Design Study for a Combined Lethal and Non-Lethal Munition

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Program Overview

- Objective
  - Increase warfighter capability by providing one cartridge delivering variable effects from non-lethal to lethal at greater non-lethal range than currently available
- Contract
  - NBCH3090001-0002
  - Phase I Design Study
  - Phase II Component/Subsystem Demonstrations
- Quantitative Metrics

Measure	Current	Threshold	Objective	TRL
Combined Lethal & Non-Lethal Warhead	None	Non-Lethal to Lethal	Optimize on Target	Start 2 End 4

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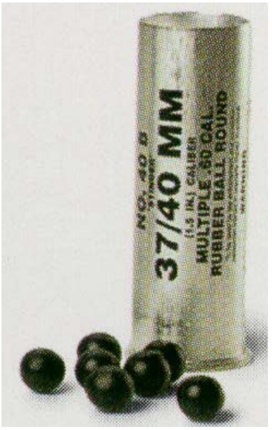
Current Non-lethal/Less-than-Lethal Launchers & Cartridges

12 Gauge Shotgun

XM 1012 and XM 1013

37mm Flare Gun/40mm Grenade Launcher



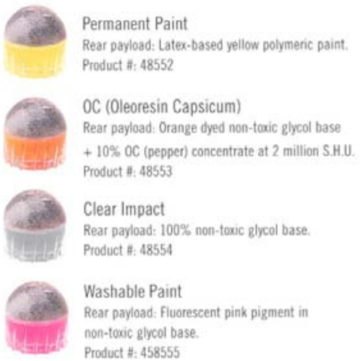
AAI Law Enforcement Products

(Legacy Product Line)

40 MM CS FERRET

12 GA SS-100 (SOFT SLUG)

FN 303 (.68 caliber)



M1006

Requirements Analysis
Key Design Parameters (1 of 2)

1. Lethal vs non-lethal impact demarcation
   - Trauma metrics evaluated for applicability
     - **Viscous Criterion (VCmax)-** No contact area factor
     - **Blunt Criterion (BC)-** Impact location specific
     - **Maximum Force-** Good predictor for head injuries
     - **Energy Density**
       - Best predictor for skin penetration and internal injuries
       - Accounts for impact area better than other criteria
       - Selected as evaluation criteria
   - Energy density approximate transition zone
     - Lethal $>$ 52 $\text{lbm}\cdot\text{ft}^2/\text{s}^2/\text{in}^2$ $\geq$ Non-lethal
     - Sufficiently accurate for preliminary design studies
     - Further distinctions possible but outside scope of effort

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Requirements Analysis
Key Design Parameters (2 of 2)

2. Effective range ≥ 100m

3. Mode setting
   - Factory setting- non-lethal
   - Ability to revert mode settings
   - No projectile component removal or addition to change mode

4. Must be fired from standard 12 ga / 40mm weapons (no modifications)

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Methodology for Concept Development

- Develop 3D-CAD Designs
  - Solid models were developed- inertial characteristics
- Establish Internal Ballistics
  - PRODAS analysis to establish propellant load/Pch/Vm
- Evaluate External Ballistics Characteristics
  - PRODAS analysis to determine stability and drag of the fin and spin stabilized projectiles
- Evaluate Terminal Ballistic Effects
  - Energy Density was used to estimate lethality
- Evaluation vs. key requirements
  - All concepts developed were compared based on key requirements

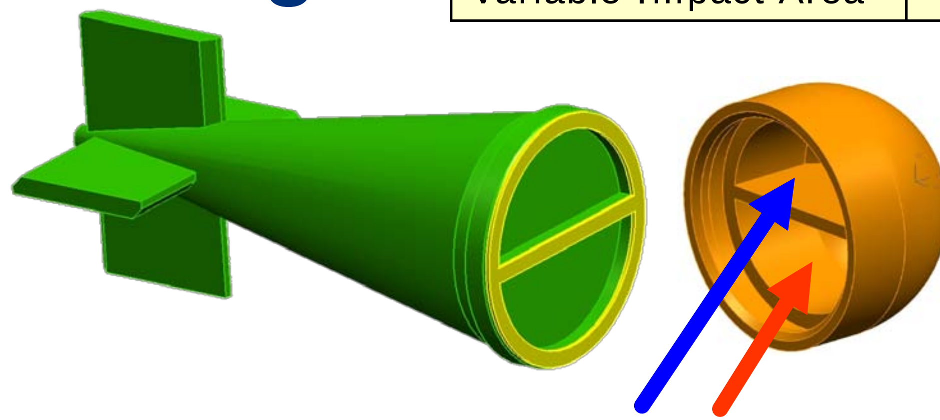
Concept Design Summary

Description	Variable Mass	Variable Velocity	Variable Impact Area
C1- Chemical Hardening			✓
M1- Nested Dual Projectiles	✓		✓
M2- Frangible Body			✓
M3- Liquid Expulsion	✓		
M4- Subcaliber Dual Projectiles	✓	✓	✓
M5- Tandem Dual Projectiles	✓		

