Program Objectives

In support of PM-MAS and JSSAP development programs:

- Determine the viability of using FEA as a tool for **predicting** small arms ammunition terminal ballistic performance

- **Evaluate** the effectiveness of various small arms projectiles, after they have penetrated through metal barriers

- Determine the viability of using FEA as **developmental tool** for small arms ammunition and weapon system development

“Lethality”

“Lethality”

Target Reaction to Hit

Project Focus

Bullet-Target Interaction
- Location of hit
- Target Composition
- Projectile Ballistics

Probability of Hit

Probabilities

Incapacitation

Warfight Actions

Target Actions

RDECOM

Approach

Create Model

- Diverse projectile configurations and calibers evaluated
  - M855, MK262, M995, M855/.265, M855/.308, M855/Pb, M855/Al, M855/ WC
  - Targets: 1/8" Mild Steel, 3/8" Mild Steel, ¼" RHA. ¼" RHA 30 ob
- Material research

Simulate effectiveness

1. Use FEA to Simulate ballistic impact with barrier material
2. Use CFD* as well as analytical means to determine post-barrier projectile drag mechanics
3. Use FEA* as well as analytical/empirical models to simulate the impact of the post-barrier projectile into ballistic gelatin
4. Use physical/empirical models quantify the potential effectiveness against a human target

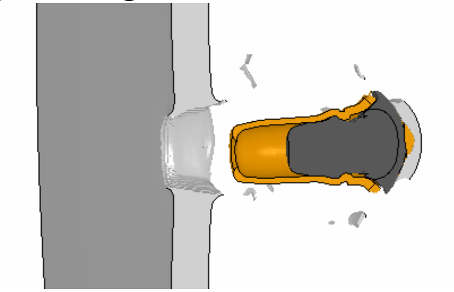
Evaluate

- Briefly compare effectiveness variations against user needs

* On going efforts

Technical Background

1) LS-Dyna impact model generates mass, velocity, shape and orientation of projectiles after passing through a barrier.



2) LS-Dyna output put into Sturdivan-Bexan equations to predict subsequent yaw history in 20% gelatin. Simultaneously, LS-Dyna output with Surdivan-Bexan yaw history placed into Peters equation to predict velocity decay in gelatin

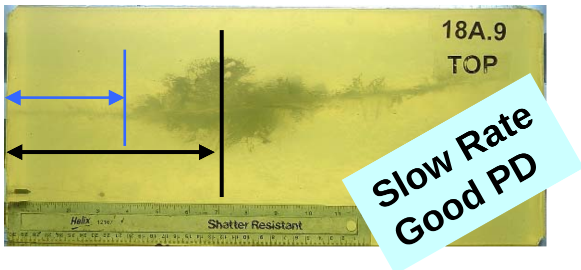
$$V(x) := \sqrt{V_o^{2} \cdot \left[\left[1 + \left(\frac{a \cdot U}{V_o} \right)^{2} \right] \cdot e^{\left(-\frac{\rho \cdot C_D \cdot A}{m} \cdot x \right)} - \left(\frac{a \cdot U}{V_o} \right)^{2} \right]}$$

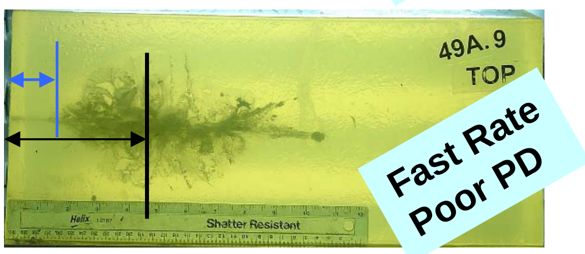
3) Velocity decay information, as well as retained mass from LS-Dyna used to feed EKE equation, providing the final estimation of effectiveness in the human Thorax.

