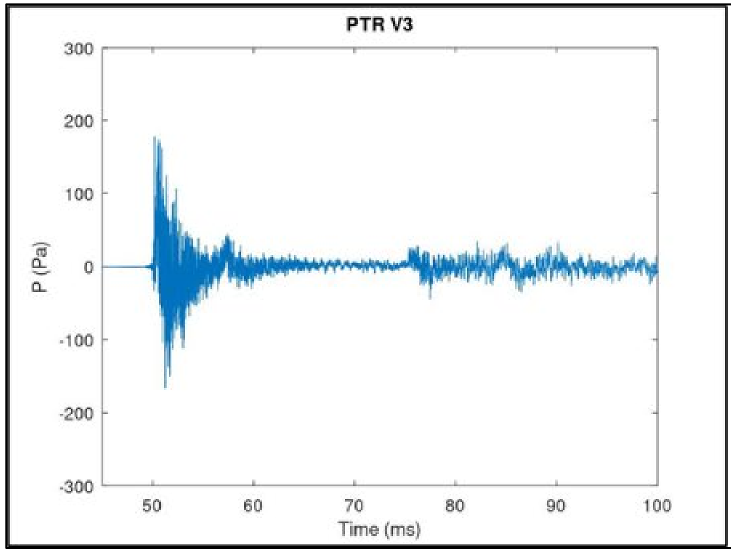
**AP L-30**

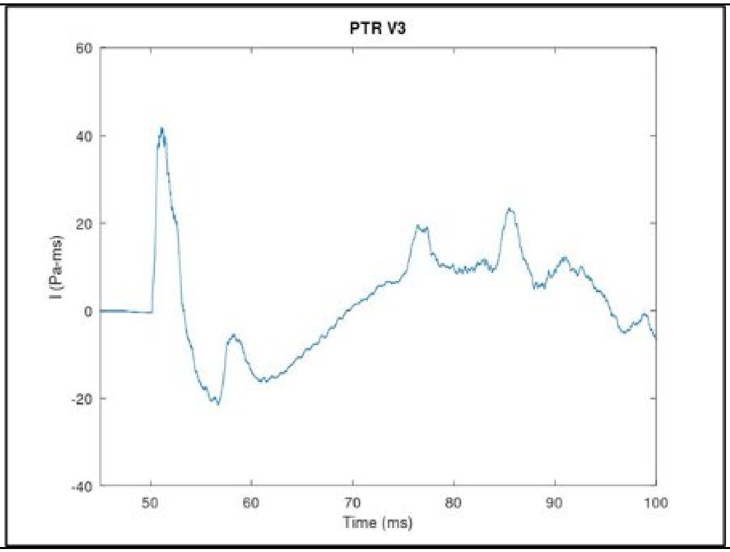


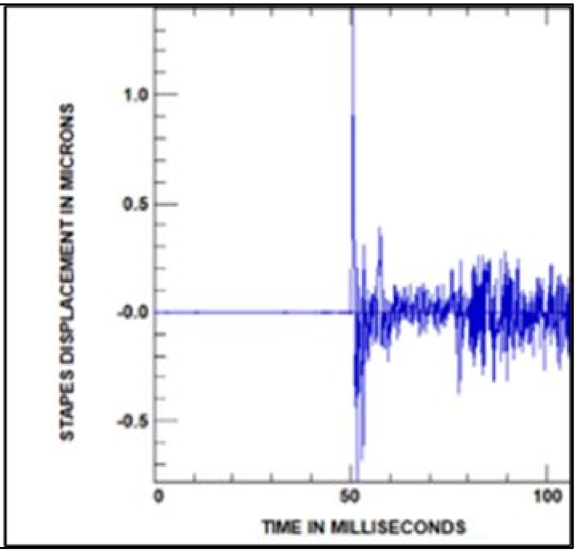




**PTR V3**



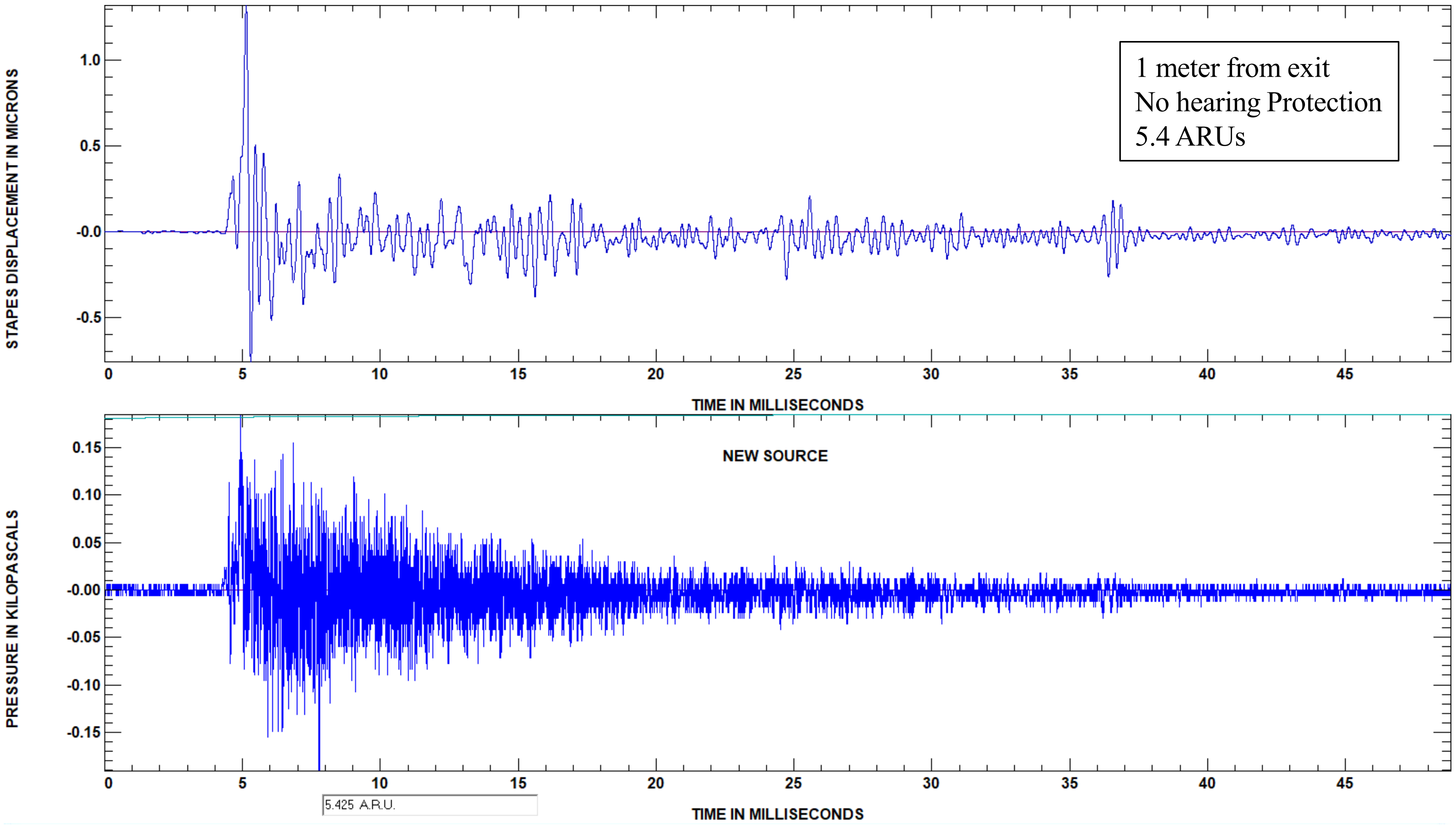




*https://thunderbeastarms.com/sound/summit2023 & summit2024

PFM DEVICES
THE SOUND OF SCIENCE ™

# PFM Model A Measurement & ARUs



# PFM Prototypes

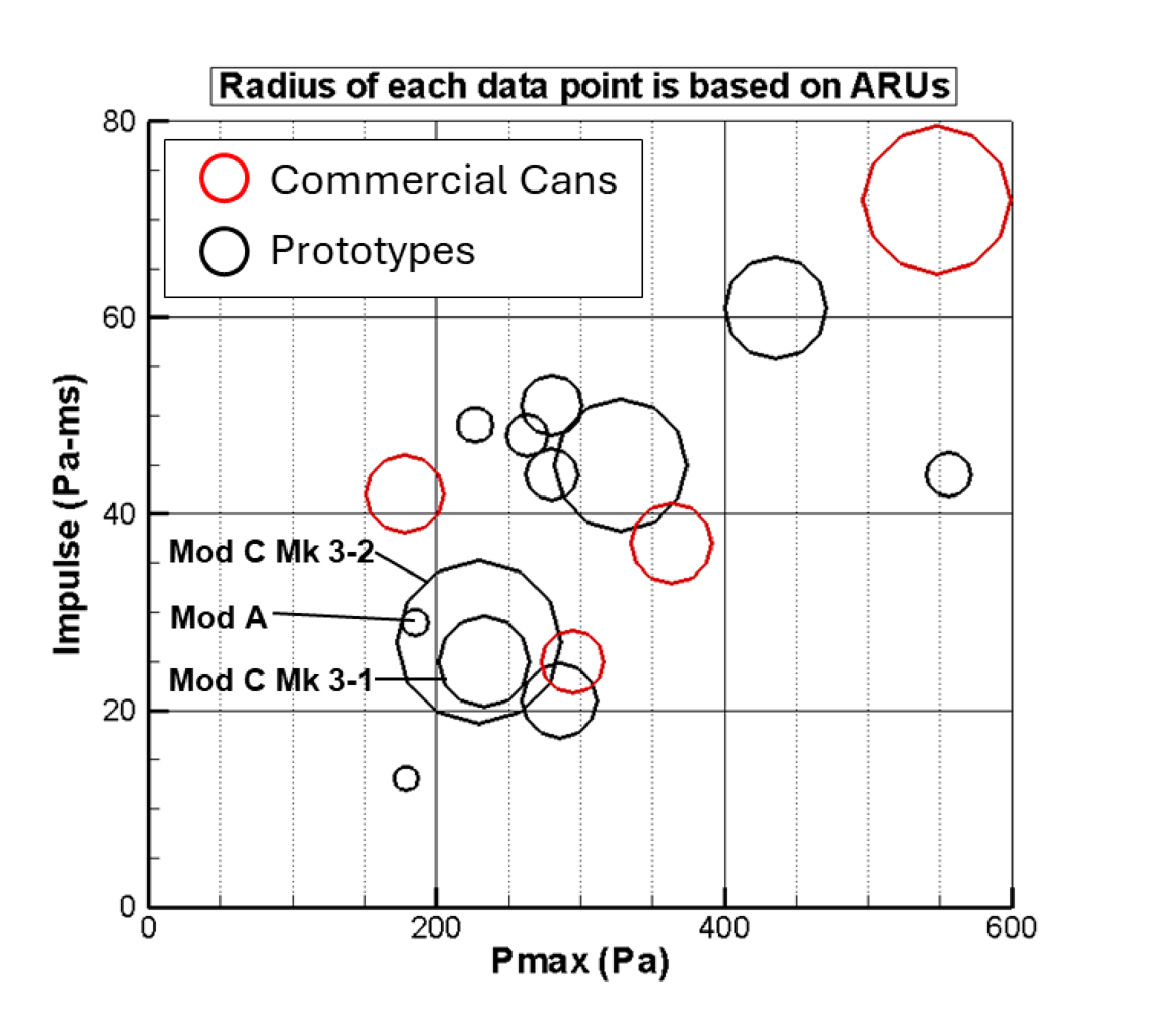
- Various internal configurations used to produce a data set for comparisons

| Model | dB | Pmax (Pa) | Imax (Pa-ms) | ARUs |
|---|---|---|---|---|
| 9B | 141 | 227 | 49 | 7.1 |
| BLV | 153 | 847 | 169 | 29.4 |
| CCA2 | 143 | 280 | 44 | 10.5 |
| OG3 | 144 | 328 | 45 | 27 |
| OG4 | 143 | 280 | 51 | 12.4 |
| Mod A | 139 | 185 | 29 | 5.4 |
| Mod B Mk 1 | 147 | 436 | 61 | 20.7 |
| Mod C Mk 1 | 139 | 179 | 13 | 5 |
| Mod C Mk 2 | 142 | 263 | 48 | 8.6 |
| Mod C Mk 3-1 | 141 | 233 | 25 | 18.6 |
| Mod C Mk 3-2 | 141 | 230 | 27 | 33.3 |
| Mod C Mk 4 | 140 | 191 | 29 | 13.9 |
| Mod C Mk 5 | 135 | 117 | 20 | 1.7 |