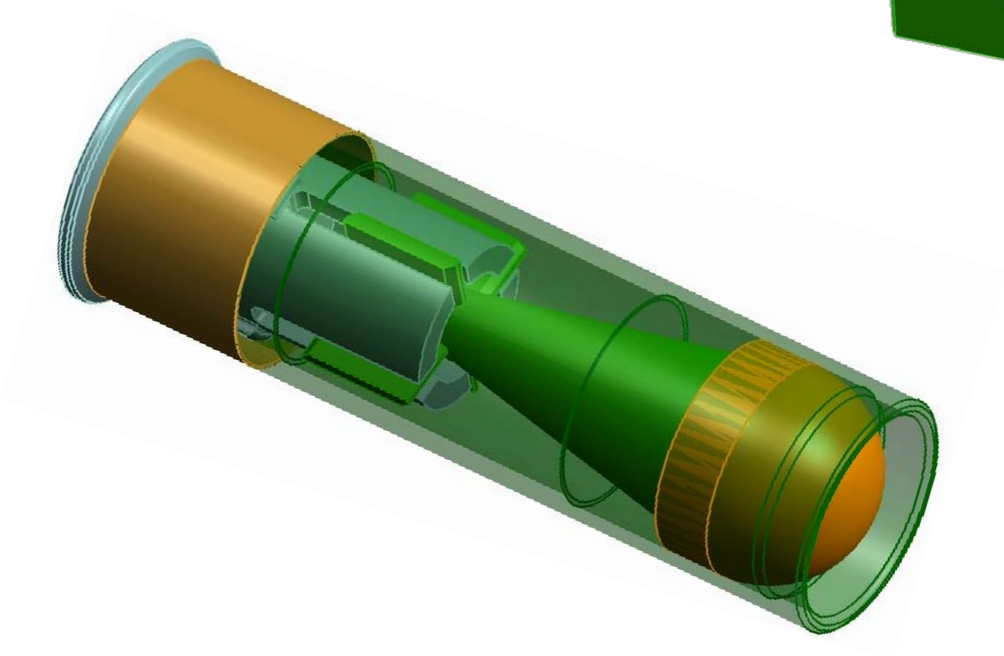
Design Concept C1 Chemical Hardening

Variable Proj Mass	
Variable Proj Velocity	
Variable Impact Area	✓

- 12ga
- Fin-Stabilized



Projectile Nose Contains Two Liquid Chemical Chambers

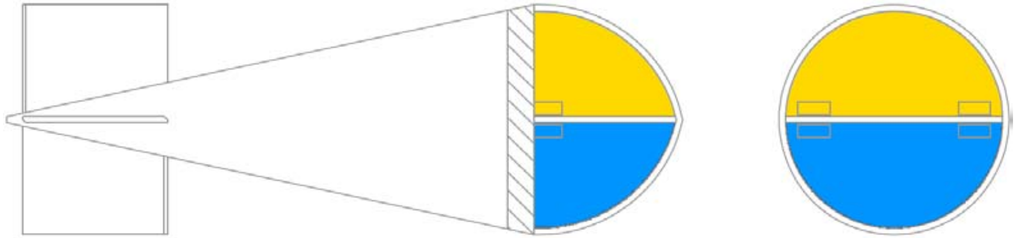


Non-lethal mode
- Factory setting
- Liquids separated

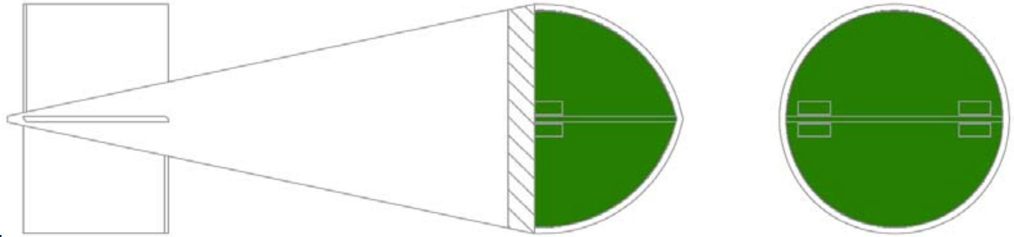
Lethal mode
- Operator setting
- Rotation of cartridge mixes liquids
- Reaction initiates rapid hardening

Design Concept C1
Impact Mode Characteristics

Non-lethal Impact (default)- Liquid reactants disperse on impact, reducing energy density



Lethal Impact Pre-fire chemical reaction hardens nose, forms slug type projectile



Design Concept C1
Evaluation of Candidate Chemicals

- Chemical Classes Evaluated
  - Epoxy
  - Polyurethane
  - Polyamide
  - Polyester
  - Acrylate
- Variety of curatives and catalysts evaluated

- Primary Evaluations
  - Mixing Potential
  - Cure Time
  - Temperature Effects
  - Human Hazard (toxicity)
- Secondary Evaluations
  - Long term Storage Requirements
  - Compatibility with Projectile Material
  - Environmental Hazard

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Evaluation of Design Concept C1 Chemical Hardening

Stabilization Method	L-NL Trajectory Match	Muzzle Velocity	Terminal - Non-Lethal		Lethal
			Muzzle Energy Density	Max Range	Energy Density @ 100m
Fin	Yes	300 ft/s	<52 ft-lbs/in^2	120 m	60 ft-lbs/in^2

Advantages

- Identical propulsion
- Identical trajectories
- Mixing will change nose color to indicate setting
- Potential for additives to enhance non-lethal effects
  - Rubber balls for blunt trauma
  - Paint for marking
  - CS or Pepper
- Demonstrated successful rapid hardening reaction times (≤ 5 sec)

