Enhanced Fragmentation Studies for a 40mm Dual Purpose Grenade

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Program Overview

- Objective
  - Increase warfighter effectiveness through the use of small fragmenting munitions that provide an increase in Pi/Lethal Area of at least 25% against a specified array of threats in specified scenarios
- Contract
  - NBCH3090001-0003
  - Phase I Design Study
- Quantitative Metrics

		RPP Requirement		
Measure	**Current**	**Threshold (T)**	**Objective (O)**	**TRL Level**
Small Fragmenting Munitions- P(I)	Pi/Lethal Area	25% over current systems	>25% over current systems	Start TRL 2 End TRL 4

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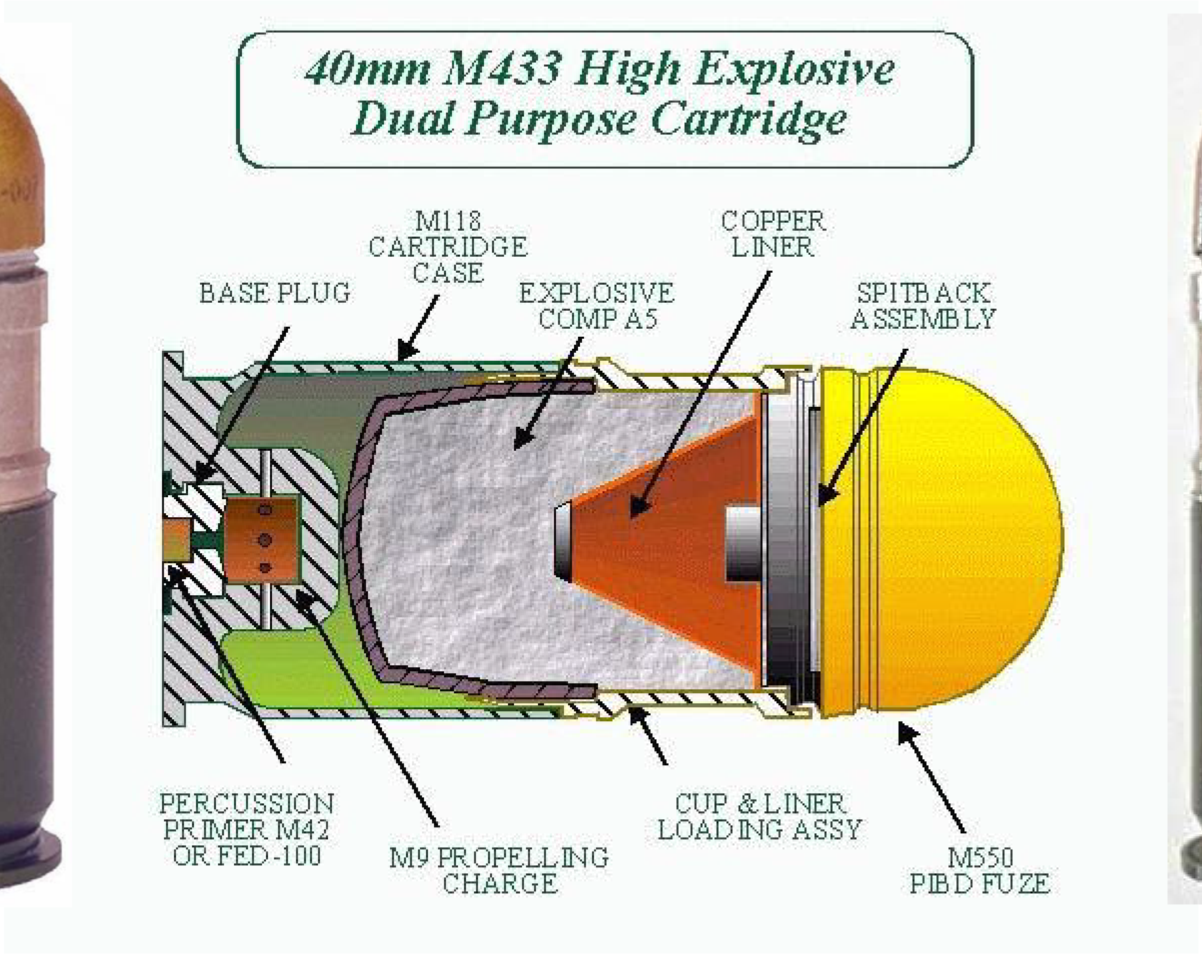
Program Approach

- Improve 40mm M433 dual purpose grenade
- Improve both kill mechanisms
  - Fragmentation- primary emphasis
  - Armor Penetration (shaped charge)- secondary emphasis
  - Combined optimization tradeoffs

M433 40mm HEDP Cartridge



Requirements Analysis- Key Req'ts

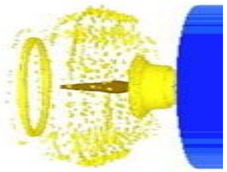
- Maintain dual-purpose projectile design
  - Anti-armor & Anti-personnel
  - Maintain shoulder fire capability (same max impulse)
  - Minimal max range degradation
- Anti-Personnel (Fragmentation)
  - Increase Pi/Lethal Area footprint by 25%
  - Consider full 360 degree lethality effects
  - Consider impact geometry
- Anti-Armor (Shaped Charge)
  - Penetrate RHA- same or better than current
  - Increase behind armor effects

Shaped Charge Tradeoff Analysis

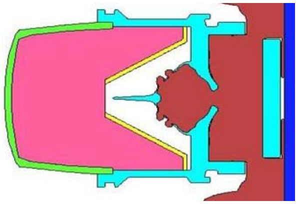
Shaped Charge Modeling Approach (CTH)

2D non-spinning, standoff against RHA

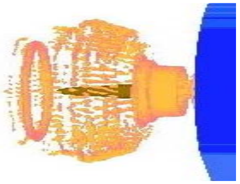
Add spin effects of (2D geometry, 3D CTH)



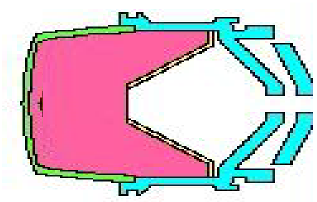
Add spit-back initiation effects



Add 3D fuze component effects with spit-back and spin



2D equivalent geometry of full up 3D run. Utilized for baseline and tradeoffs.



Tradeoff Studies and Performance Measures

- Shaped Charge Trade Studies
  - Detonation Location(s)/ Wave Shaper
  - Liner Geometry
  - Liner Material
  - Explosive Material
  - Confinement
- Performance evaluation measures
  - Spall ring area
  - Spall ½ cone angle
  - Average through hole diameter

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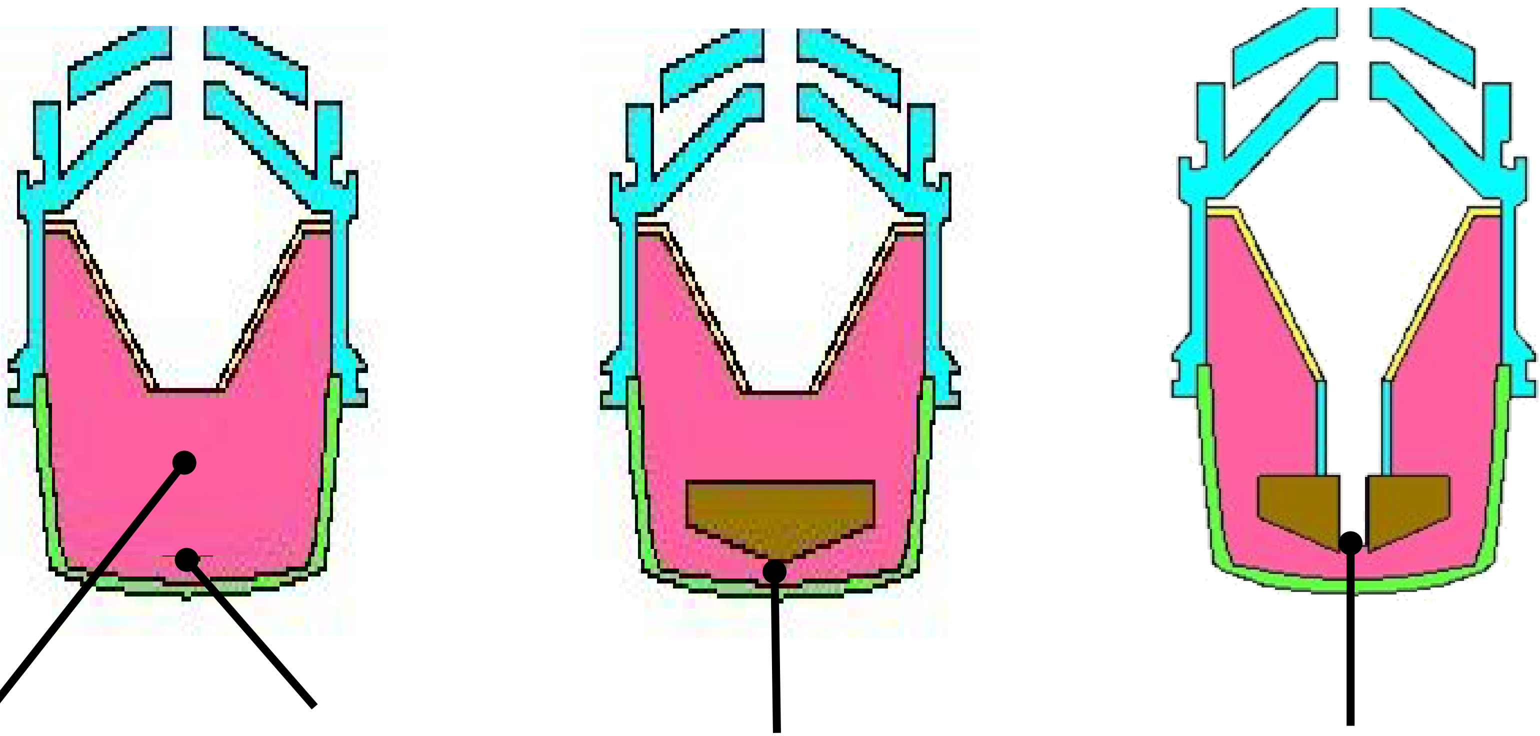
Detonation Location Configurations



