Conceptual Scalable Non-Lethal Ballistic System Built with Existing and Developmental Hardware

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Introduction:

Non-Lethal (NL) Fires are Complex Compared to Lethal Fires

- Range limitations
- Accuracy limitations
- Sighting is complex
- Risk of Significant Injury (RSI)
- Risk of ineffective fires (striking velocity too low)

Only 2 Requirements for Effective Non-Lethal Fires

1. A weapon and munition which enables the shooter to reliably impact the **torso** of the targeted person at the engagement range
2. A weapon and munition that produces the Appropriate Impact Velocity (AIV) to achieve the Desired Effect & Risk of Significant Injury (DERSI) at the engagement range

The Principal is Simple

Hit Target → Produce Desired Effect

Point of Impact and AIV key to Achieving DERSI

Relative to the ***torso*** impacts to the neck, face and head raise RSI, impacts to the large muscle groups lower RSI

The AIV is not a discrete velocity but a small range: ~ $\pm$ 5m/sec. which corresponds to a footprint on the ground 20 to 50 meter

- A simple projectile: AIV determined by the range to the target (shorter range = higher impact velocity)
- Constant Velocity (CV) projectile: impact effect independent of range. Effect varies with the physical stature, mental state, health, and clothing/counter measures worn by the target
- Variable Muzzle Velocity: ability to vary the impact velocity at each range to produce the DERSI

Variable Muzzle Velocity Makes DERSI Across a Broader Range of Distances Possible

- Scalable terminal effect: proportional response with option for escalation of force at each range increment
- Shorter minimum range and farther maximum range where the impact velocity produces the DERSI
- Shortens time of flight and flattens trajectory as range to target increases (except for CV projectile)

Approaches to Variable Muzzle Velocity and Constant Velocity

- Variable Thrust
  - Variable pneumatic power
  - Variable electric power: Gauss gun, rail gun, impulsive bolt
  - Variable propellant charge: liquid, gas, or solid
  - Multiple independent fixed charges
  - Fixed charge with venting
  - Combinations
    - Fixed charged with electric/magnetic breaking or boost
    - Multiple fixed charges with venting
- Constant Velocity projectile
  - Thrust in-flight = drag
    - Rocket engine
    - High velocity base bleed

Advantages and Disadvantages

Approach	Advantages	Disadvantages
Pneumatic, Electric, Variable Charge	may provide greater tuneability in muzzle and impact velocity variation	more complex, larger, heavier, may be more logistically burdensome
Multiple Fixed Charges	consistent increments of muzzle velocity to compensate for velocity loss with range	small increments for escalation of force probably not possible
Fixed Propellant, Multiple Fixed Charges w/Venting	mechanically and logistically simple	venting perturbs interior ballistics affecting shot-to-shot velocity variation
Constant in-flight velocity	terminal effect is independent of range to the target	difficult to maintain small thrust = drag of small projectile

A single weapon/munition for both lethal and non-lethal fires

Operationally Attractive:

reduced logistics and load

Technically very challenging

- Typical NL energy < 5% the energy of 5.56 NATO
- Weapon operation at both extremes requires complex weapon design
- Vastly different trajectories
- A dual lethality projectile would not be optimized at either extreme for RSI or Lethality and for stability

Optimal performance at the two extremes significantly easier to achieve with two separate dedicated systems

Dual Lethal/Non-Lethal Platform

A single weapon/munition for lethal/non-lethal fires

is too complex

- $\leq$0.5 kg non-lethal modular accessory is a practical solution to dual purpose fires
  - Non-lethal is optimized for non-lethal fires
  - Lethality of parent weapon remains the same