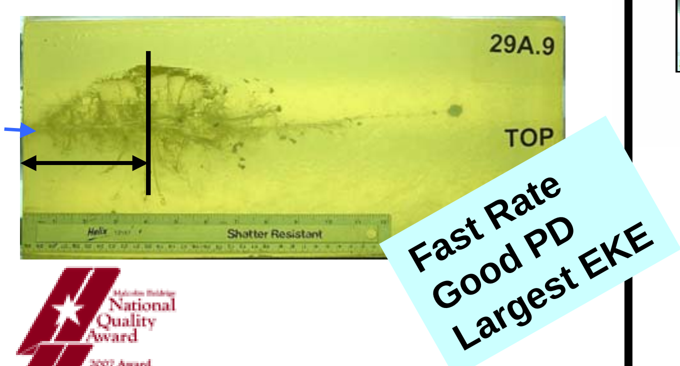
$$EKE = \frac{m}{2} \sum_{x} Pi(\Delta V)^{2}$$

Damaging Soft Targets

Energy Deposit rate and penetration depth

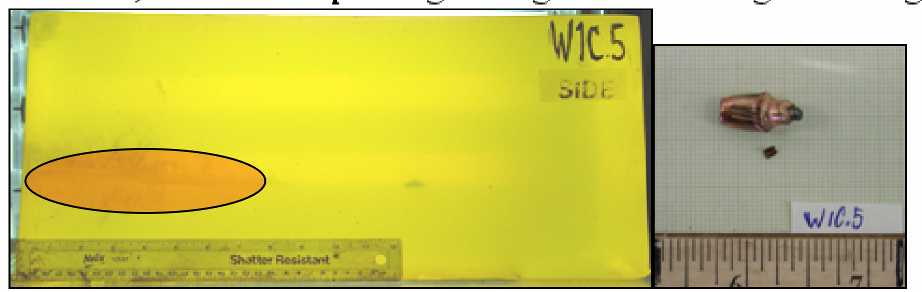






Post Barrier Damage, as a result of projectile mass

5.56mm, M855 after passing through windshield glass into gelatin @ ~ 2700fps



7.62mm, M80 after passing through windshield glass into gelatin @ ~ 2700fps

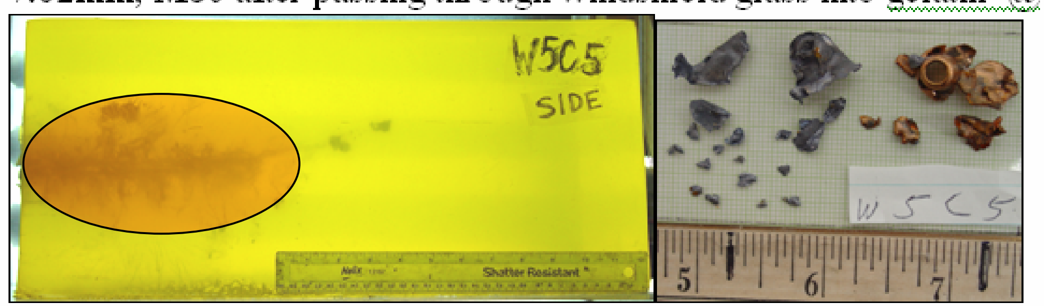
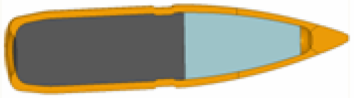
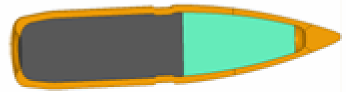
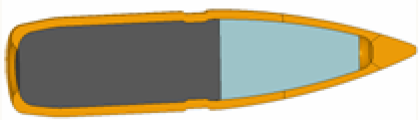
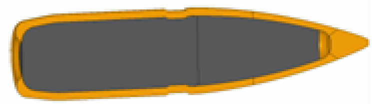
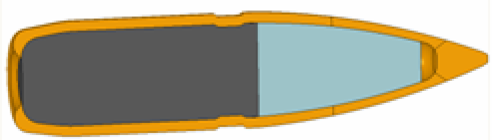
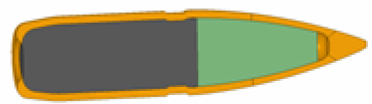
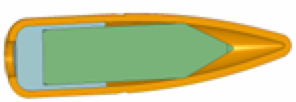
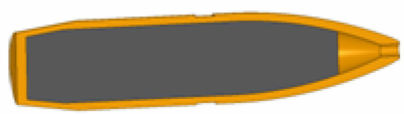