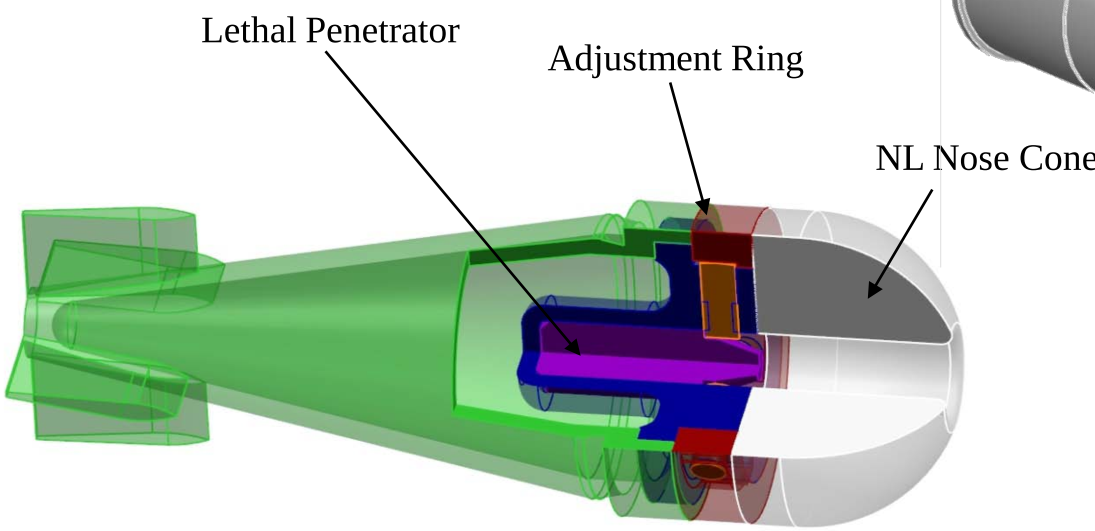
Disadvantages

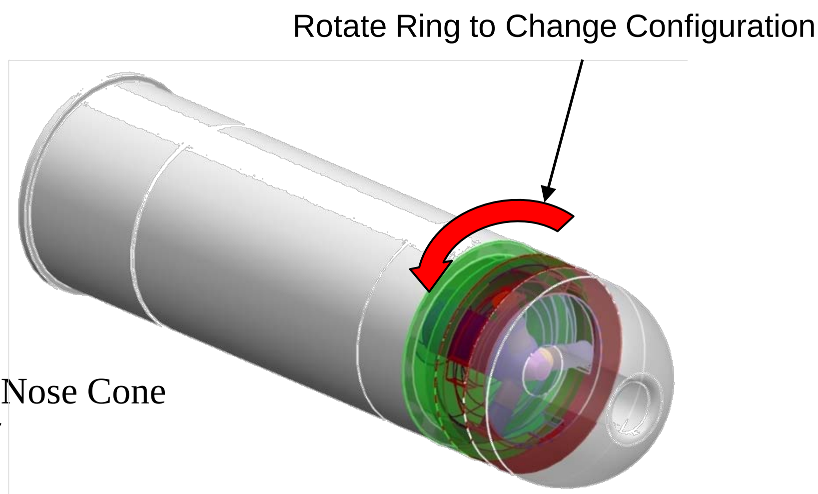
- Lethal setting not reversible
- Human hazards from liquids
  - Non-lethal mode
  - Dispersal of chemicals on impact
  - Potential toxicity/injury

Design Concept M1
Nested Dual Projectiles

Variable Proj Mass	✓
Variable Proj Velocity	
Variable Impact Area	✓

- 40 mm
- Fin-Stabilized



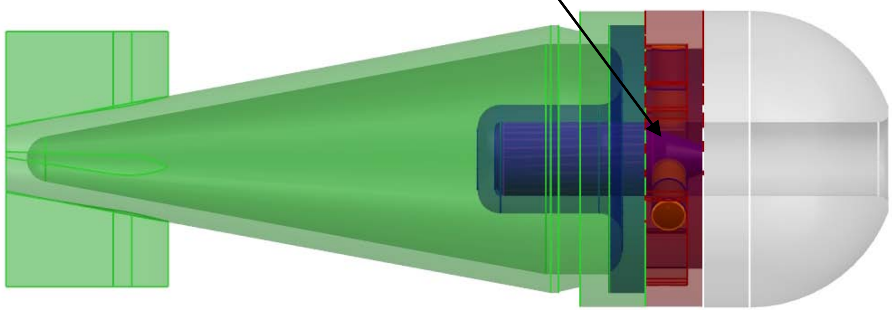


Default Position: Non-Lethal

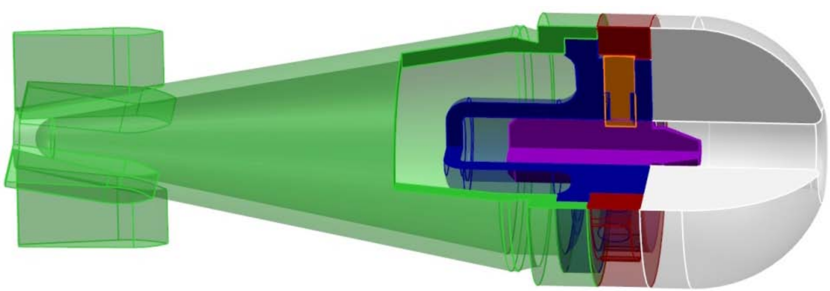
Design Concept M1
Impact Mode Characteristics

Non-lethal Impact

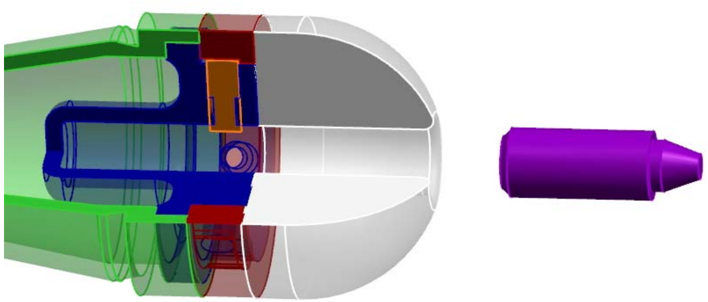
Projectile contacts target with large, soft NL Nose cone.
Penetrator is restrained from reaching target by pins



Lethal Impact



NL Shell stops on impact but penetrator continues with Lethal effects



Penetrator released on impact

Evaluation of Design Concept M1 Nested Dual Projectile

Stabilization Method	L-NL Trajectory Match	Muzzle Velocity	Terminal - Non-Lethal		Lethal
			Muzzle Energy Density	Max Range	Energy Density @ 100m
Fin	Yes	220 ft/s	<52 ft-lbs/in^2	120 m	95 ft-lbs/in^2