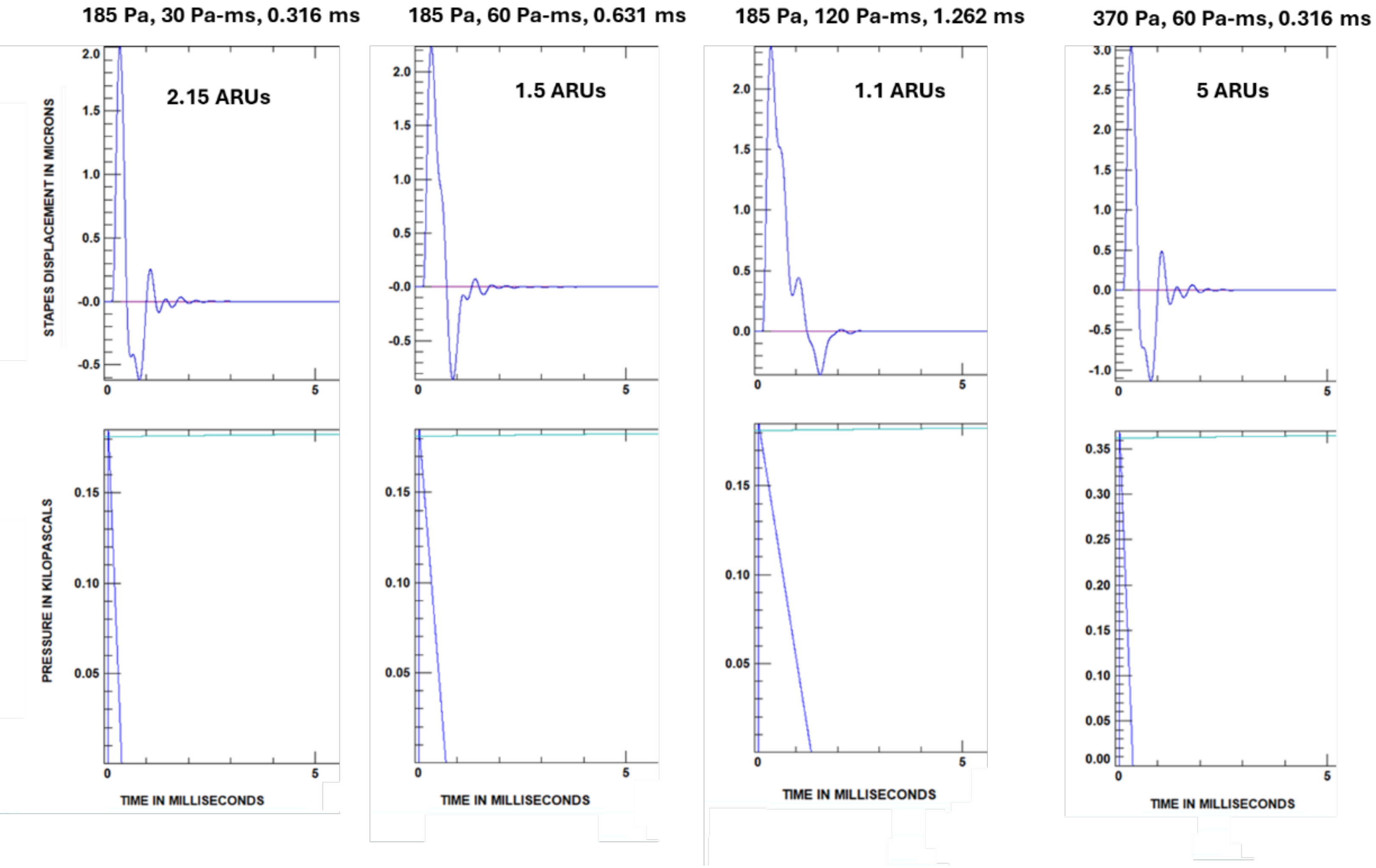
# ARUs Related to Peak Pressure & Impulse

- Not a simple correlation between peak pressure & impulse to ARUs
- Actual pressure signature key
- Complex nature of signature makes it difficult to isolate elements driving the ARU rating

| Model | Sound (dB) | Pmax (Pa) | Imax (Pa-ms) | ARUs |
|---|---|---|---|---|
| Mod A | 139 | 185 | 29 | 5.4 |
| Mod C Mk 3-1 | 141 | 233 | 25 | 18.6 |
| Mod C Mk 3-2 | 141 | 230 | 27 | 33.3 |



# Relationship Between P, I & ARUs




| Pmax (Pa) | Imax (Pa-ms) | td (ms) | ARUs |
|---|---|---|---|
| 185 | 30 | 0.315 | 2.15 |
| 185 | 60 | 0.631 | 1.5 |
| 185 | 120 | 1.262 | 1.1 |
| 370 | 60 | 0.315 | 5 |