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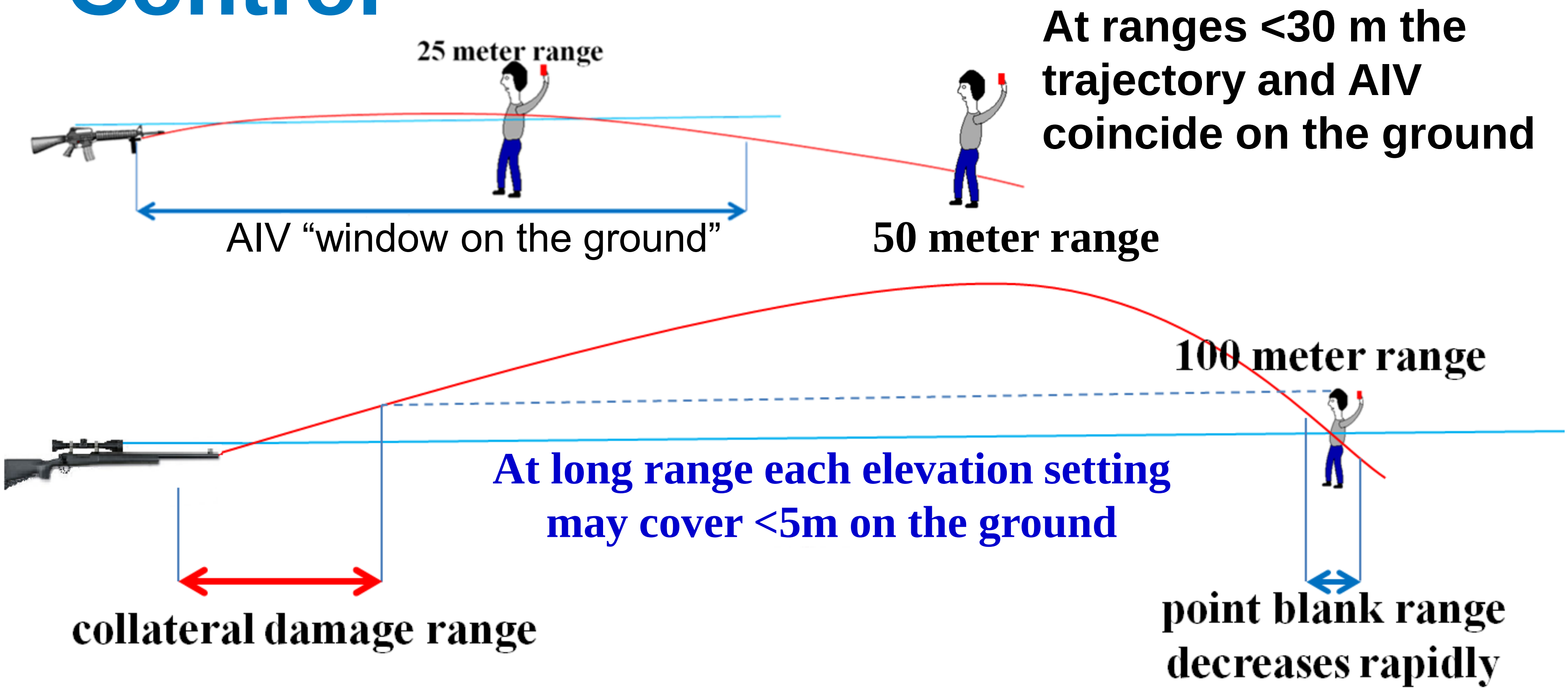
Sighting Requires a Ranging Fire Control



The arched trajectory reduces the effective range on the ground. At long range relatively large elevation adjustments are required for very small increments of range

Conceptual Extended Range Non-Lethal System

- Modular accessory to lethal arm that can also operate as standalone weapon
- Point accurate (>80% probability of torso hit) beyond 100 m
- Variable muzzle velocity
- Fire Control that accepts user input for desired effect
  - Range target
  - Measure atmospheric conditions and inclination
  - Adjust muzzle velocity to achieve desired effect at target
  - Adjust elevation and windage for range, inclination and atmospheric conditions

Designing a Point Accurate Non-Lethal Weapon

Just Like Conventional Lethal Arms

Accurate Non-Lethal Arms Require:

- Mechanically repeatable weapon platform
- Precision barrel
- Consistent shot-to-shot muzzle velocity
- Consistently aerodynamically stable projectile
- Sighting system that coincides the point of impact with the point of aim

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Build a variable velocity weapon system that is comparable in size and weight to existing accessories used on the rail.

- Goal is optimal performance with reduced size/weight
  - Design weapon and munition in concert
    - Consistent interior ballistics = consistent muzzle velocity
    - Stable projectile *via* spin stabilization
    - Variable muzzle velocity on a shot-to-shot basis
    - Semi-automatic or automatic fires
    - Point accuracy to >100 m
  - Unique munition design
    - Elevated burn pressure maintained by variable volume combustion chamber
    - Force transmitted to projectile by sub-caliber captive piston
    - Piston controls interior ballistics
    - High thrust for engraved rifling
    - Fires from a fixed-open breech