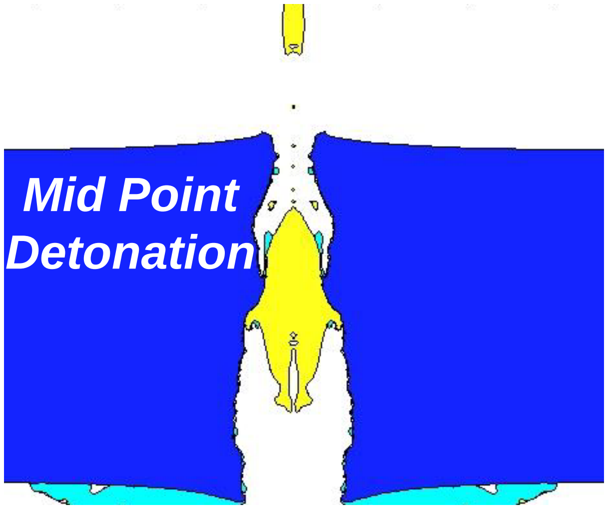
Midpoint Detonation

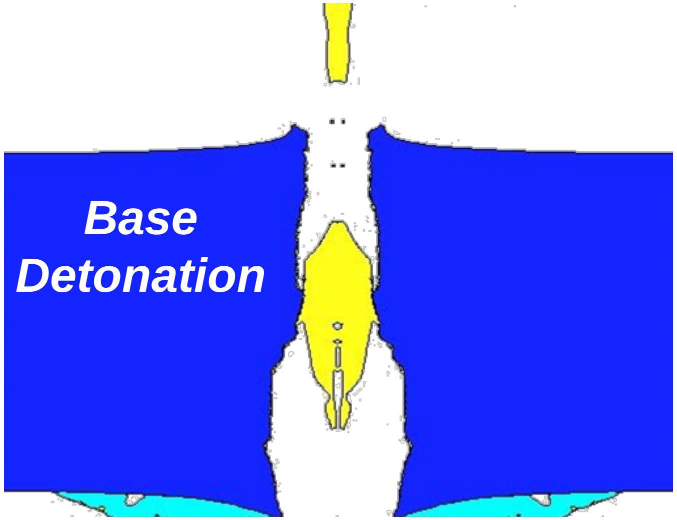
Base Detonation

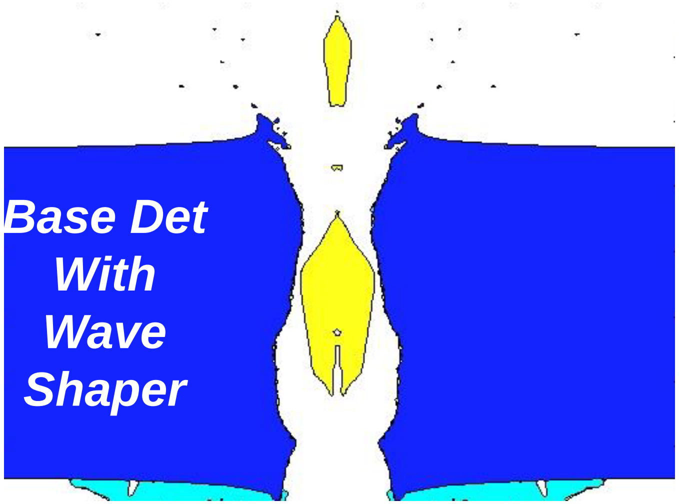
Base Detonation With Waveshaper

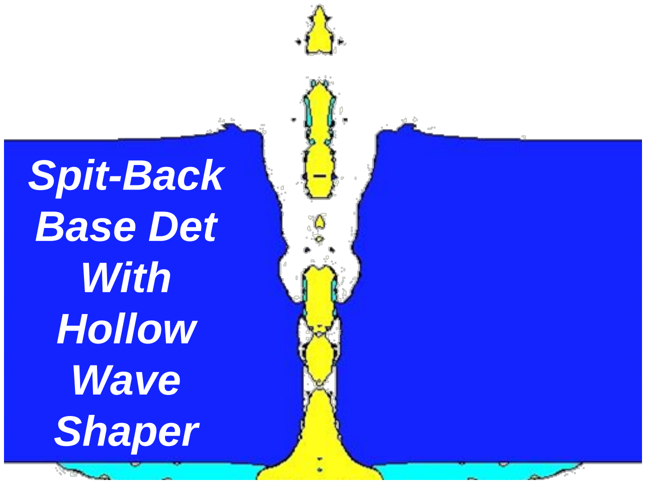
Spit-Back Base Detonation With Hollow Waveshaper

Detonation Location Effect
Target Perforation Characteristics









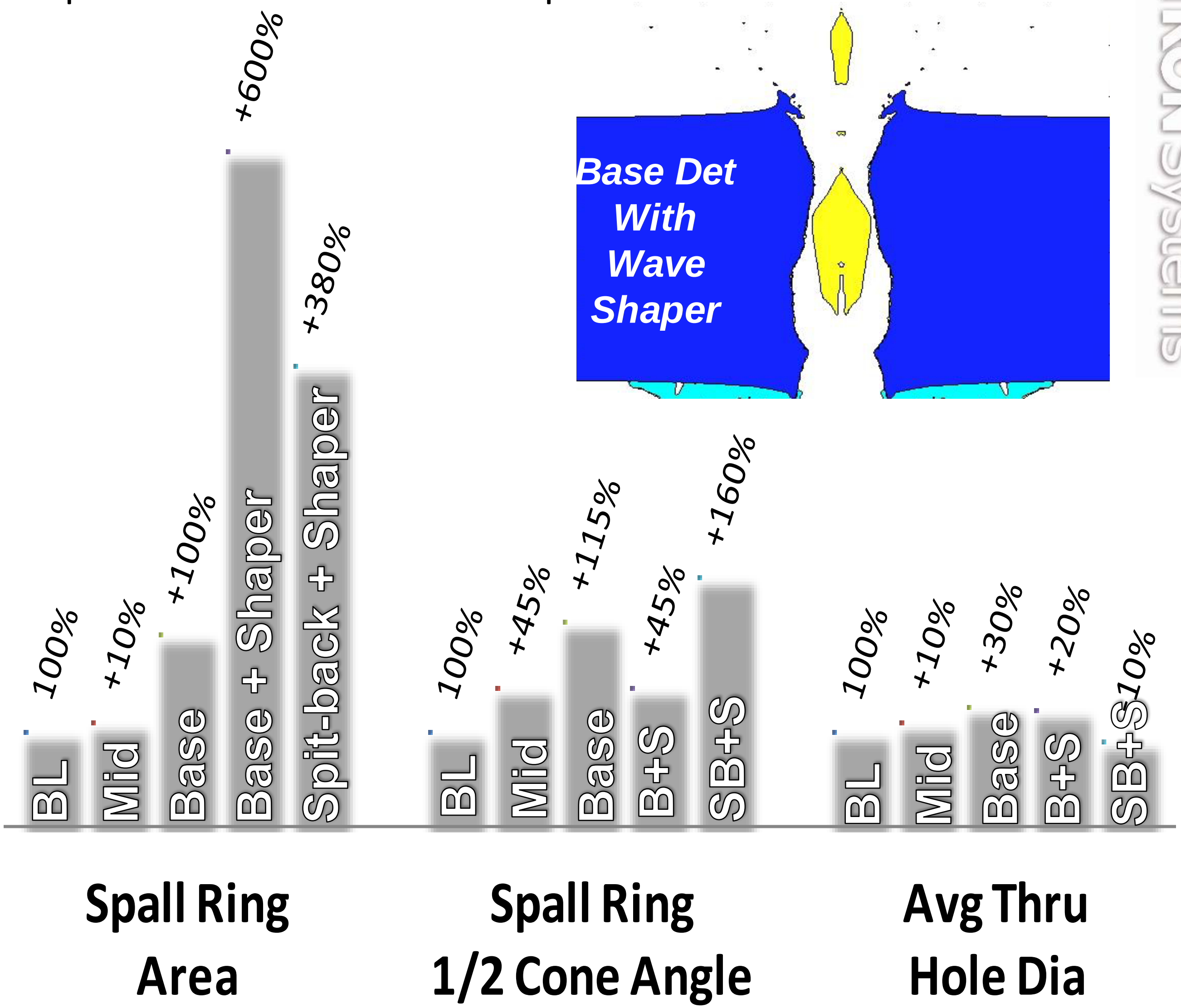
Detonation Location Effect

Configuration

- No other changes to M433 baseline

Conclusions

- Base detonation with wave shaper offers significant benefit
- Spitback initiation with hollow wave shaper enhances performance and allows current fuze arrangement