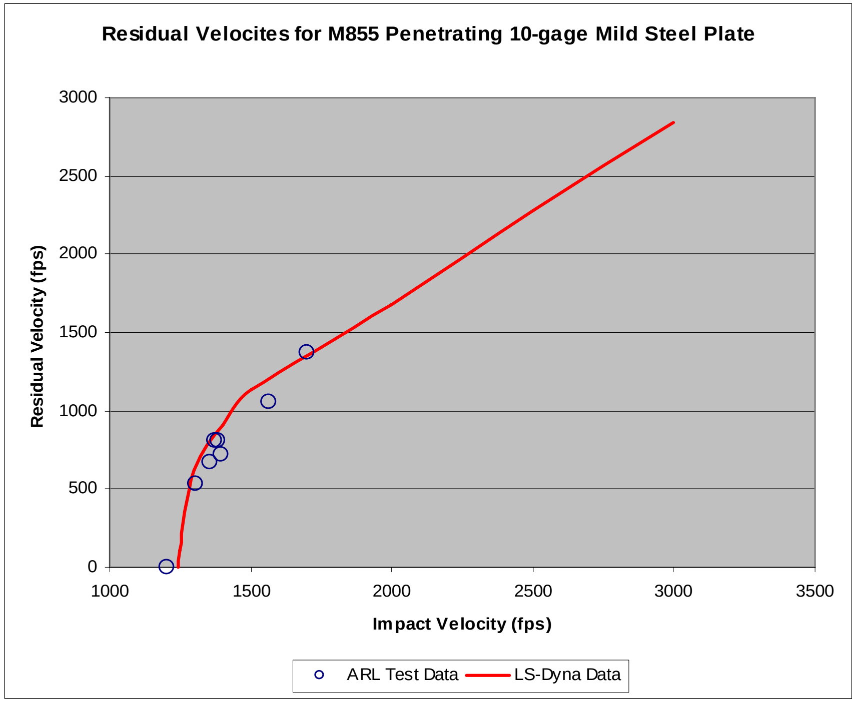
Figure 5. M855 vs. M80 through Auto Windshield

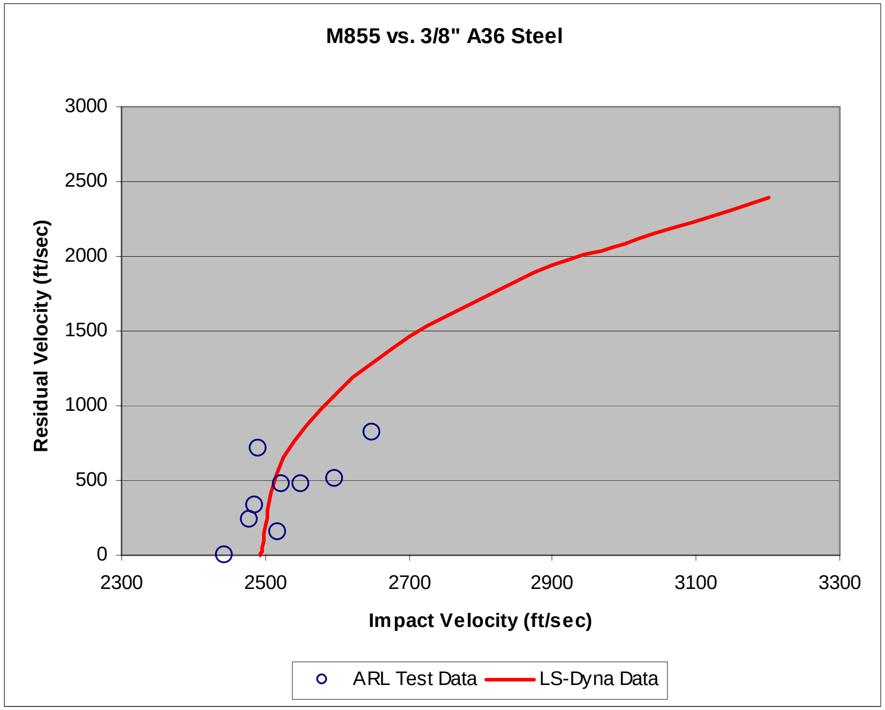
Remember…"Ballistics vs. Logistics"