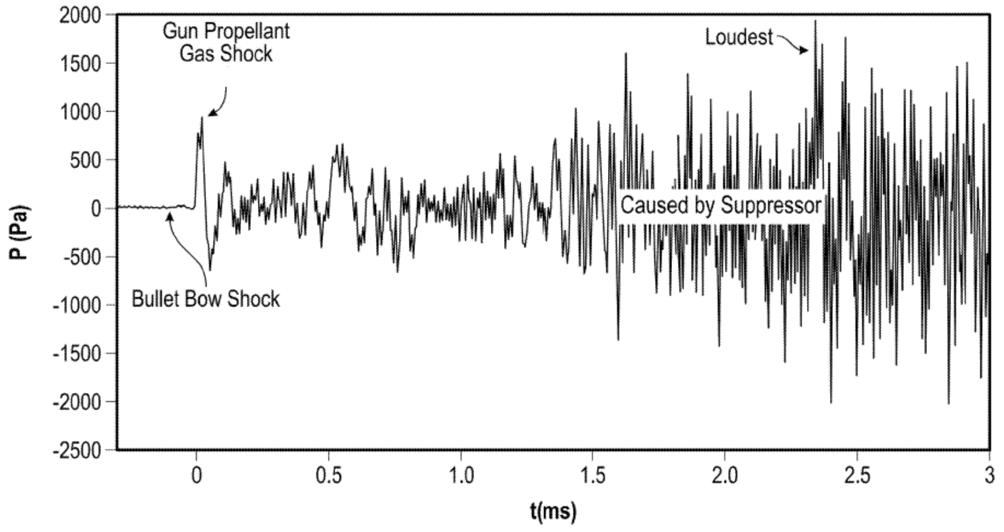
- Increase in impulse for single pulse load actually reduces ARUs
- As expected, increase in peak pressure increases ARUs
- Analysis has identified the frequency that is key in ARU rating*
- Suggests loading/unloading pattern is important; investigated with simulation

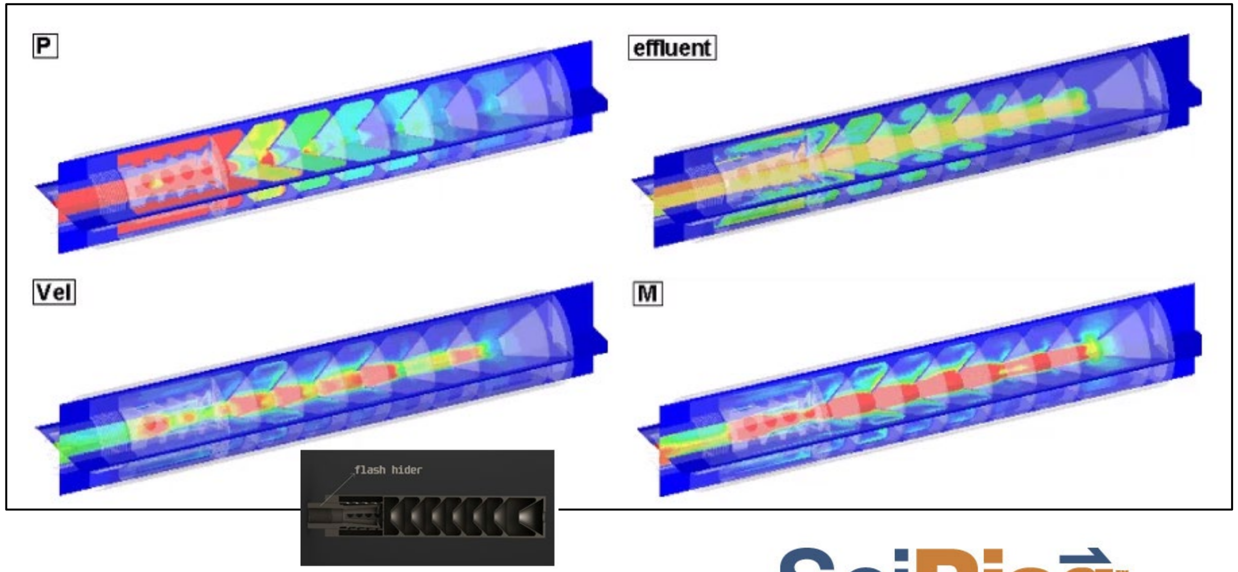
*Clutter, JK, “Suppressor Performance Assessment Methodology”, 34th Int. Symp. on Ballistics, May 2025.

# Findings Via Simulation

- Simulation used to study what drives the full sound signature; isolate cause of the pulsating pattern
- Simulations performed with CAMBER code, www.scirisq.com
- IB data for 5.56 used; 3D time accurate simulations that capture pressure, temperature and gas movement

**Example Test Data**



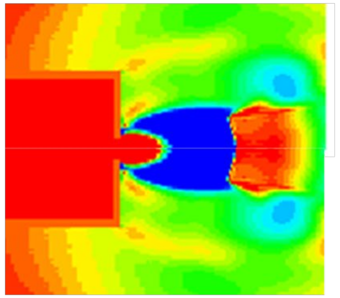

SciRisq science + risk

PFM DEVICES
THE SOUND OF SCIENCE ™

# Phenomena Producing Pulses

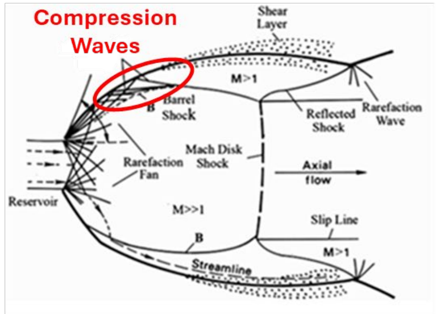
- Classic under expanded flow
- Suppressor becomes a pressurized vessel that must "blow down"
- Flow pattern is quasi-steady
- Pulses in pressure are due to compressed ambient air that expands