Liner Apex Angle Effect

Liner Included Angle

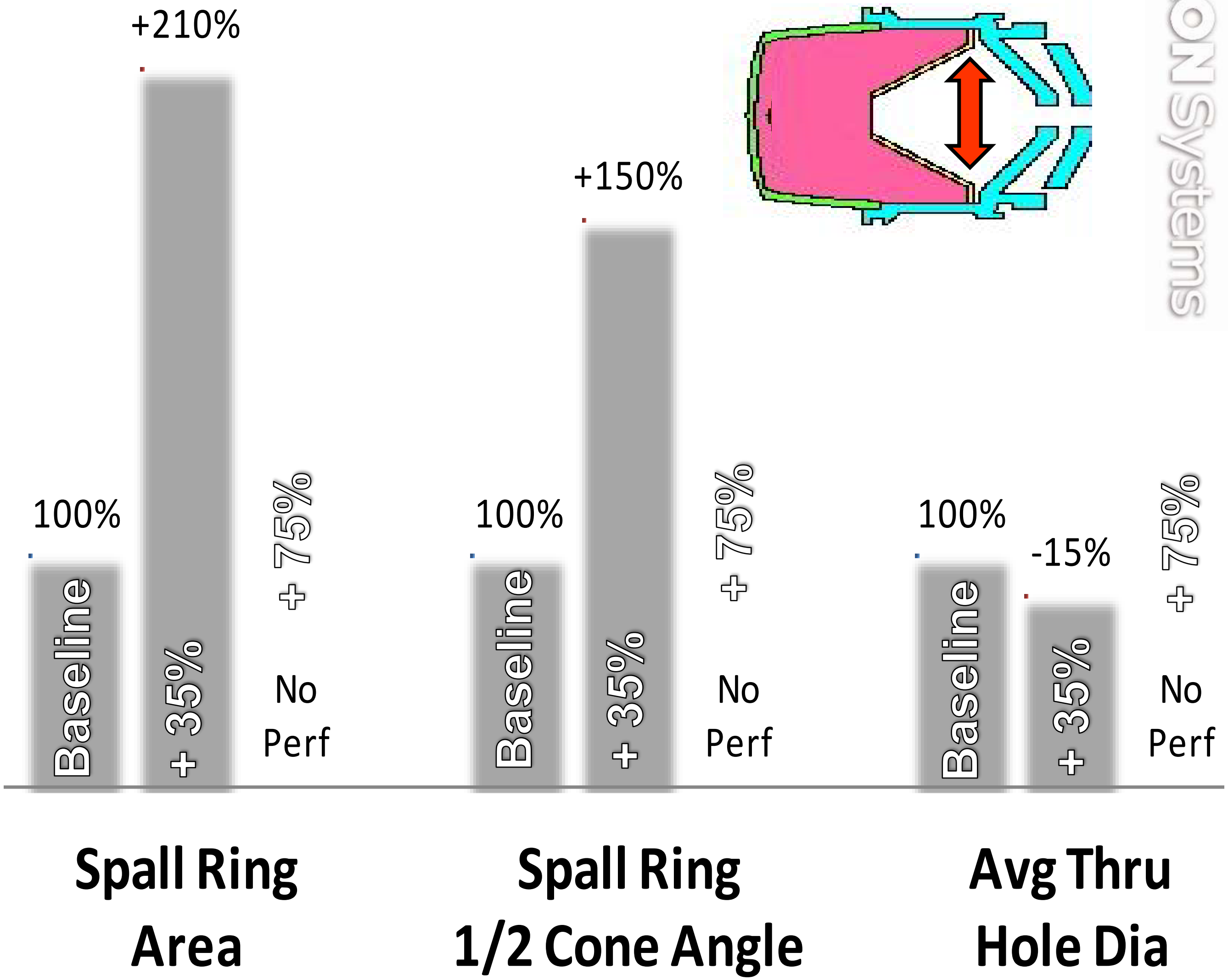
- Baseline
- \+ 35%
- \+ 75%

Configuration

- Liner thickness increased 50% with angle increase
- No other changes to M433 baseline

Conclusions

- Moderate increase in apex angle beneficial



Liner Material Effect

Materials

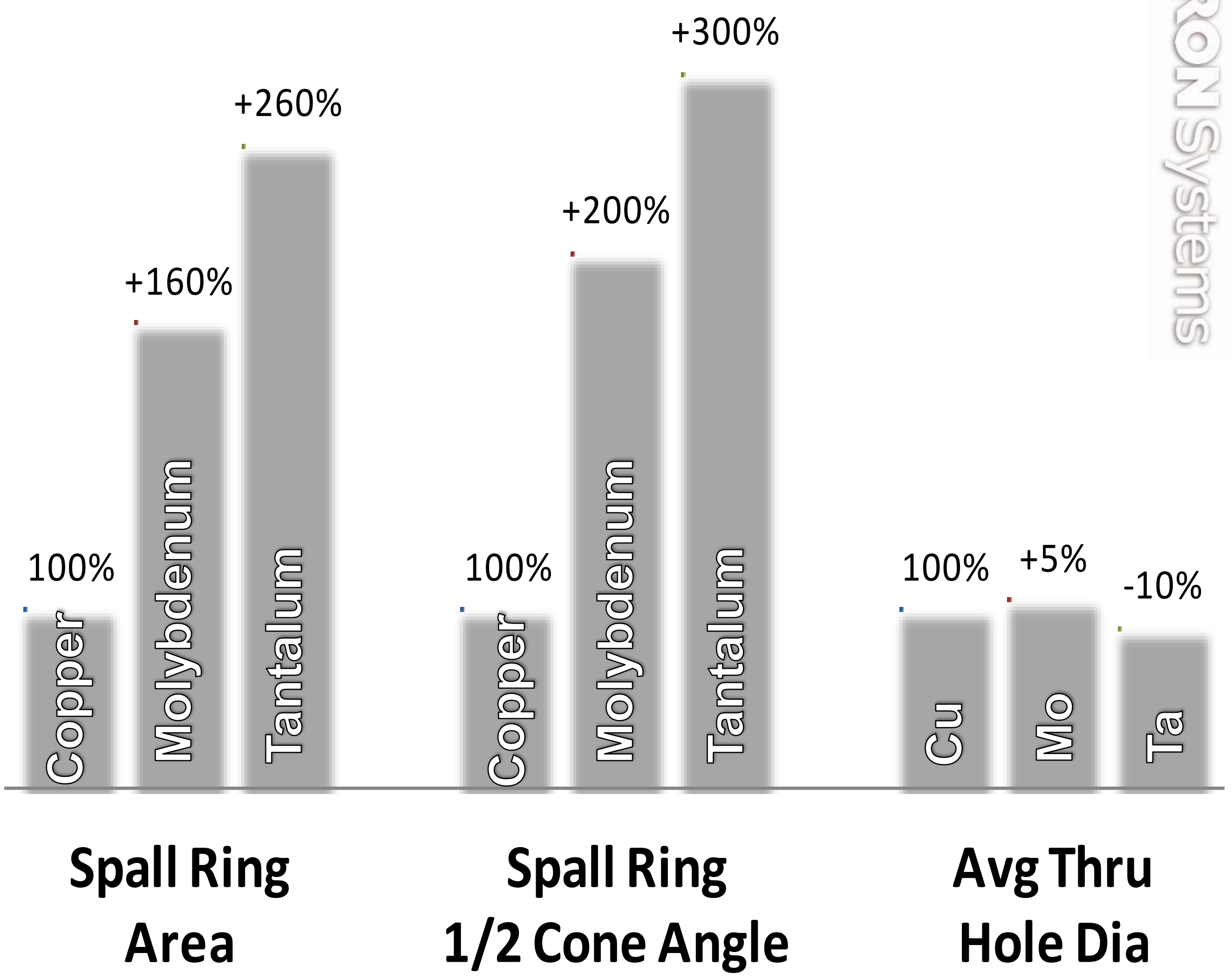
- Copper (baseline)
- Molybdenum
- Tantalum
- Both materials more dense

Configuration

- Liner thickness scaled to obtain equal mass for all materials
- No other changes to M433 baseline