Advantages

- Identical propulsion
- Identical trajectories
- Settings reversible

Disadvantages

- Low velocity of lethal projectile

Design Concept M2
Frangible Projectile

Variable Proj Mass	
Variable Proj Velocity	
Variable Impact Area	✓

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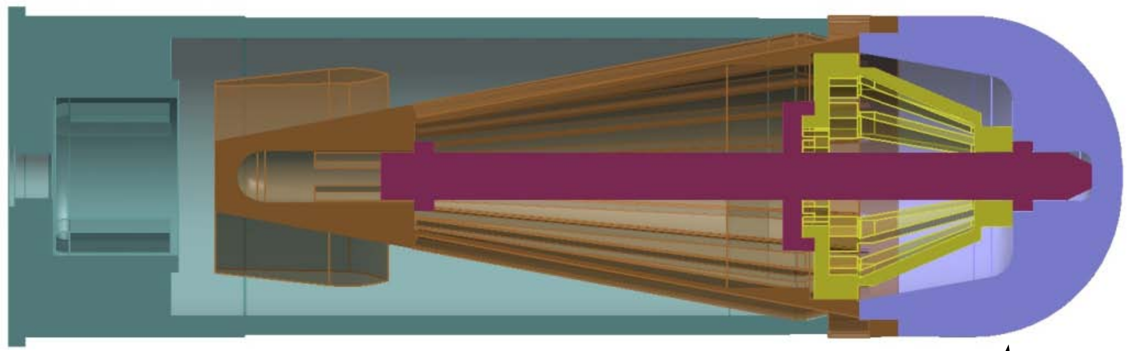
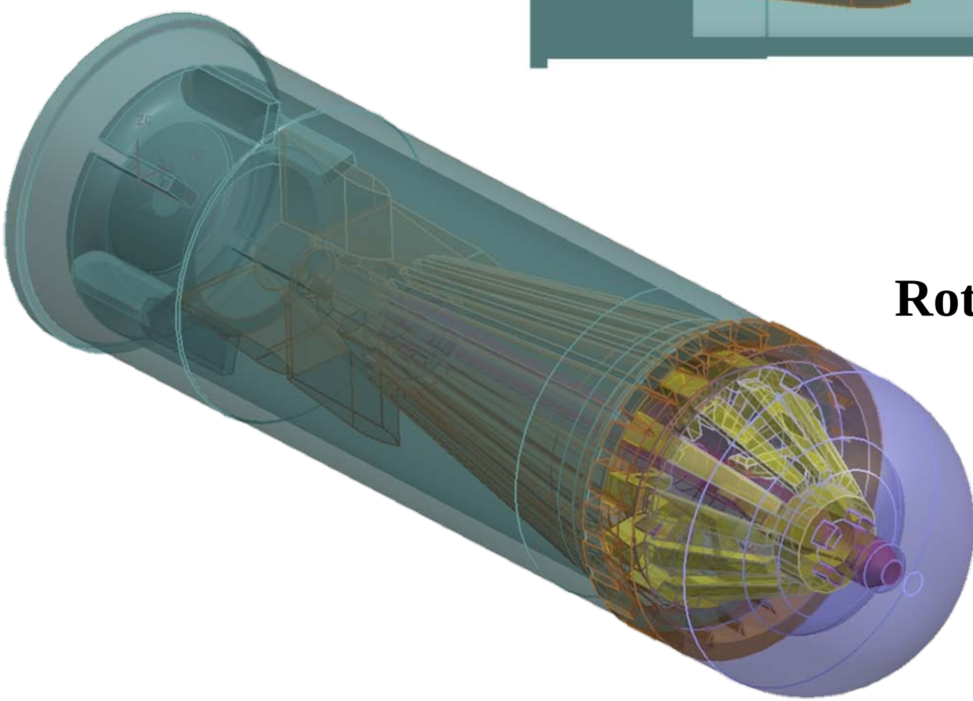
- 12 gauge
- Fin-Stabilized





Soft Nose Cone
Rotates 45 deg to Set Lethality Mode

Default Mode is Non-Lethal

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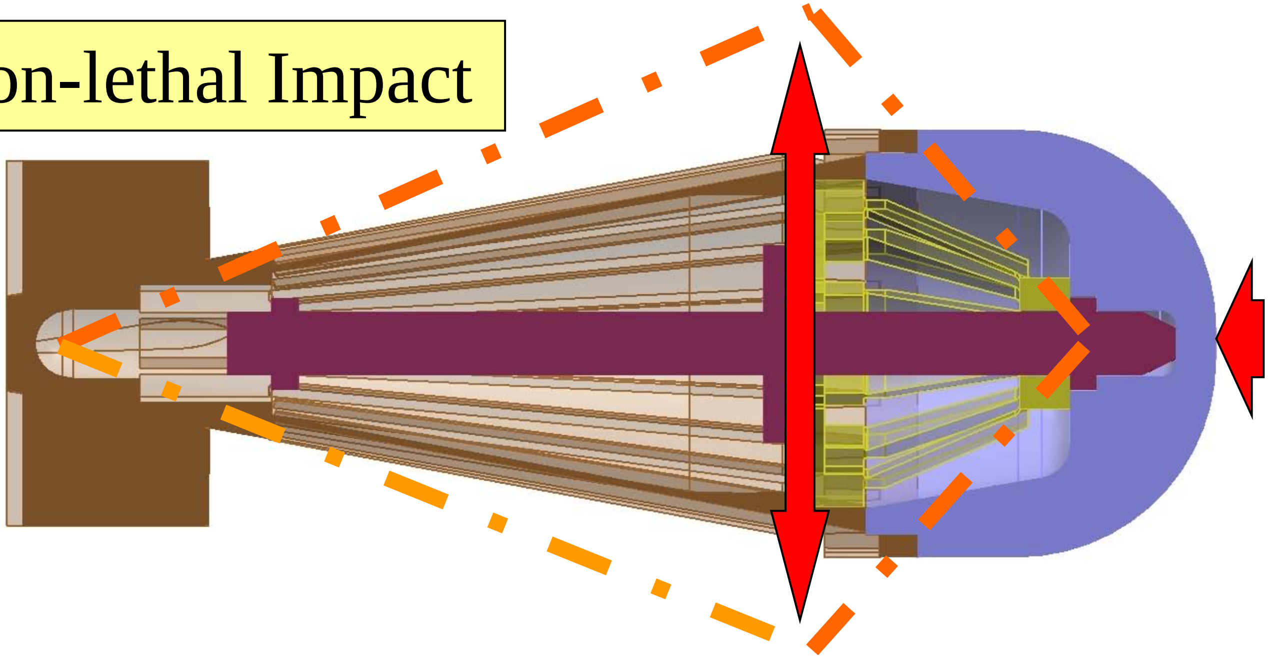
Design Concept M2
Impact Mode Characteristics