Sim Results for Flat Baffle at $t_1$

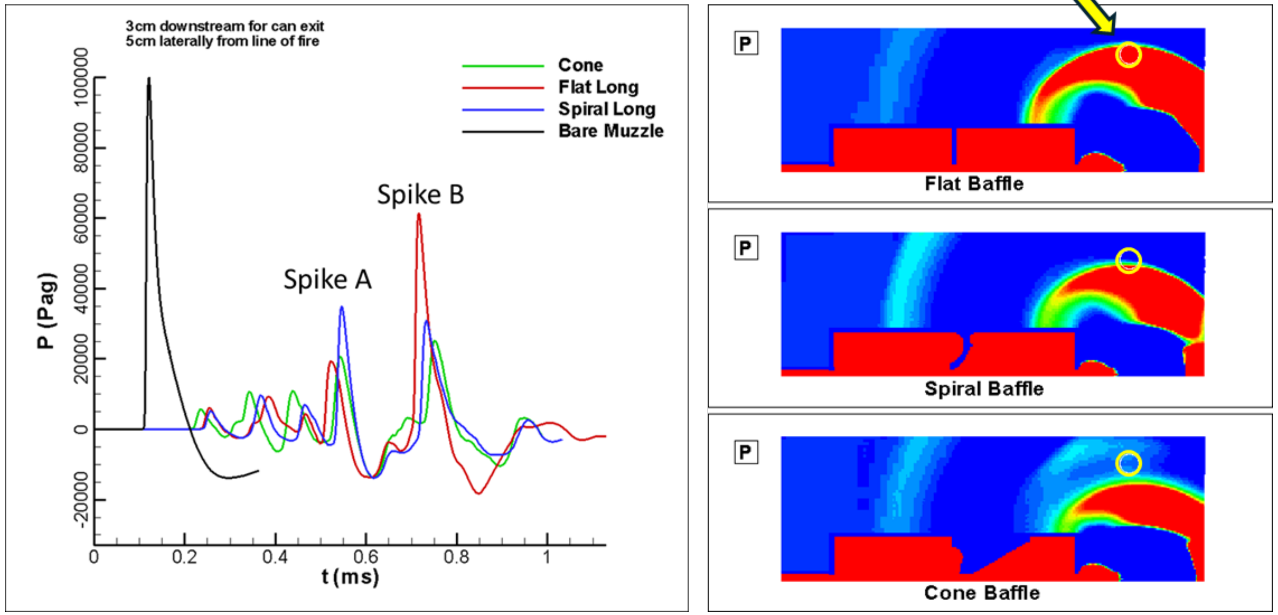


Mach No. Contour

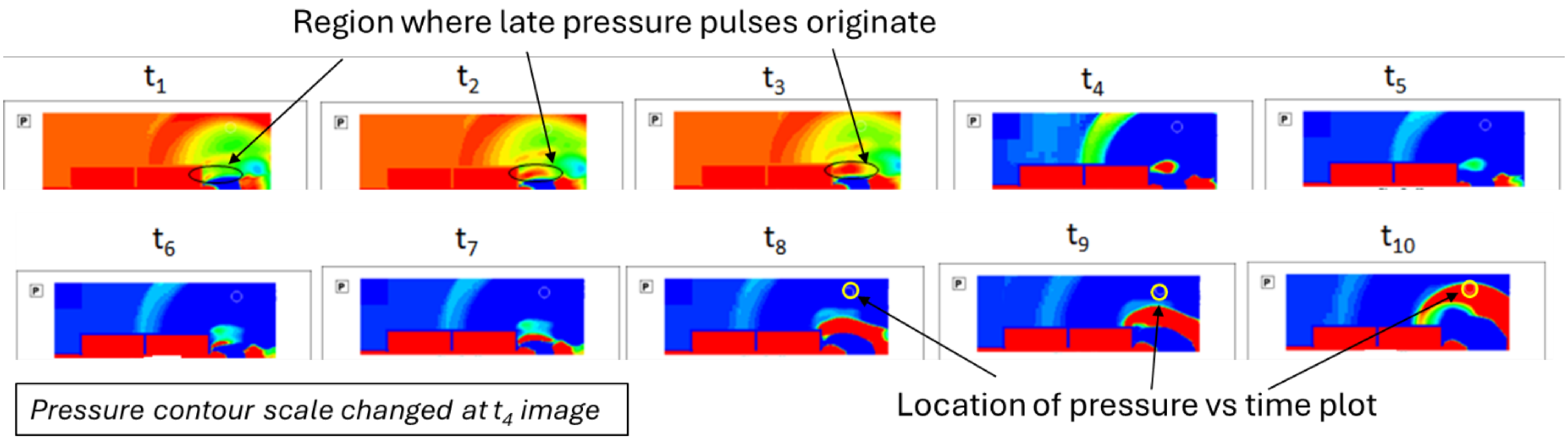
Classic Under Expanded Jet Flow Pattern




Location of recorded time history



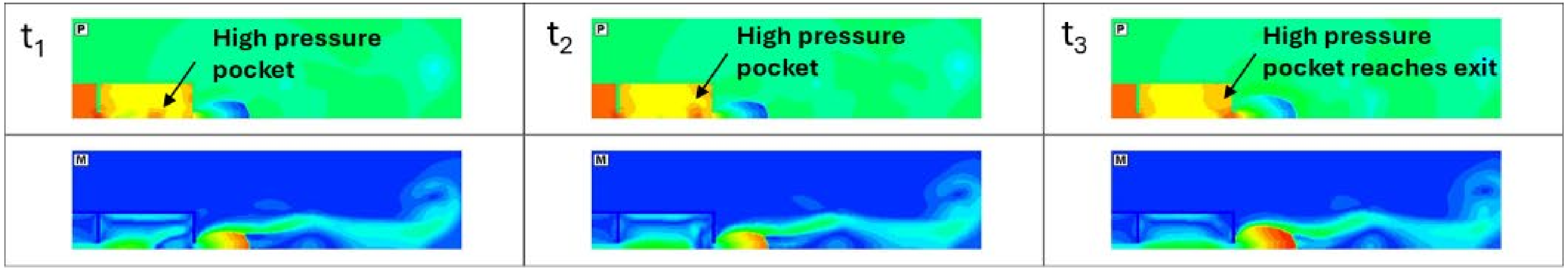
# External Process Driving Sound Signature



# Internal Process Driving Sound Signature

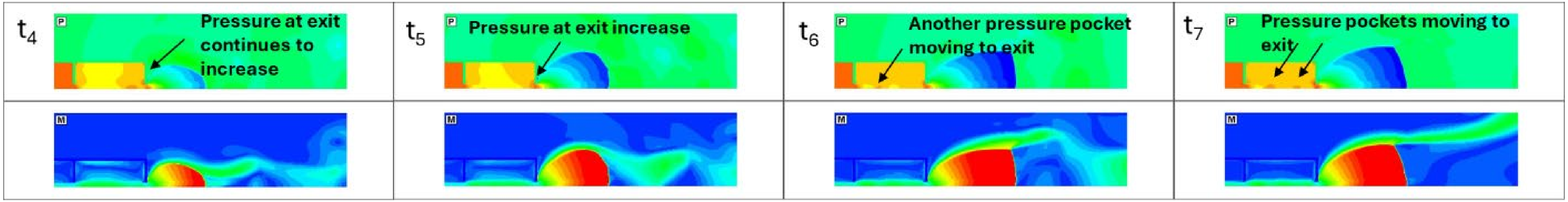
Pressure

Mach No.