Conclusions

- Significant gain with increased density



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Explosive Material Effect

Explosive

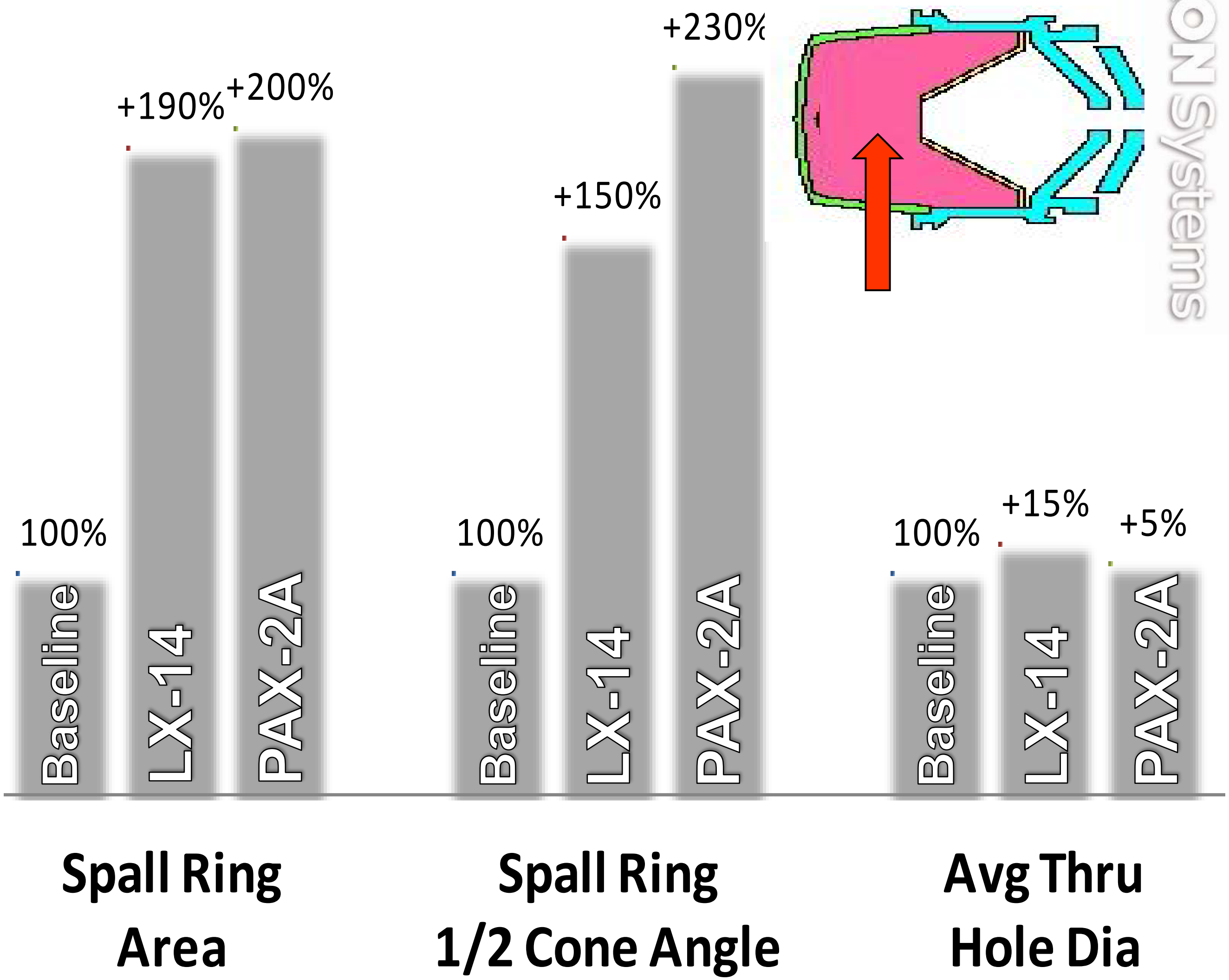
- Baseline- Comp-A5 (modeled A3)
- LX-14
- PAX-2A (IM Compliant)

Configuration

- No other changes to M433 baseline

Conclusions

- Both replacement explosives offer significant benefit
- PAX-2A gives best performance



Casing Confinement Material Effect

Explosive

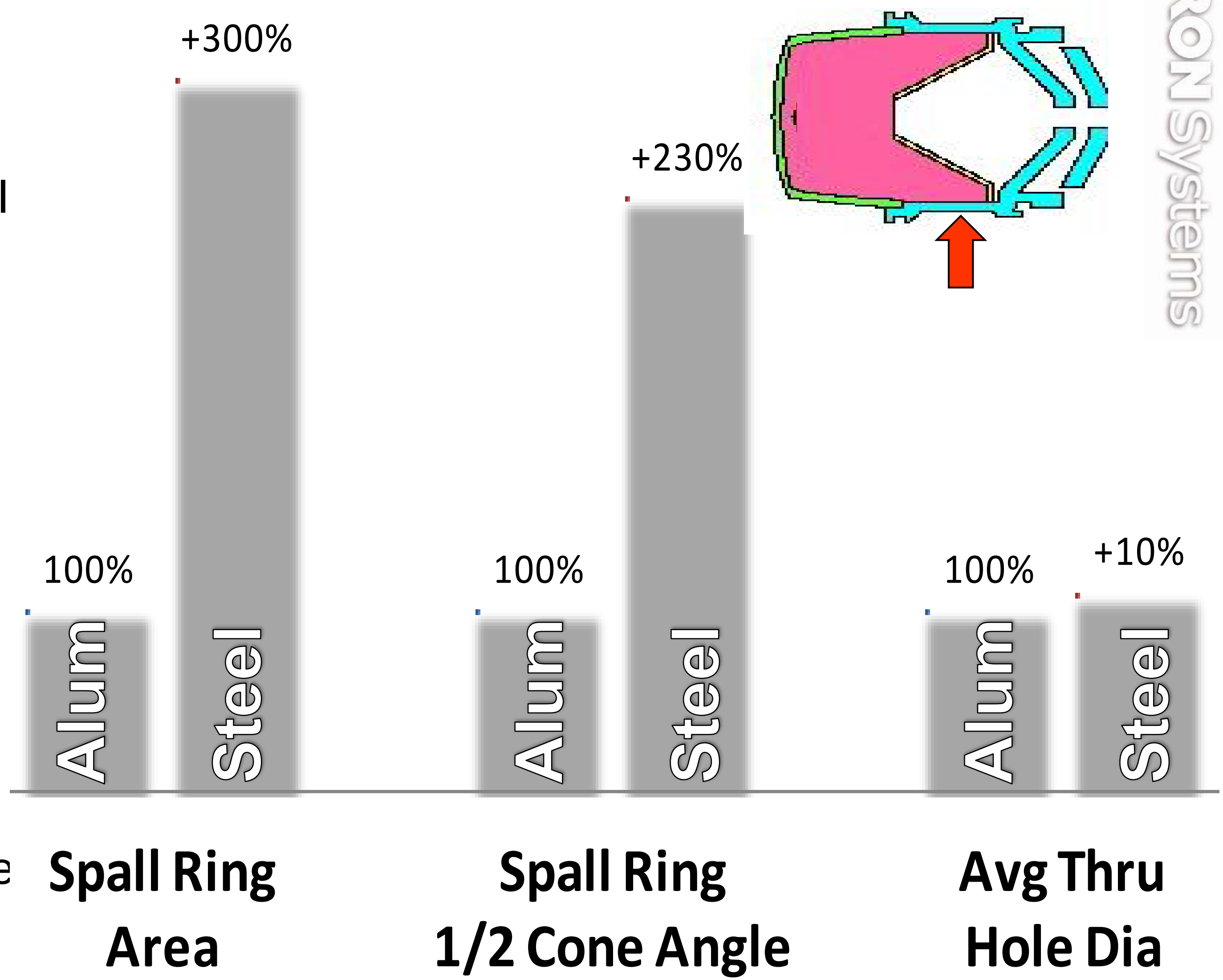
- Baseline- Aluminum
- Substitute steel

Configuration

- No other changes to M433 baseline

Conclusions

- Offers significant benefit
- Weight increase a consideration



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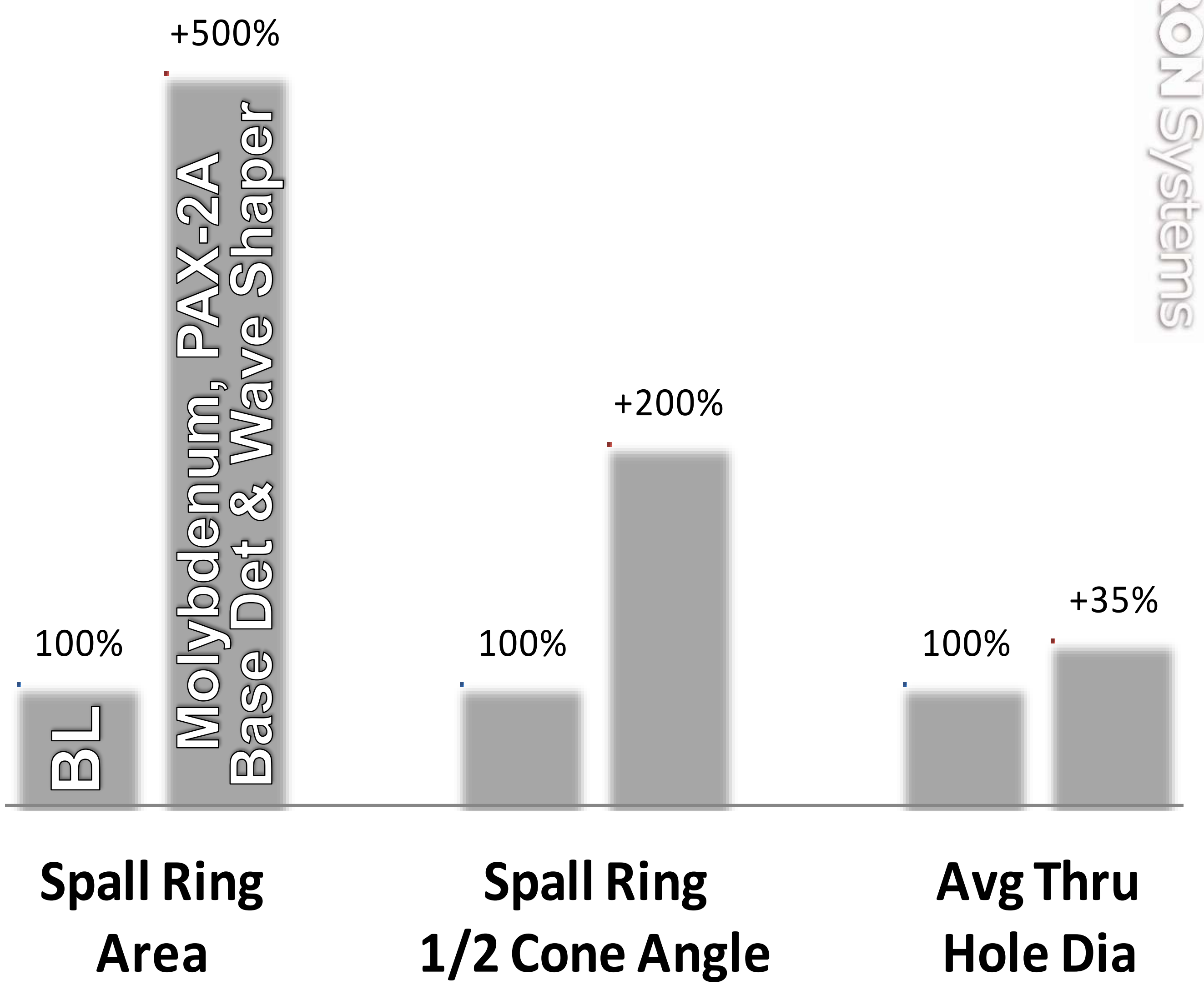
Combined Improvement Effects