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Current State of Effort

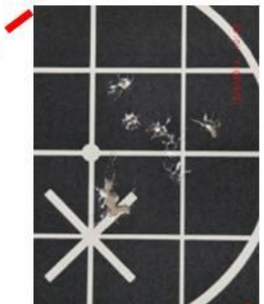
- Ammunition developed to TRL 7
  - Demonstrated with single-shot weapon on lower rail
  - Performance measured with Doppler radar and impact dispersion
- Weapons developed to TRL 4-5
  - Single-shot 2 velocity modular accessory for M4 demonstrated
  - Multi-shot modular accessory proof of principle demonstrated
  - Multiple reticle second focal plane scope allows elevation adjustment via zoom useable for demonstration at known ranges
  - Working with industry partner to integrate commercial fire control

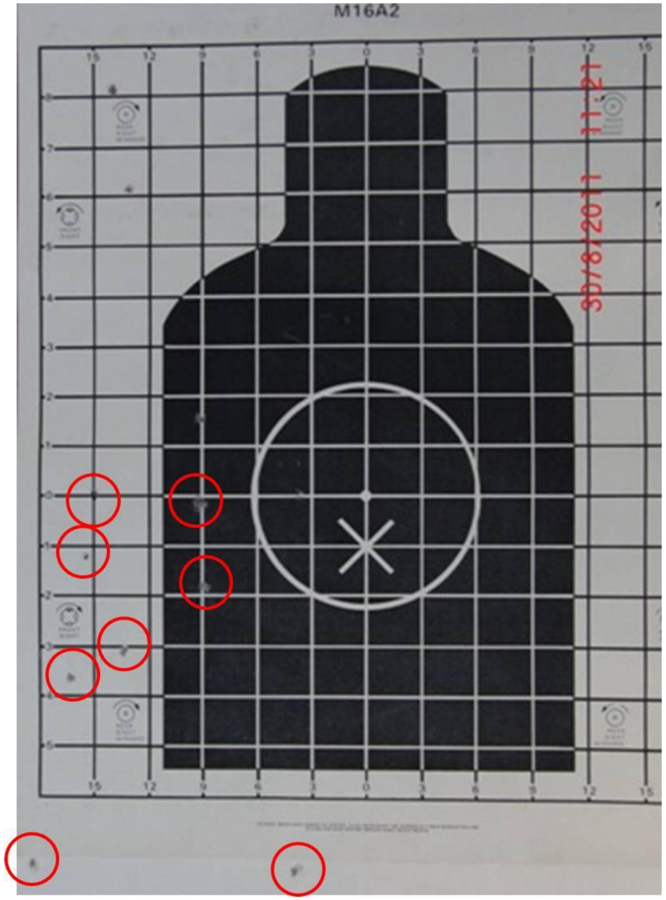
100 rounds of Battelle non-lethal munition fit in the same packaging as 100 rounds of .45 ACP approximately the same size as three 5.56 magazines and weight of two loaded 5.56 magazines

Doppler Radar Results

	Doppler Radar Data Measured by ARDEC ATF										
	High Velocity Mode									Low Velocity Mode	
	Raw Data			Group of 14 Shots			Group of 6 Shots			Raw Data	
	Velocity m/sec			Velocity m/sec			Velocity m/sec			Velocity m/sec.	
Shot	muzzle	30 m	100 m	muzzle	30 m	100 m	muzzle	30 m	100 m	muzzle	30 m
1	112.5	102.9	75.0	--	--	--	112.5	102.9	75.0	lost	lost
2	113.5	103.9	77.0	--	--	--	113.5	103.9	77.0	lost	lost
3	112.9	106.5	89.0	112.9	106.5	89.0	--	--	--	102.9	96.3
4	113.9	107.4	90.0	113.9	107.4	90.0	--	--	--	105.9	97.5
5	111.2	104.9	88.0	111.2	104.9	88.0	--	--	--	103.6	96.1
6	113.4	107.0	90.0	113.4	107.0	90.0	--	--	--	106.0	97.0
7	117.0	109.4	93.0	117.0	109.4	93.0	--	--	--	103.9	93.4
8	113.4	106.4	88.0	113.4	106.4	88.0	--	--	--	105.3	95.4
9	111.1	104.9	88.0	111.1	104.9	88.0	--	--	--	107.1	100.3
10	117.2	105.8	72.6	--	--	--	117.2	105.8	72.6	106.8	98.4
11	111.9	105.8	90.1	111.9	105.8	90.1	--	--	--	103.3	95.8
12	114.7	104.9	77.5	--	--	--	114.7	104.9	77.5	104.7	97.1
13	113.4	103.8	77.0	--	--	--	113.4	103.8	77.0	105.2	98.6
14	115.3	109.2	93.6	115.3	109.2	93.6	--	--	--	101.1	92.8
15	117.4	110.9	93.9	117.4	110.9	93.9	--	--	--	103.2	94.1
16	114.6	107.5	91.6	114.6	107.5	91.6	--	--	--	--	--
17	114.7	107.5	91.2	114.7	107.5	91.2	--	--	--	--	--
18	112.4	101.7	71.3	--	--	--	112.4	101.7	71.3	--	--
19	115.8	109.3	92.3	115.8	109.3	92.3	--	--	--	--	--
20	115.3	107.7	93.0	115.3	107.7	93.0	--	--	--	--	--
ave =	114.1	106.4	86.1	114.1	107.5	90.8	113.9	103.8	75.1	104.5	96.4
st dev =	1.9	2.4	7.7	2.0	1.8	2.1	1.8	1.4	2.6	1.7	2.1
extreme spread =	6.3	9.2	22.7	6.3	6.0	5.9	4.7	4.0	6.2	6.0	7.5