Flow field produced after gun pressure has reached exit

Causes cone shock to pulsate out

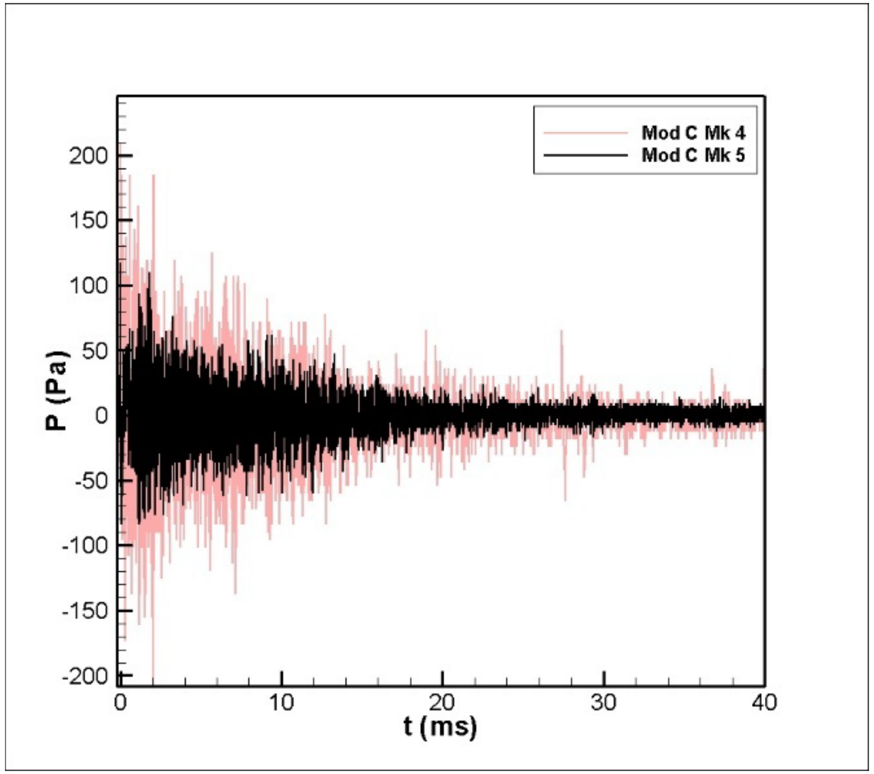


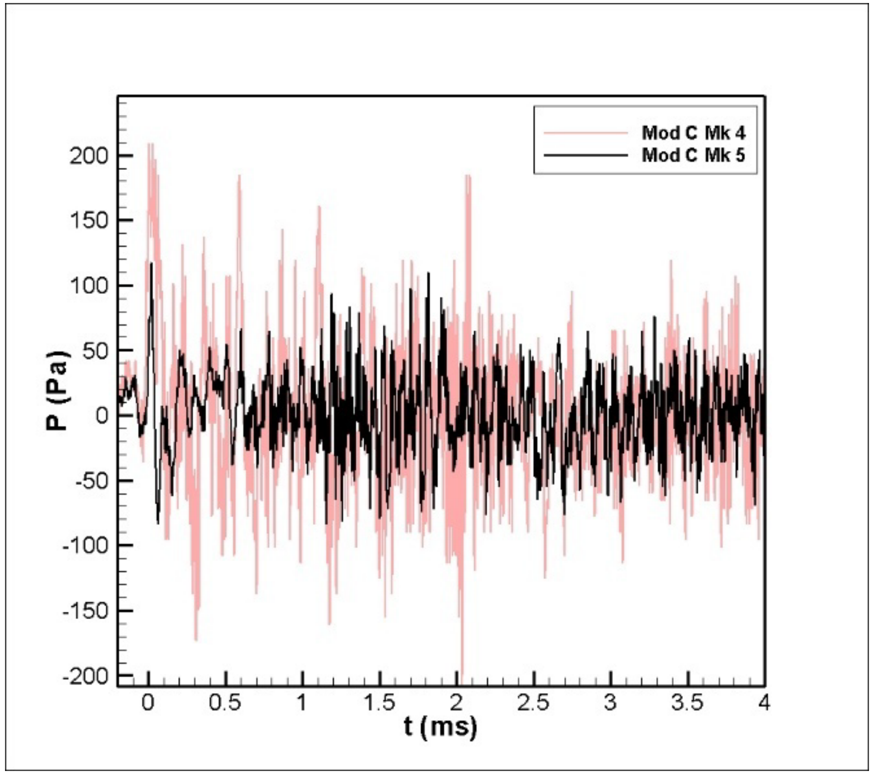

Causes cone shock moves out further

Causes cone shock moves out further

- Design controls the internal process
- Pressure at exit is dominated by stagnated flow & reflection