Representative Improvements

- Molybdenum liner
- PAX-2A explosive
- Base initiation with wave shaper
- No other changes to M433 baseline

Conclusions

- Significantly exceeds program goals



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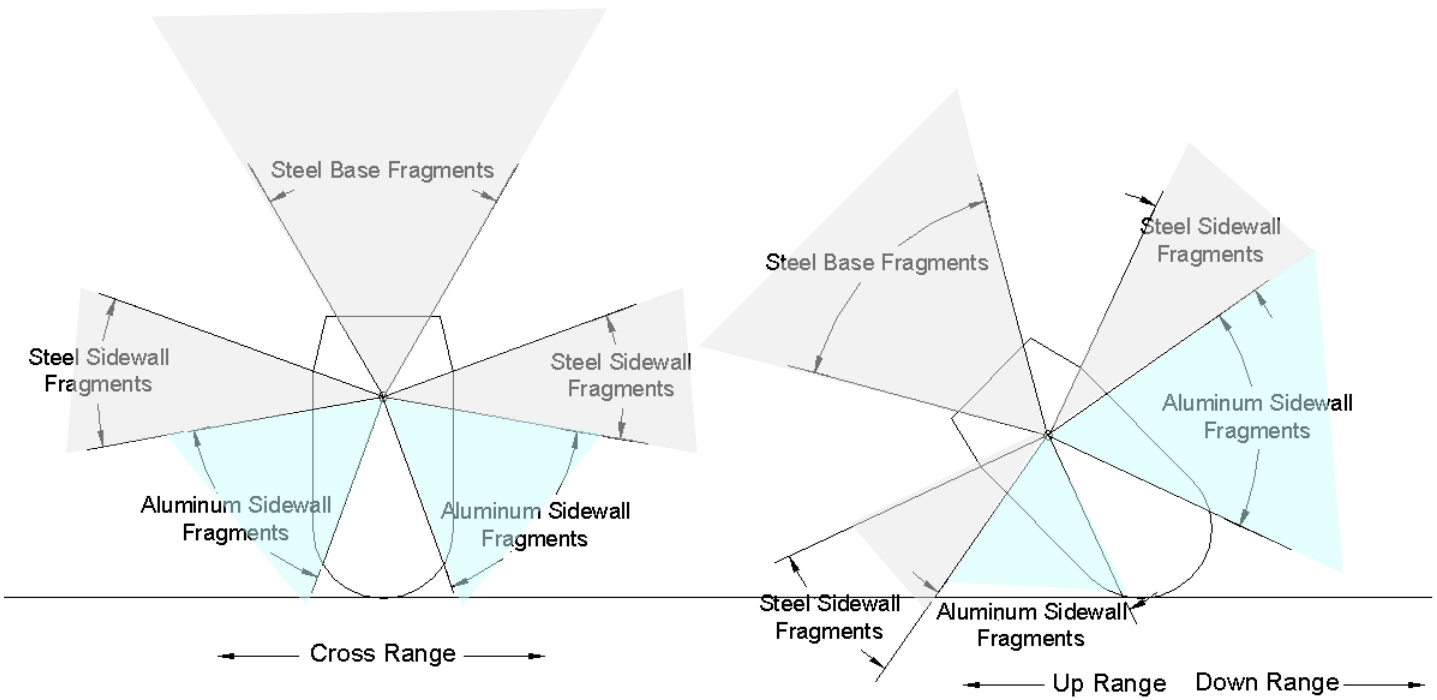
Conclusions- Shaped Charge

- All options improved performance
  - Detonation Location(s)/ Wave Shaper ....***+600%***
  - Liner Design.. ***+210%***
  - Liner Material.. ***+260%***
  - Explosive Material...***+200%***
  - Confinement.. ***+300%***
  - Implementation complexity varies
- Combining options provides significant improvements
- Performance potential significantly exceeds program goals
- Provides trade space for fragmentation improvements

Fragmentation Tradeoff Analyses

Baseline Fragmentation Distribution

- Cross range- Fragmentation primarily from sidewall of steel cup
- Up range- Primarily steel fragments from cup base
- Down range- Primarily aluminum sidewall fragments