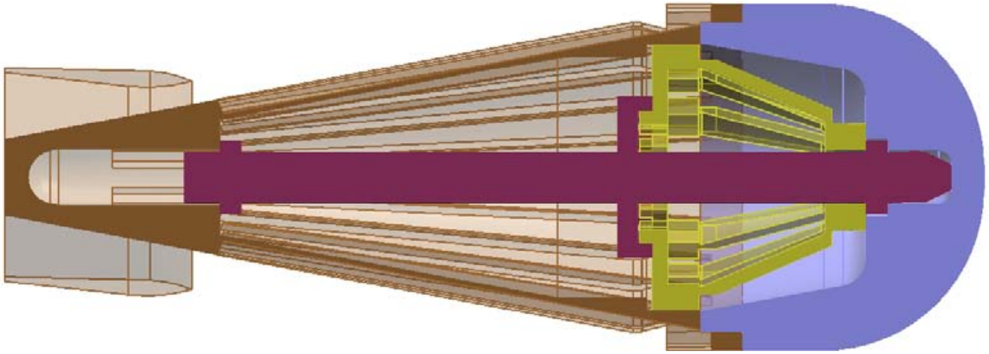
Non-lethal Impact



Projectile Expands Upon Impact, Absorbing and Distributing Impact Energy

Lethal Impact

Projectile maintains integrity and delivers Lethal effects to target



Evaluation of Design Concept M2 Frangible Projectile

Stabilization Method	L-NL Trajectory Match	Muzzle Velocity	Terminal - Non-Lethal		Lethal
			Muzzle Energy Density	Max Range	Energy Density @ 100m
Fin	Yes	475	<52 ft-lbs/in^2	50 m	NA

Advantages

- Identical propulsion
- Identical trajectories
- Settings reversible

Disadvantages

- May be difficult to obtain large difference in terminal effects
- Lethal range <100m

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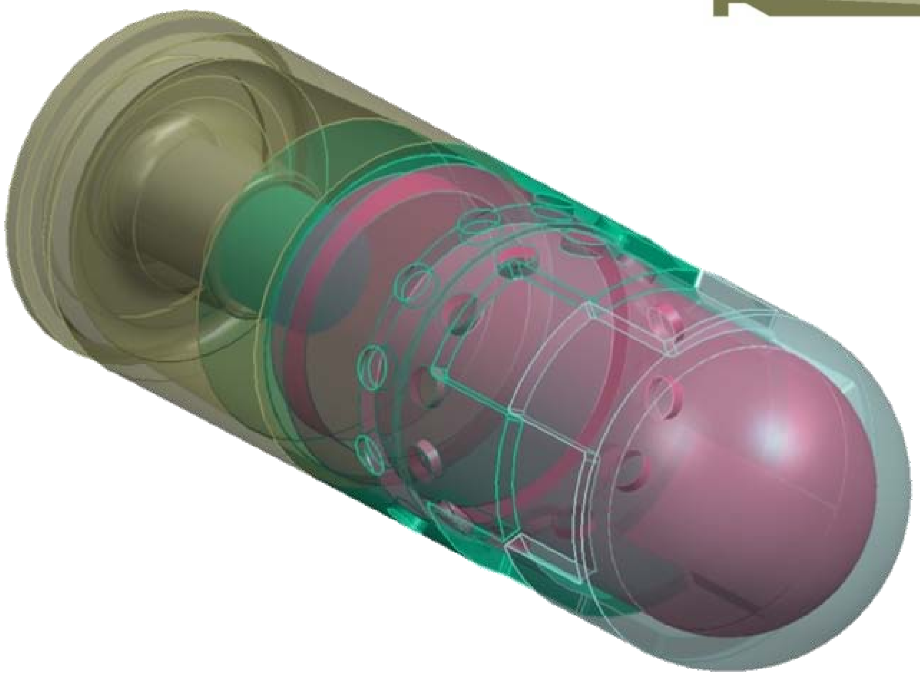
Design Concept M3
Liquid Filled Projectile

Variable Proj Mass	✓
Variable Proj Velocity	
Variable Impact Area	

- 40 mm
- Spin-Stabilized

Projectile Body Rotates to Set Lethality Mode

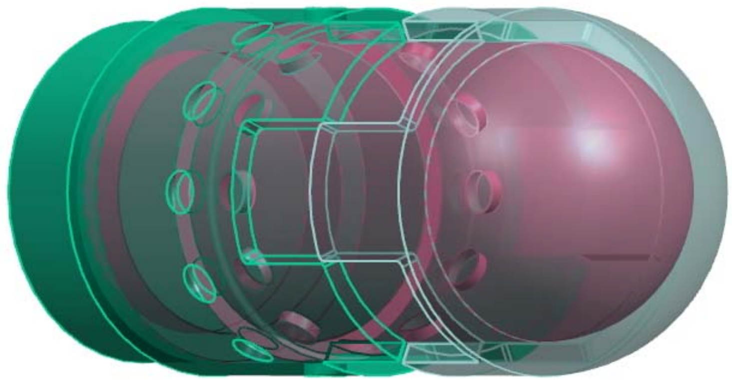


Default Mode is Non-Lethal

Design Concept M3
Impact Mode Characteristics

Non-lethal Impact

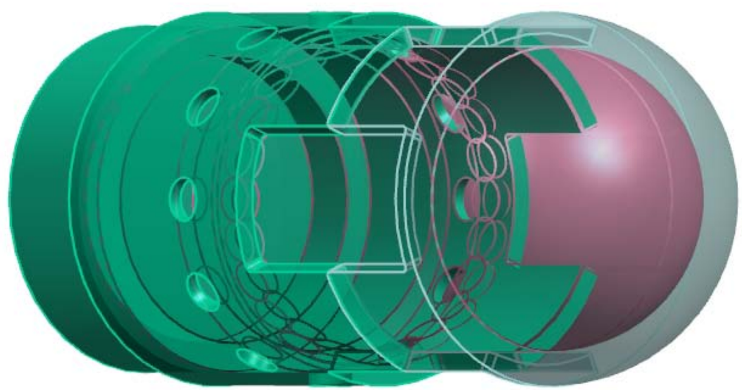
During projectile compression, holes align and allow liquid/gel to escape, reducing mass & absorbing energy



Nose cone tabs misaligned with base to allow for compression

Lethal Impact

Projectile maintains its shape and mass during impact producing lethal effects



Nose cone and base of projectile aligned, nose cone cannot move.