# Current Design

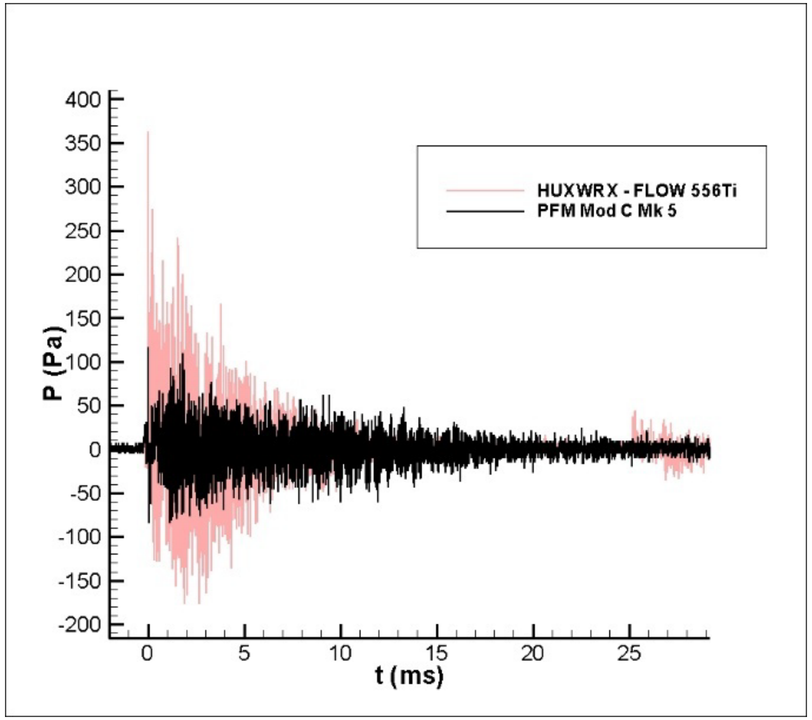


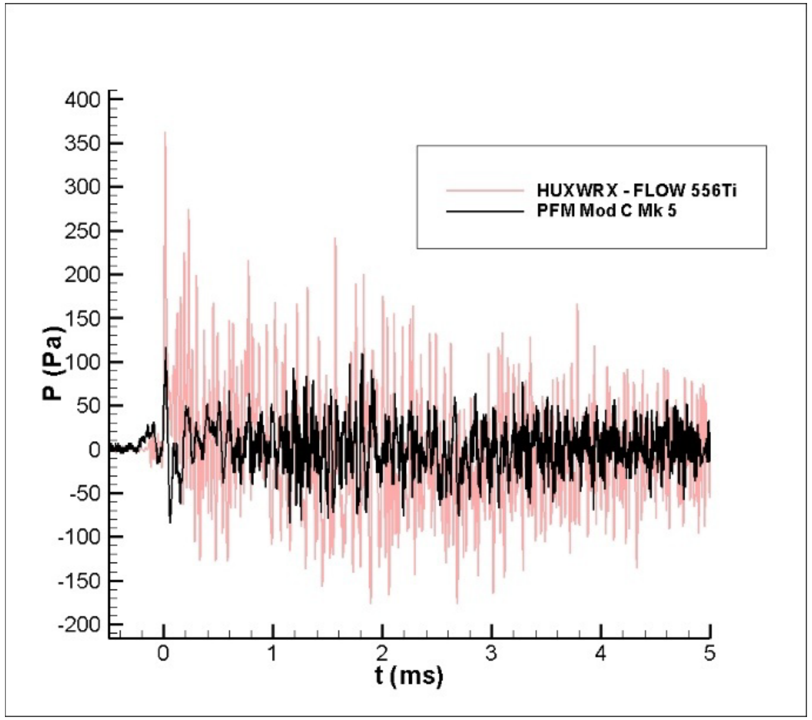




- Controlling the internal pressure wave dynamics results in better performance
- Both configurations were similar in general arrangement so frequency of pulses similar, but some changes affected magnitude

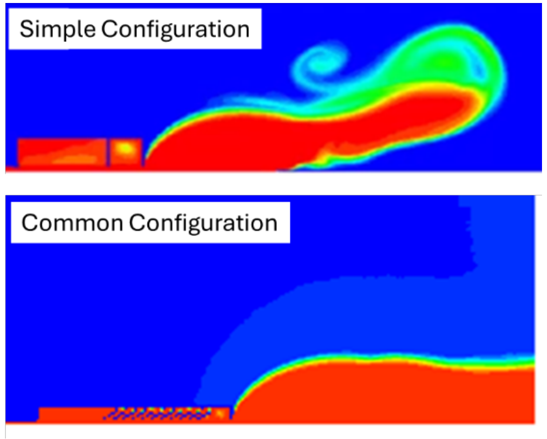
# Investigation of Other Designs

- Many concepts strive to reduce signature by "cooling" the gas; event is over in 50 ms so limited time for any "cooling" to occur
- Appears to be the assumption that cooler gas at exit results in lower pressures at exit and thereby lower pressure in field