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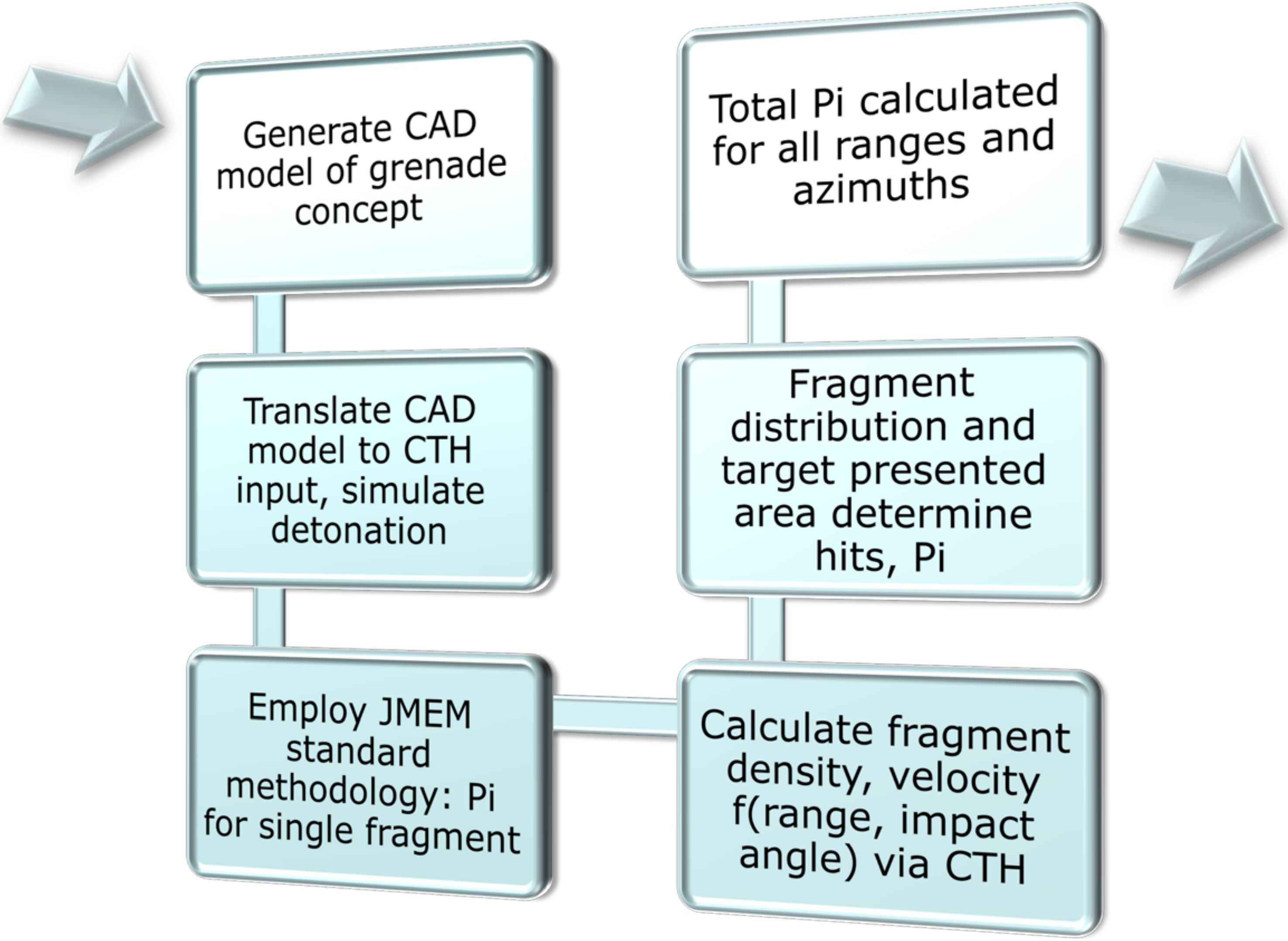
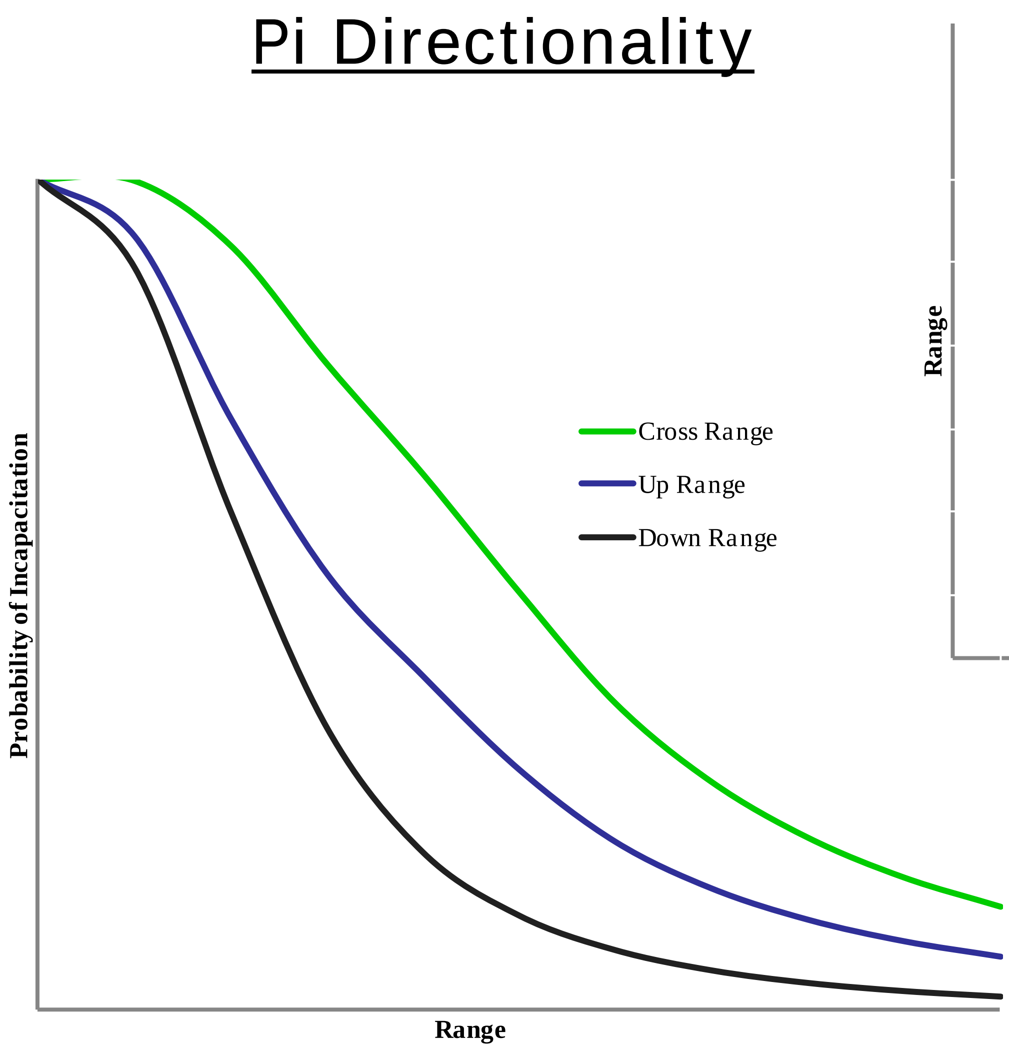
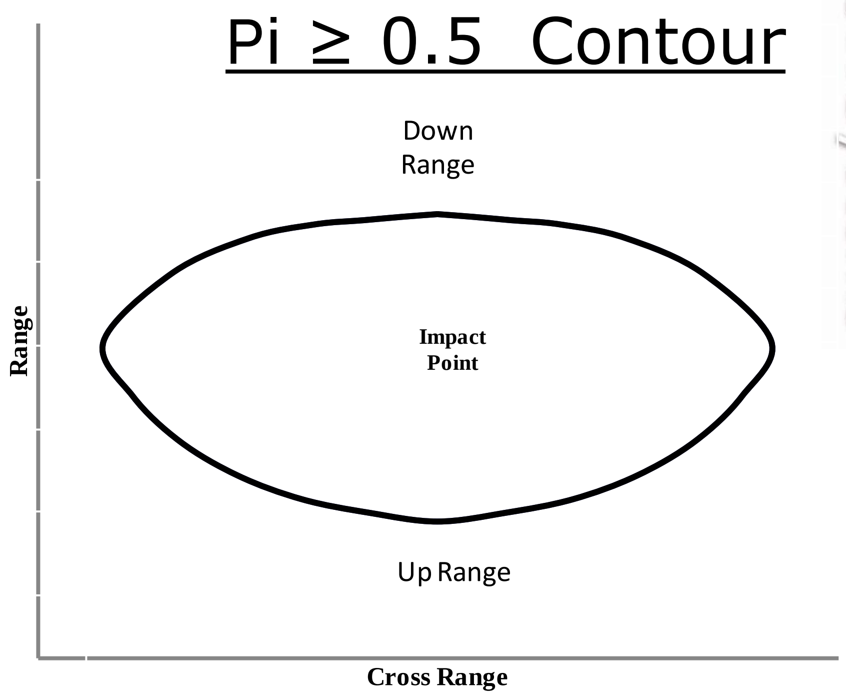
Fragmentation Lethality Analysis Approach



Baseline Fragmentation
Lethality Directionality





Fragmentation Performance Evaluation Parameters

Items From Shaped Charge Study	Additional Fragmentation Specific Items
Detonation Location	Fragment Shape
Detonation Wave Shaper	Fragment Material
Explosive Material	Number of Fragments
Liner Material	Total Fragment Mass
Liner Shape	Warhead Shape
Fwd Sidewall Material	