Candidates for Study

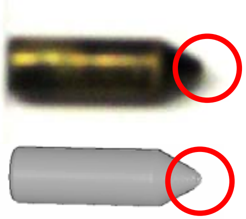
M855, Nominal (.223 cal)  FMJ; 62.6 grains; Steel penetrator backed by lead core encased in copper jacket	**M855/AL-pen**  FMJ; 56 grains; Aluminum penetrator backed by lead core encased in copper jacket
M855/.265 cal  FMJ; 109 grains; Steel penetrator backed by lead core encased in copper jacket	**M855/Pb-pen**  FMJ; 67 grains; lead penetrator backed by lead core encased in copper jacket
M855/.308 cal  FMJ; 171 grains; Steel penetrator backed by lead core encased in copper jacket	**M855/WC-pen**  FMJ; 78 grains; Tungsten Carbide Penetrator backed by lead core encased in copper jacket
M995  FMJ; 53 grains; Tungsten-Carbide penetrator centered with an aluminum cup encased in copper jacket	**MK262**  OTM; 77 grains; All lead core encased in copper jacket

Baseline

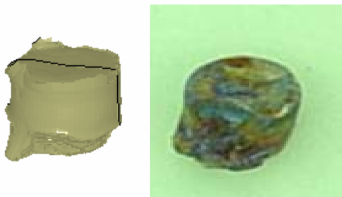


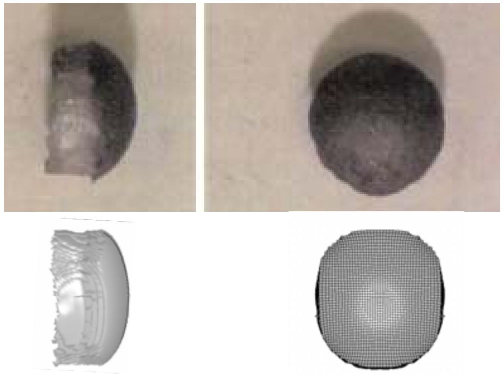