Evaluation of Design Concept M3 Liquid Filled Projectile

Stabilization Method	L-NL Trajectory Match	Muzzle Velocity	Terminal - Non-Lethal		Lethal
			Muzzle Energy Density	Max Range	Energy Density @ 100m
Spin	Yes	175	<52 ft-lbs/in^2	35 m	NA

Advantages

- Identical propulsion
- Identical trajectories
- Settings reversible

Disadvantages

- Sealing
- Structural integrity under launch loads
- Lethal range <100m

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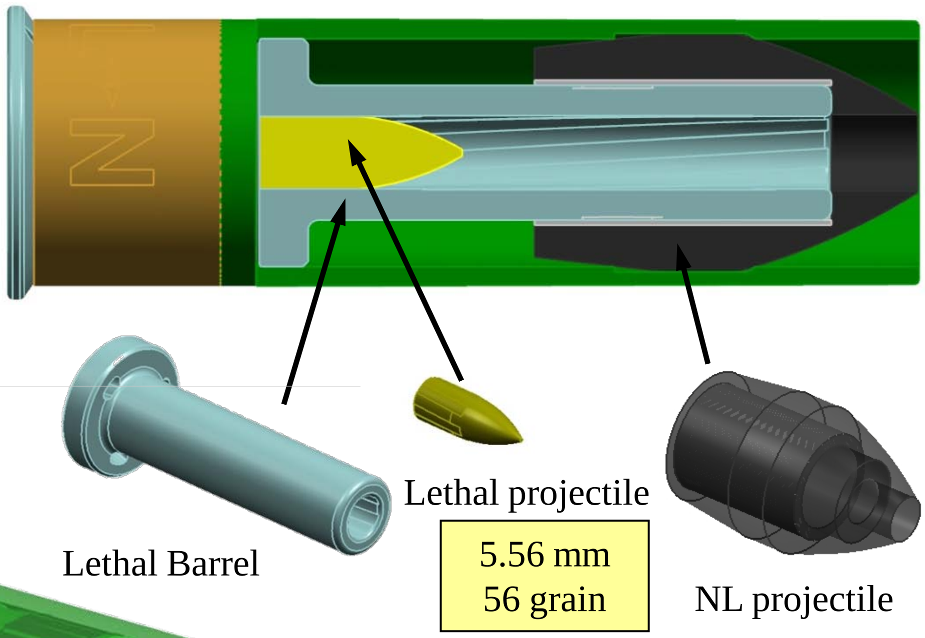
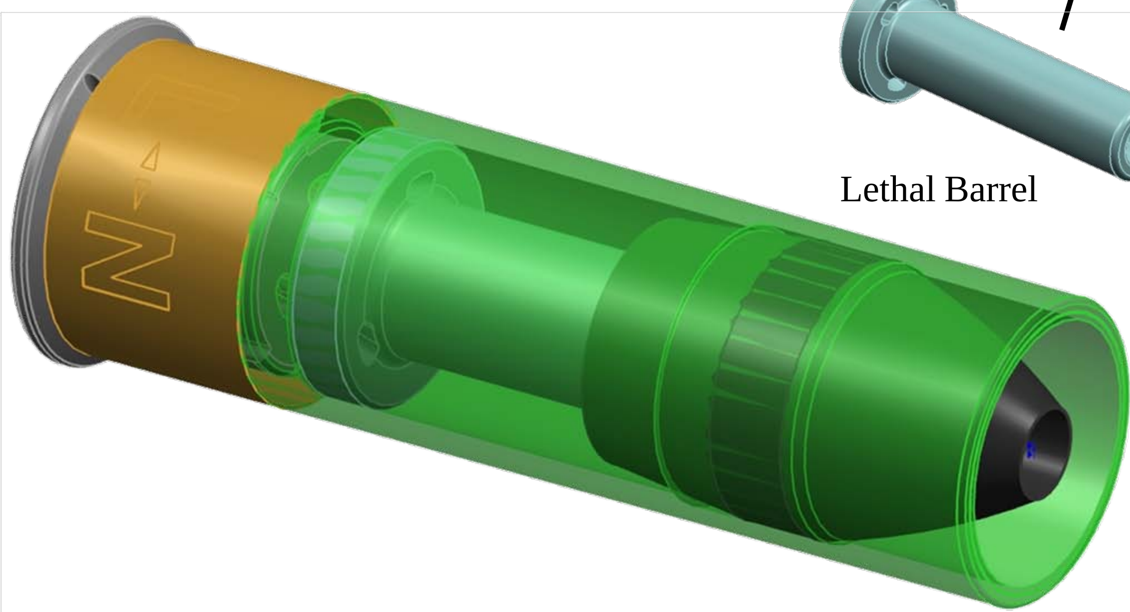
Design Concept M4
Subcaliber Dual Projectiles