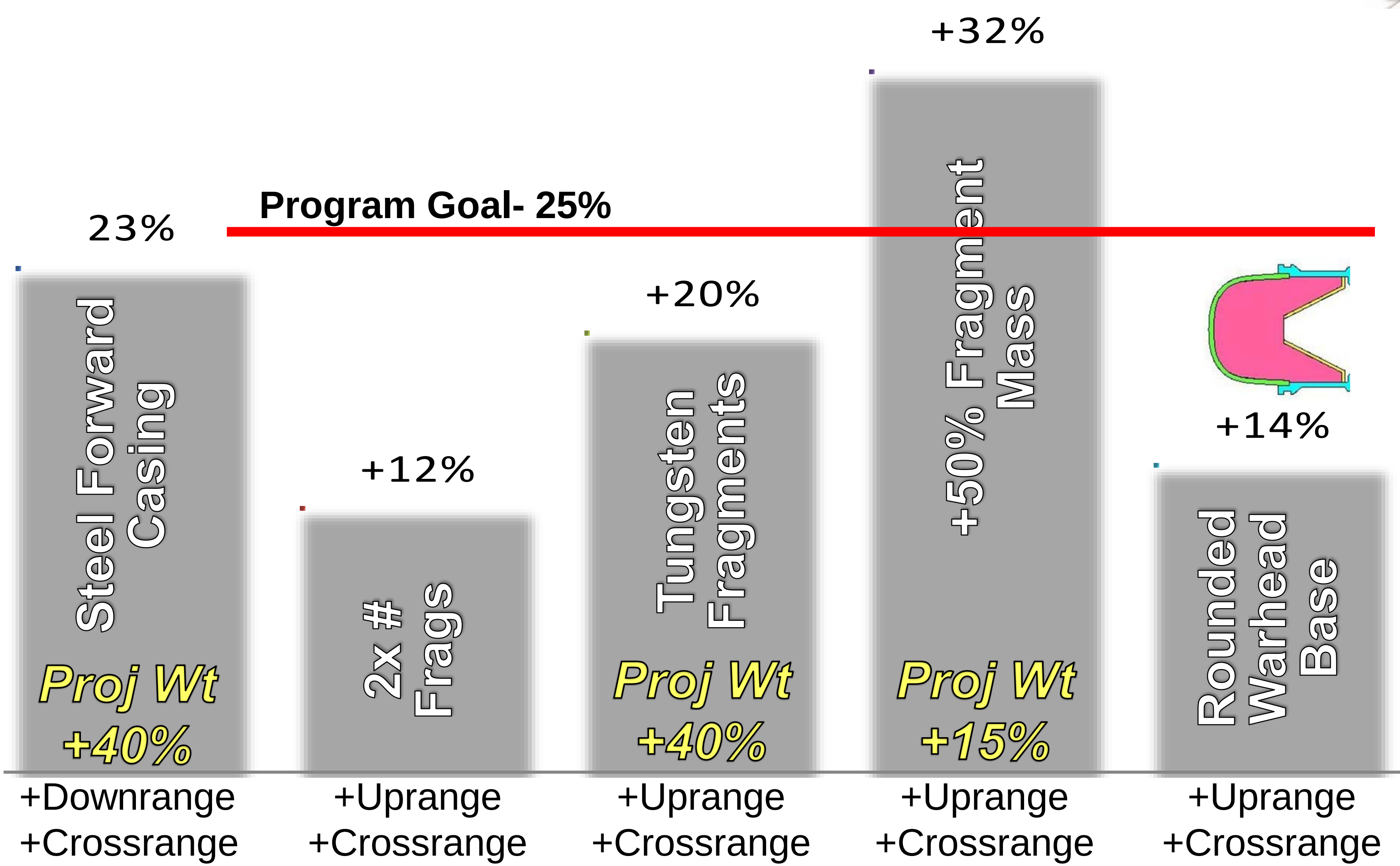
Fragmentation Performance Enhancements

Items with ≤ 10% Improvement

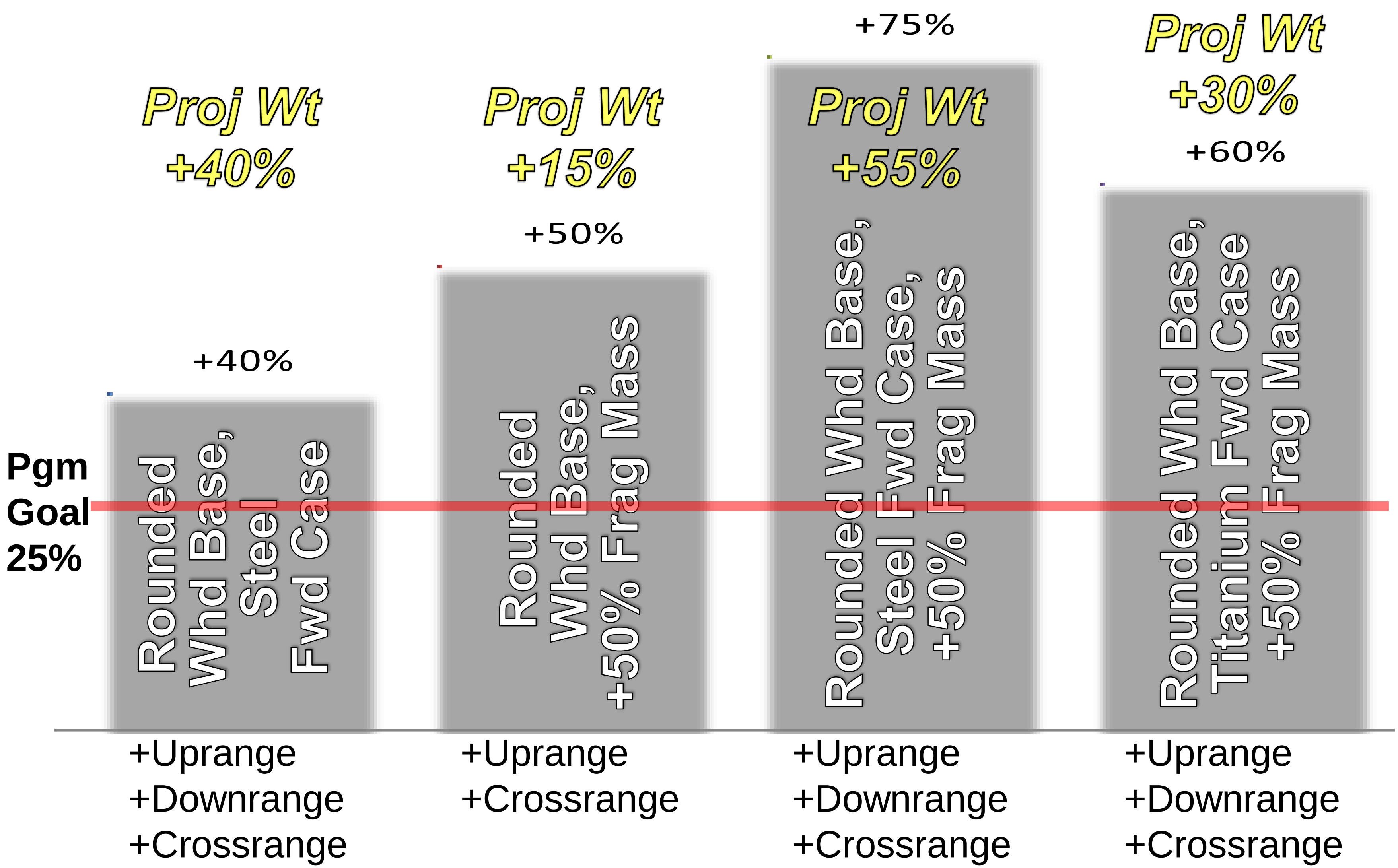
Design Parameter	Evaluation Approach
Detonation Location	Base Detonation
Detonation Wave Shaper	Wave Shaper With Base Detonation
Explosive Material	LX-14, PAX-2A, CL-20
Liner Material	Molybdenum
Liner Shape	Shallower Apex Angle
Fragment Shape	Cubes, Spheres, Rods

- **Designs that benefited shaped charge have negligible benefit to fragmentation**
- **Indicates potential to separate variables for independent optimization**

Fragmentation Performance Enhancements
Lethal Area Improvement



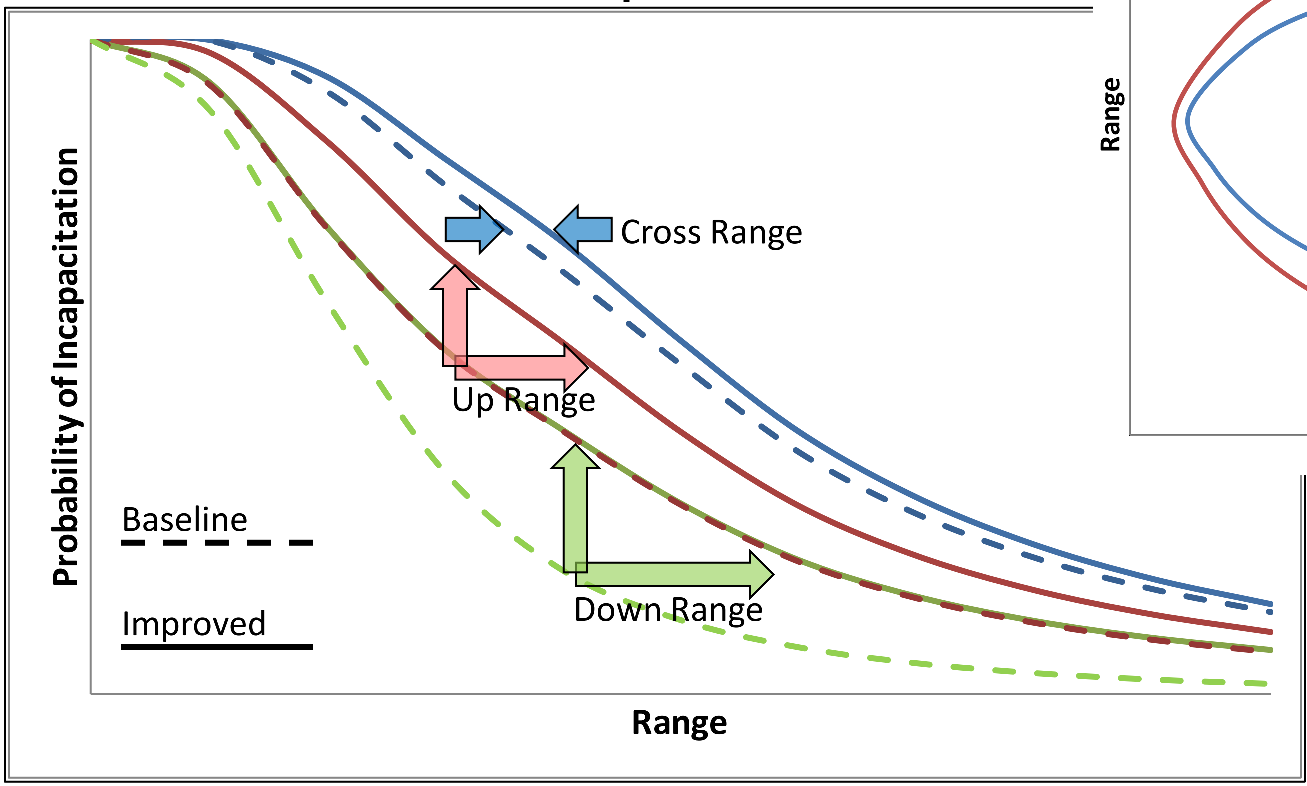
Fragmentation Performance Enhancements
Lethal Area- Combined Improvements