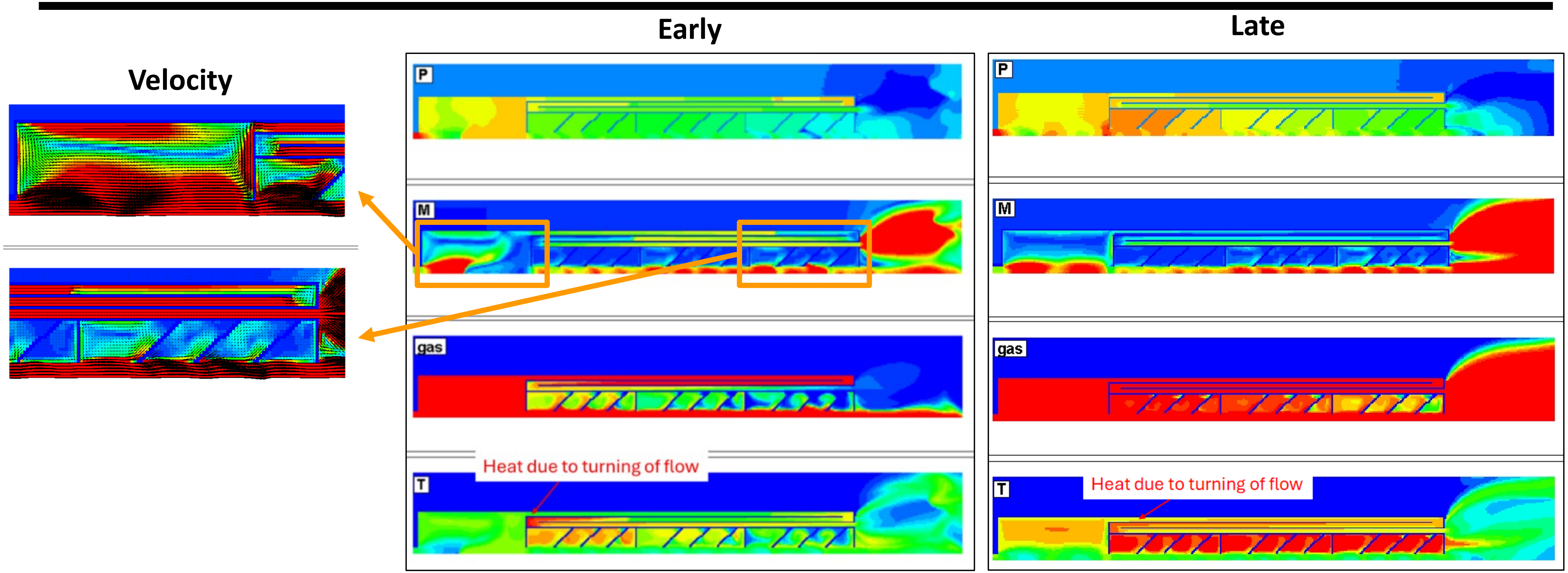



**Flow of Gun Gas**



# Flow Through Dynamics

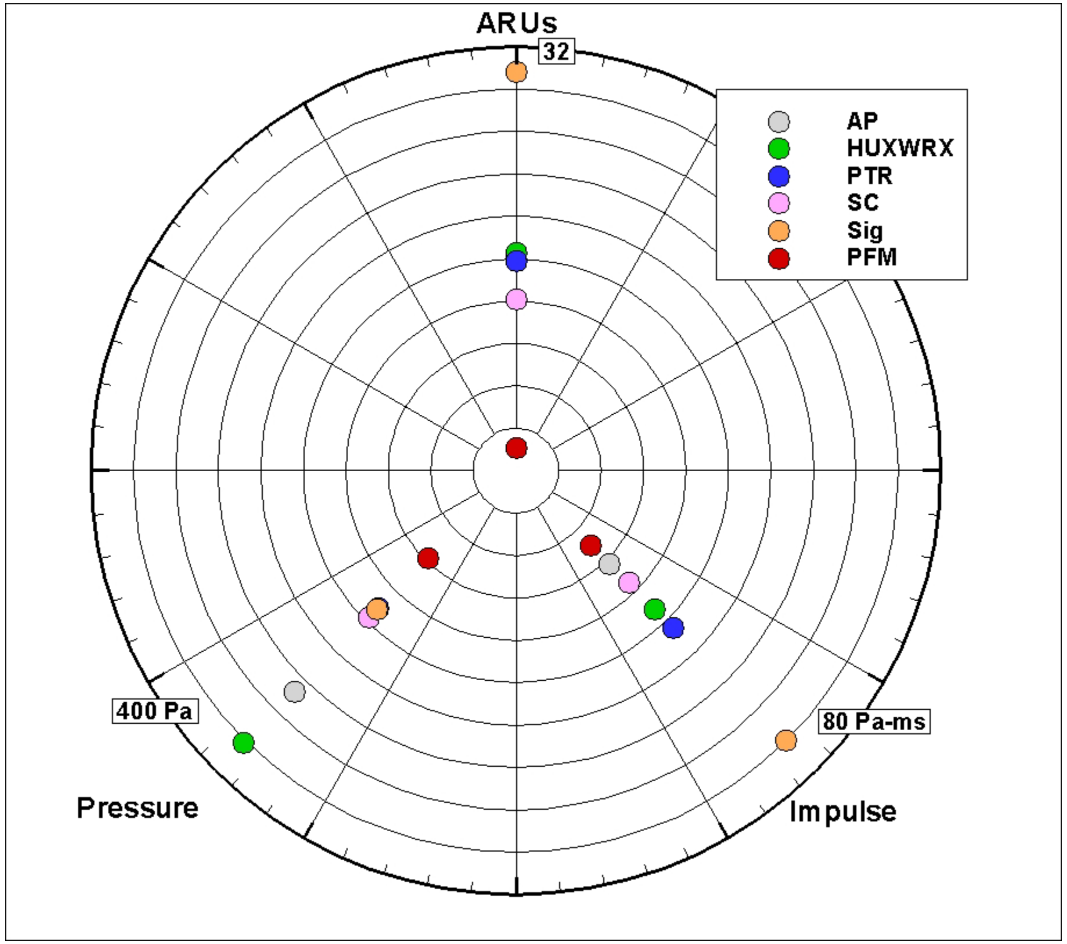



- Gas leaving through outer annulus is as hot, if not hotter than core flow
- Turning flow creates stagnation regions that heat gas
- Speeding up flow drops T but returns to To when stagnated & To is constant, even over shocks

PFM DEVICES
THE SOUND OF SCIENCE ™

# Comparison of Designs

| Manufacturer | Model | Sound (dB) | Peak P (Pa) | Impulse (Pa-ms) | ARUs |
|---|---|---|---|---|---|
| Energetic Armament | ARX | 154 | 991 | 161 | 65 |
| Aero Precision | Lahar-30 | 143 | 295 | 25 | 12.9 |
| HUXWRX | FLOW 556Ti | 145 | 363 | 37 | 16.4 |
| PTR | Vent 3 | 139 | 184 | 42 | 15.8 |
| Silencer Central | Banish 223 | 140 | 196 | 30 | 12.9 |
| Sig Sauer | SLX | 139 | 185 | 72 | 30.1 |
| PFM Devices | Mod C Mk 5 | 135 | 117 | 20 | 1.7 |



# Opinions? … Observations.

- Measurements with a decibel meter have limited value; actual full sound signature is key
- After initial pressure pulse, subsequent pressure pulses are all due to external compression wave dynamics
- Once can is pressurized, there is a quasi-steady “flow” pattern; at that point only, changes in “flow” pattern are internal pressure wave dynamics
- Gas is ~ 1800K (2780 F); no evidence cooling it down in 50 ms
  - The conjecture “we capture the flow & cool it down” or “we make the gas travel longer paths & cool it down” is not supported by analysis
- Blowback is another design objective, but tradeoff must be made; less obstructive the design, less the blowback

# Conclusion

- Best quantitative metric requires more than just pressure (dB) and impulse
- Full sound signature is key in response by ear; oscillations later in signature are just as key as initial pressure pulse
  - Controlling external cone shock pulsation is key
- Currently working plan to correlate quantitative measurements like ARU rating to qualitative assessments, i.e. what people say they hear