Variable Proj Mass	✓
Variable Proj Velocity	✓
Variable Impact Area	✓

- 12 gauge
- Spin-Stabilized

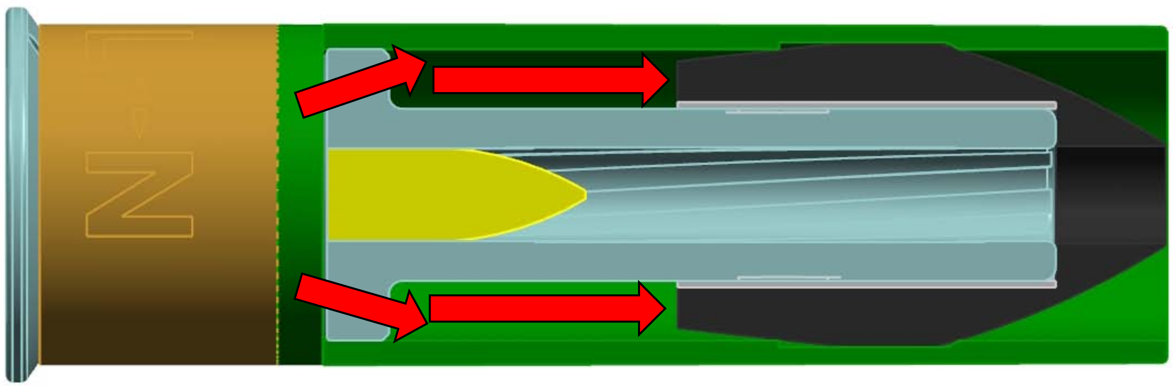




Design Concept M4
Operating Mode Characteristics

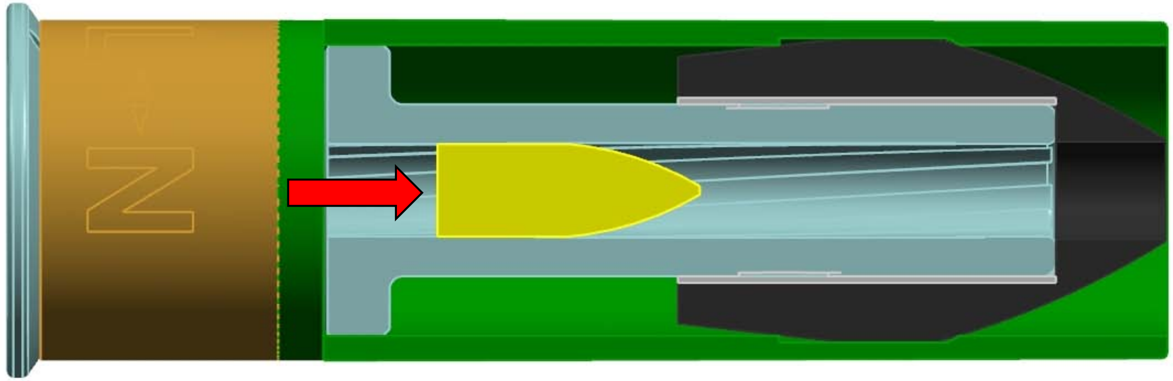
Non-lethal Operation

Propellant gasses directed to launch non-lethal projectile only



Lethal Operation

Propellant gasses directed to Launch lethal projectile only



Evaluation of Concept M4 Subcaliber Dual Projectiles

			Terminal - Non-Lethal		Lethal
Stabilization Method	L-NL Trajectory Match	Muzzle Velocity	Muzzle Energy Density	Max Range	Energy Density @ 100m
Spin	No	350	<52 ft-lbs/in^2	65 m	340 ft-lbs/in^2

Advantages

- Separate projectiles allow independent optimization for function
- Settings reversible

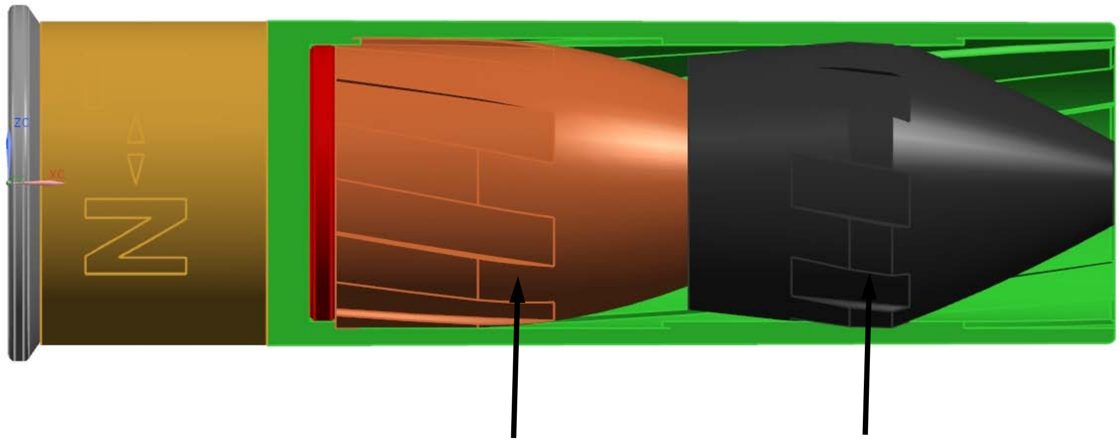
Disadvantages

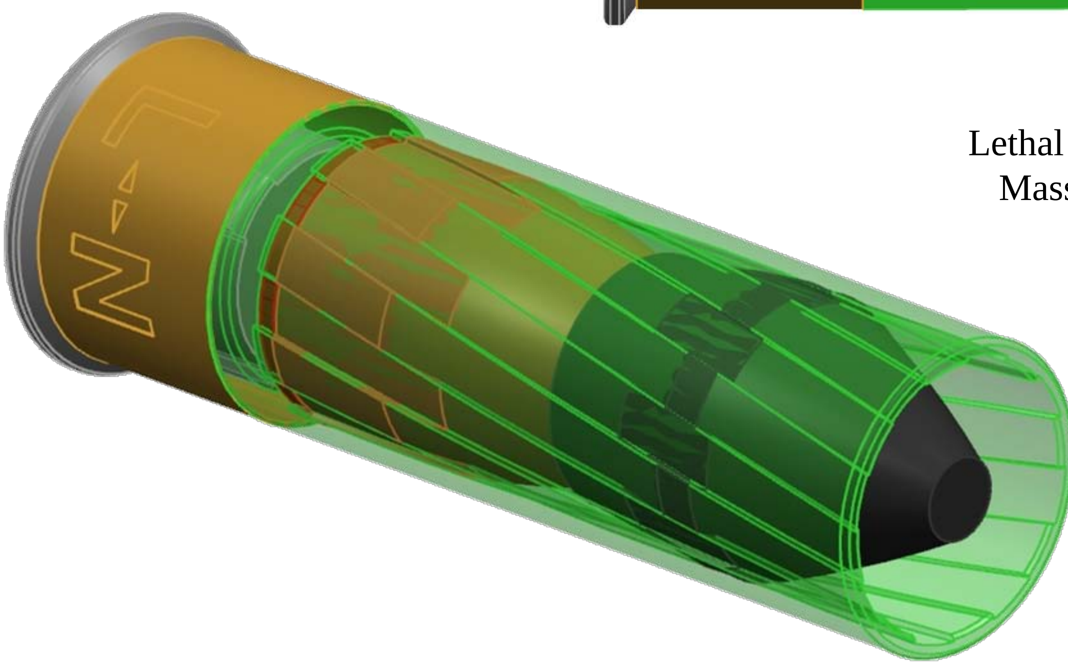
- Different trajectories/aiming for each projectile type
- Potential lethal projectile accuracy reduction- relies on cartridge case alignment in weapon
- Weight/cost of subcaliber barrel assembly