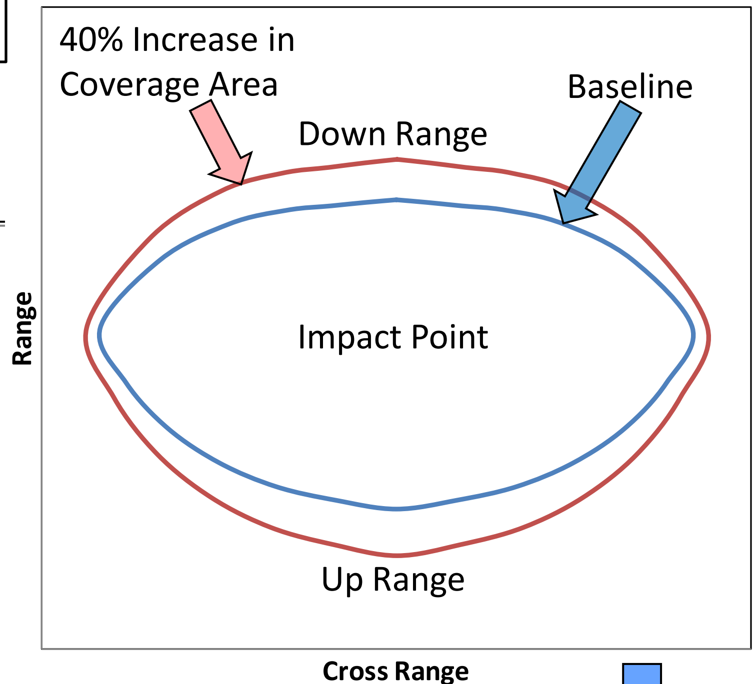
Improved Fragmentation Lethality

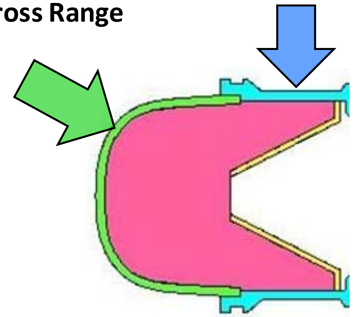
M433 vs. Rounded Warhead Base and Steel Fwd Sidewall

Directional Pi Improvements



Pi ≥ 0.5 Improvements





Conclusions- Fragmentation Improvements

- Individual design improvements offer lower magnitude gains than for shaped charge
- Incremental combination of best designs enable program requirements to be met
- Greatest benefits derive from improving up/down range effectiveness via fragment distribution pattern.
- Can achieve 40-75% improvement in lethal area, exceeds program goals
- Challenge- Most increase projectile weight

Conclusions-
System Improvement Options

- Shaped charge and fragmentation improvement approaches exhibit significant independence of variables
- Improvement potential disproportionally skewed in favor of armor penetration versus fragmentation, not reflective of program goals
- ***Most efficient use of trade space is to reduce shaped charge size/weight allocation to increase fragmentation performance.***

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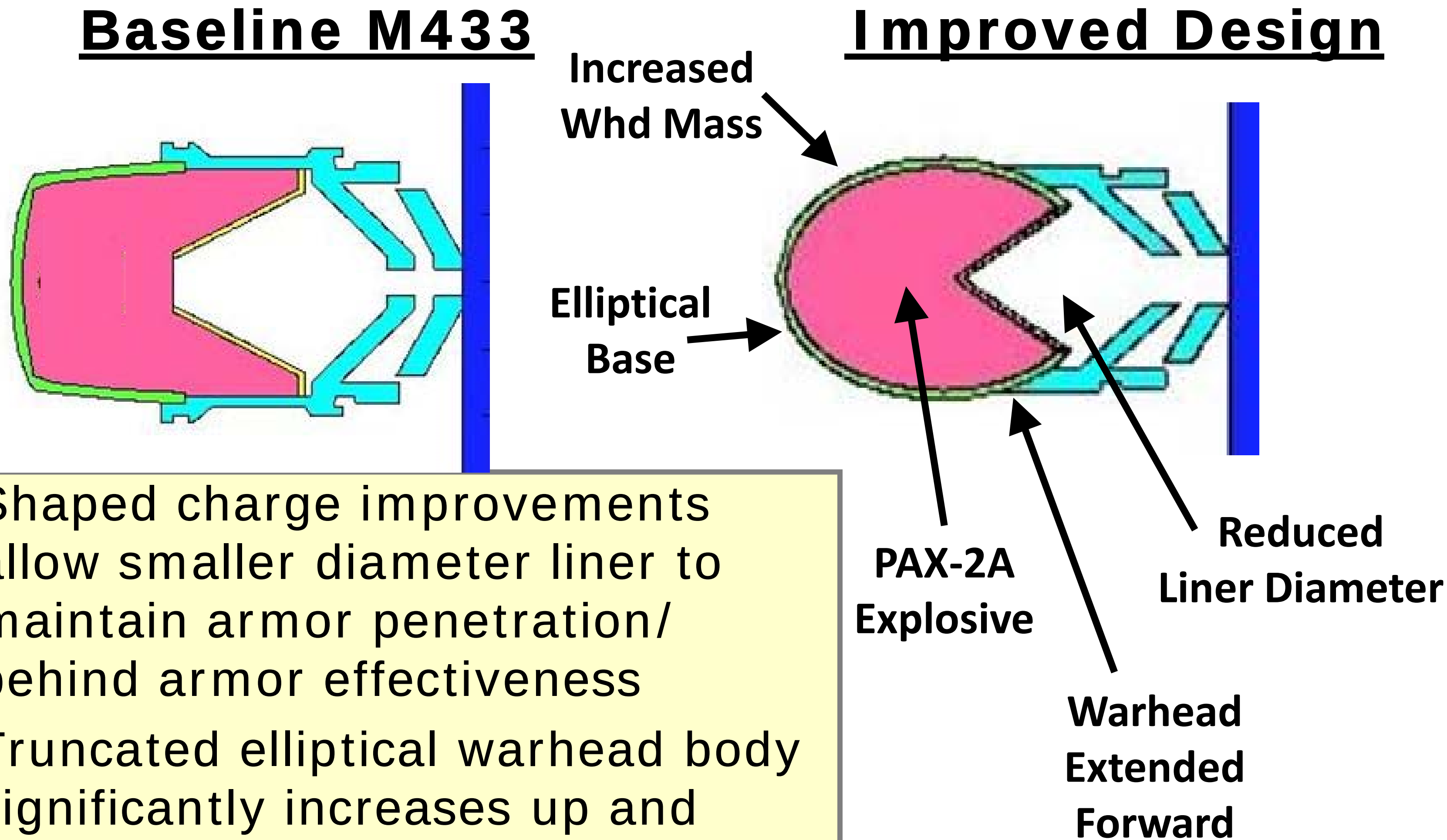
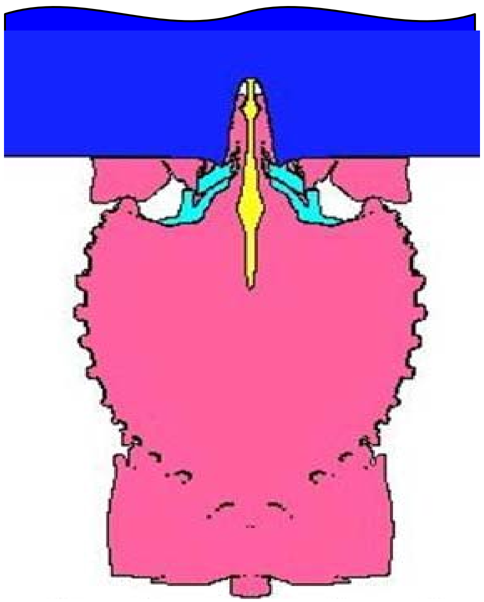
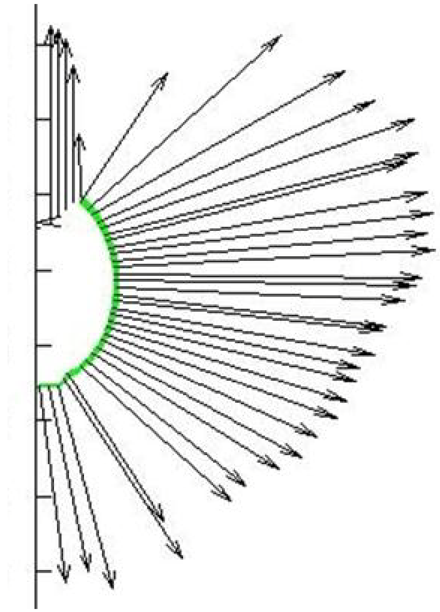
Conclusions- Proposed Grenade Concept

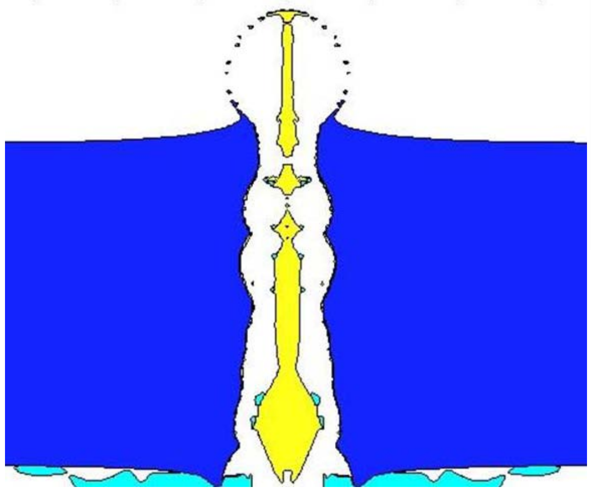


- Shaped charge improvements allow smaller diameter liner to maintain armor penetration/ behind armor effectiveness
- Truncated elliptical warhead body significantly increases up and downrange fragmentation coverage

Conclusions-
Proposed Grenade Concept







- Meets program goal of > 25% Pi/Lethality increase
  - Armor Penetration (shaped charge)
  - Fragmentation
- Applies current warhead and explosive technologies
- Conceptual feasibility established via analysis, additional detailed design required to support hardware implementation