Corresponding Targets to Doppler Data

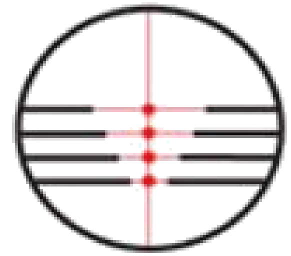




Two five shot groups at 30 m
Low velocity shots # 6-15

Eight out of 9 Shots at 100 m
High velocity shots # 12-20

Prototype Single Shot Weapon with multi-reticle scope



35 yards
top cross hair

60 yards
second cross hair

sighting in at 115 yards outdoors
prone bottom cross hair

Multi-Shot Weapon Concept

Open Breech Design for Semi-Automatic and Burst Fires

Step 1

Step 2

Step 3

No reciprocating breech
No mechanical hammer or striker
Electronic primer

→

Potential for Very Rapid Rates of Fire

2 and 3 shot burst fires to escalate force without increase in impact velocity by delivering additional impulse to target

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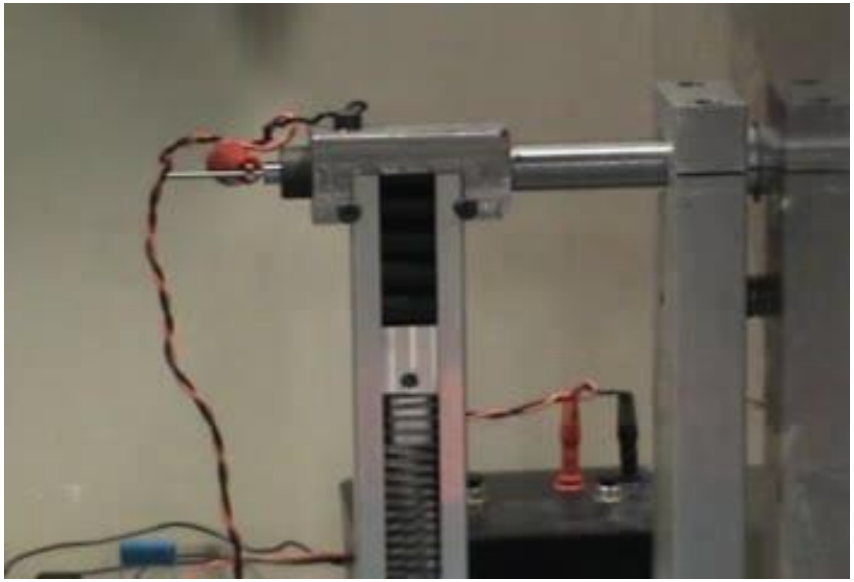
High Speed Video of Prototype

High speed video of rounds firing from magazine into barrel



Video showing multiple sequential shots

Magazine cut open showing rounds firing and advancing into battery against the barrel extension

Rates of fire in excess of 100 rounds/second are possible

1. Escalation of force via multiple simultaneous impacts (3-shot burst).

Robotic platforms with chute feeding could sustain high rate fire and cover large areas

1. Long range (200-500 meters), low velocity impact volley fires into crowds to separate non-motivated, passive from active participants
2. Short range sweeping fires at shin height to stop advancing crowds

Next Steps

- Develop a reliable multi-shot capability
  - Open breech vertical stack (like the video)
  - Rotating cylinder, belt feed, chute feed, etc.
- Integration of commercial fire control
  - Articulation of reticle (steep elevation of parent weapon)
  - Articulation of non-lethal weapon (maintain NL impact coincident with parent weapon sight)
  - Automatic selection of muzzle velocity based on user input of desired effect, environmental conditions and measured range to target
- Improved manufacturability of munition

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