Design Concept M5
Tandem Dual Projectiles

Variable Proj Mass	✓
Variable Proj Velocity	
Variable Impact Area	

- 12 gauge
- Spin-Stabilized

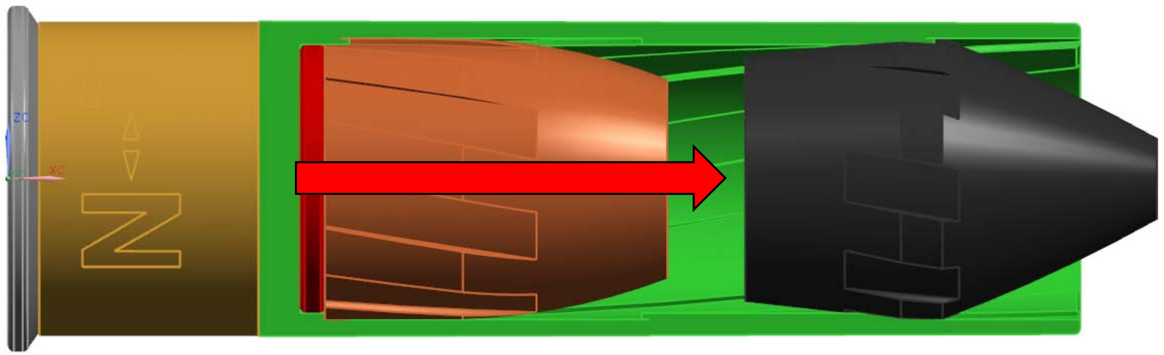




Design Concept M5
Operating Mode Characteristics

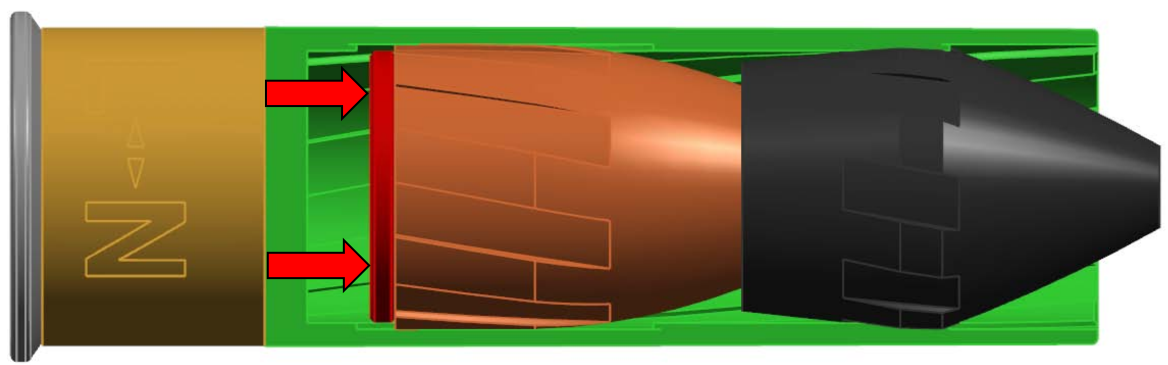
Non-lethal Operation

Propellant gasses directed to launch non-lethal projectile only



Lethal Operation

Propellant gasses directed to launch lethal and non-lethal projectile in tandem



Non-lethal projectile falls away after barrel exit, lethal projectile proceeds to target

Evaluation of Design Concept M5 Tandem Dual Projectiles

Stabilization Method	L-NL Trajectory Match	Muzzle Velocity	Terminal - Non-Lethal		Lethal
			Muzzle Energy Density	Max Range	Energy Density @ 100m
Spin	No	260	<52 ft-lbs/in^2	120 m	125 ft-lbs/in^2

Advantages

- Separate projectiles allow independent optimization for function
- Settings reversible
- Same launch velocity for each projectile
  - If desired, provides capability for differing launch velocities for each projectile

Disadvantages

- Requires rifled casing
- Potential for non-lethal projectile to disturb flight of lethal projectile during muzzle exit transition

Concept Evaluation Summary

Concept		Lethal vs Non-lethal Control Parameters			Weapon	Stabiliz Method	L-NL Traj Match?	Muzzle Velocity	Terminal- Non-lethal		Lethal
		Variable Mass	Variable Velocity	Variable Impact Area					Muzzle Energy Dens	Max Rng (≤ 26 E.D.)	Energy Dens @ 100 m
C1	Chemical Hardening			✓	12ga	Fin	Yes	300 fps	<52 ft-lbs/in^2	120 m	60 ft-lbs/in^2
M1	Nested Dual Projectiles	✓		✓	40mm	Fin	Yes	220	<52	120	95
M2	Frangible Body			✓	12ga	Fin	Yes	475	<52	50	NA
M3	Liquid Explusion	✓			40mm	Spin	Yes	175	<52	35	NA
M4	Subcaliber Dual Projectiles	✓	✓	✓	12ga	Spin	No	350	<52	65	340
M5	Tandem Dual Projectiles	✓			12ga	Spin	No	260	<52	120	125

Conclusions

- Single cartridge can selectively provide both Lethal and Non-lethal effects
- Lethality control feasible via variable projectile mass, velocity, impact area, or combination
- Tandem Dual Projectiles (Concept M5) offers best tradeoff characteristics => selected for Phase II follow-on technology maturation