M995 tip erosion



M855 penetrator deformation

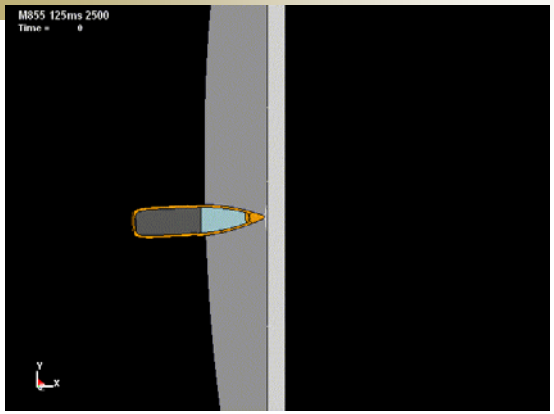




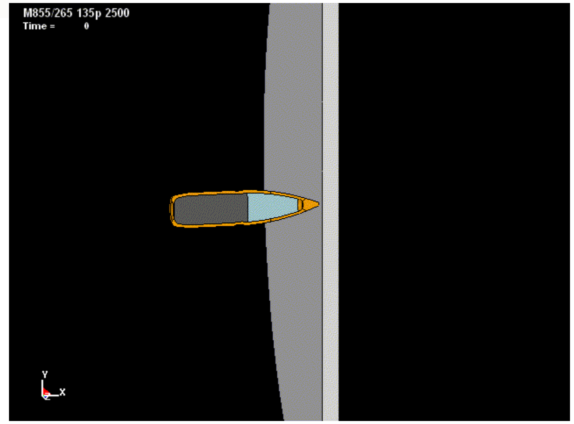
Plug from MK262

Simulations: 1/8” mild steel, 2500fps

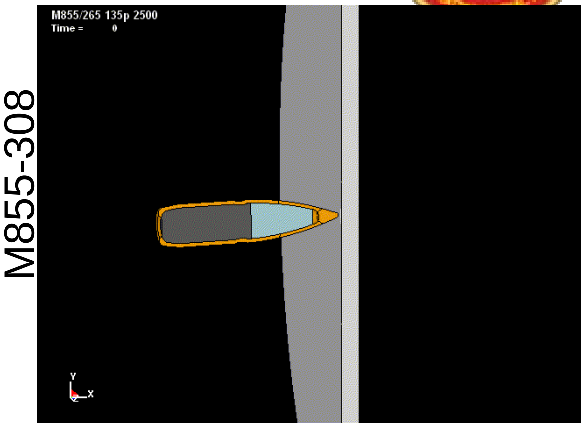
M855



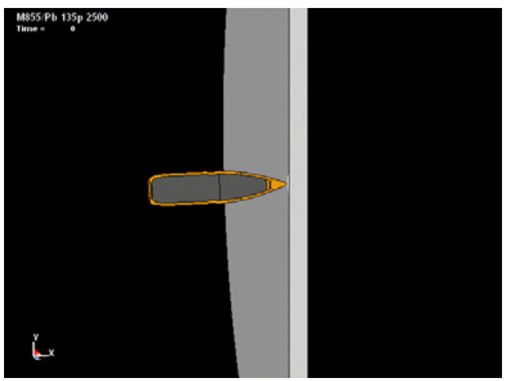
M855-265



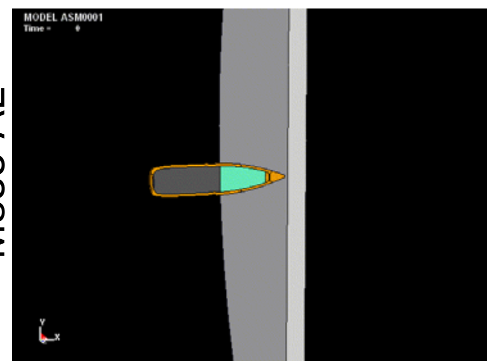
M855-308



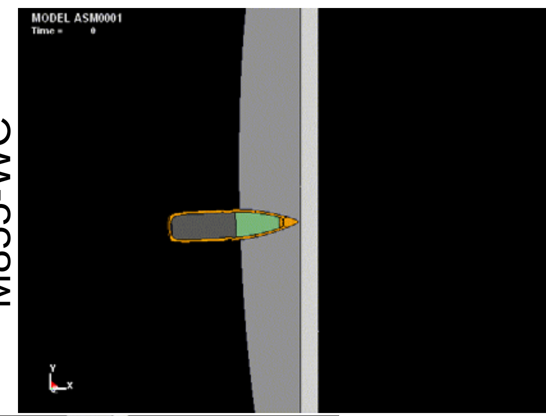
M855-PB



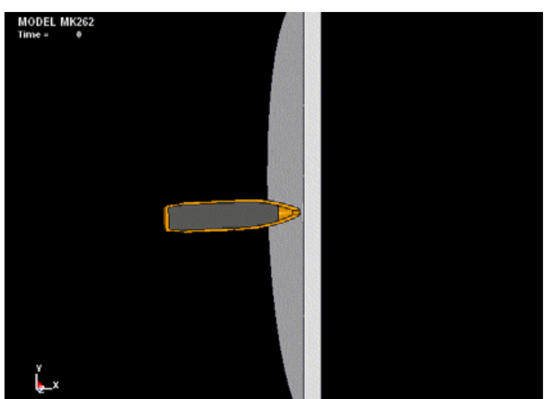
M855-AL



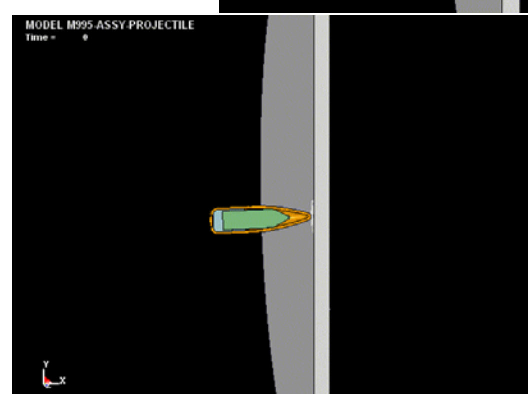
M855-WC



MK262

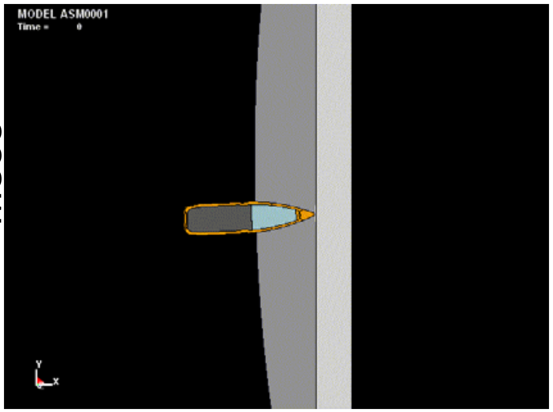


M995

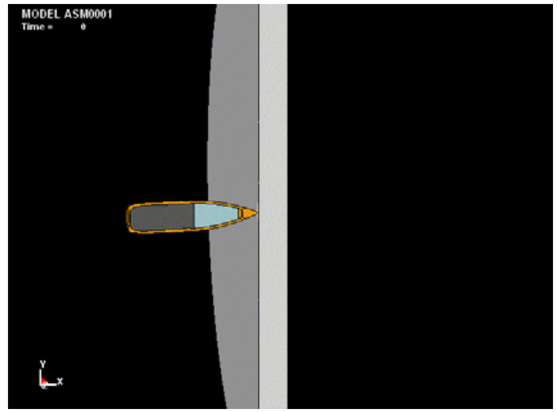


Simulations ¼” RHA, 3000fps

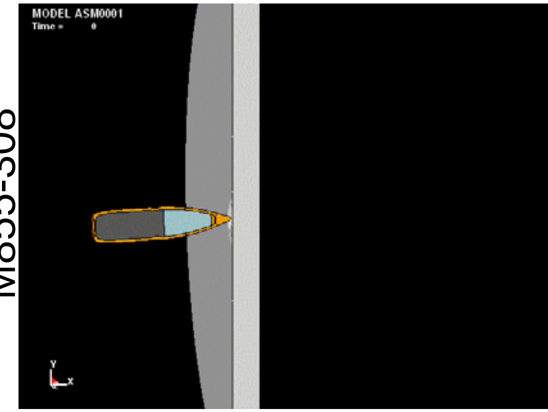
M855



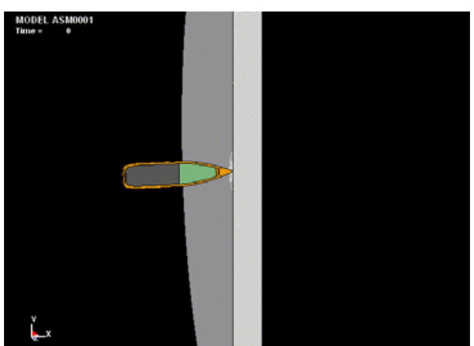
M855-265



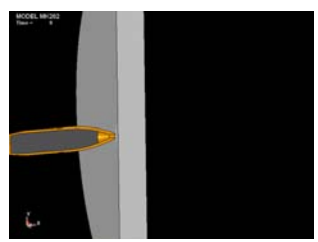
M855-308



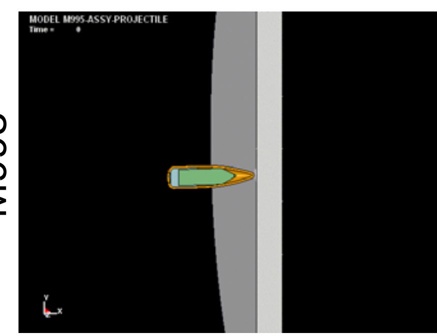
M855-WC



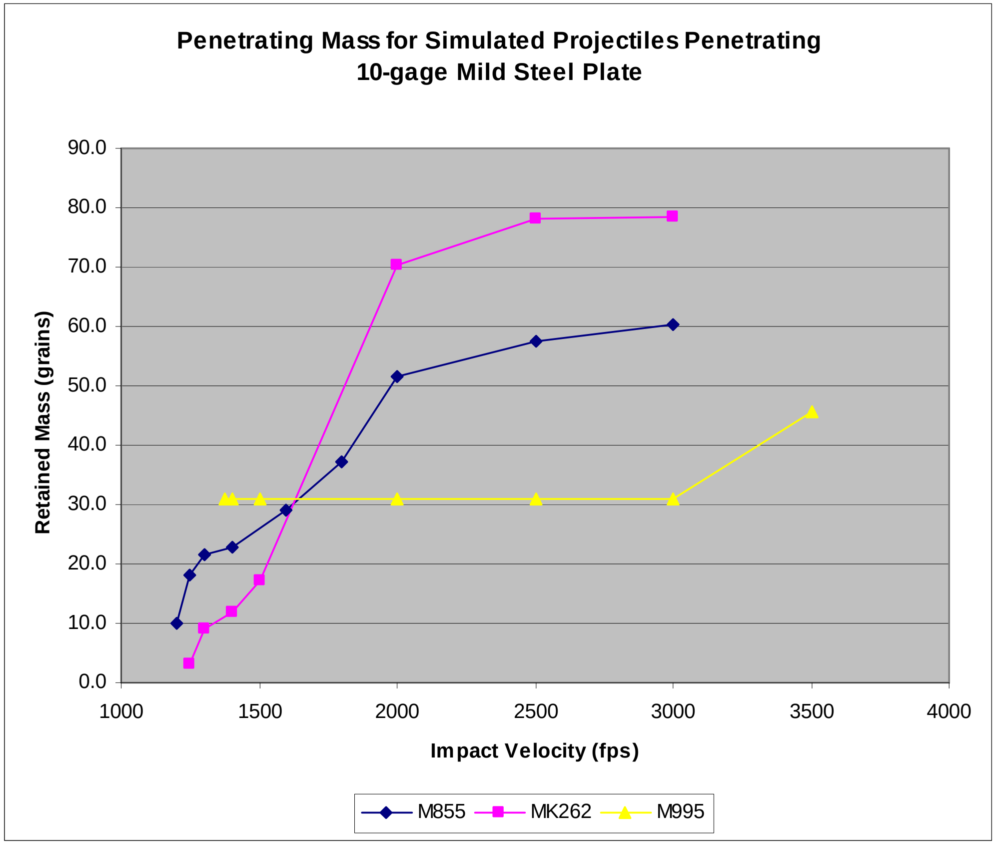
MK262

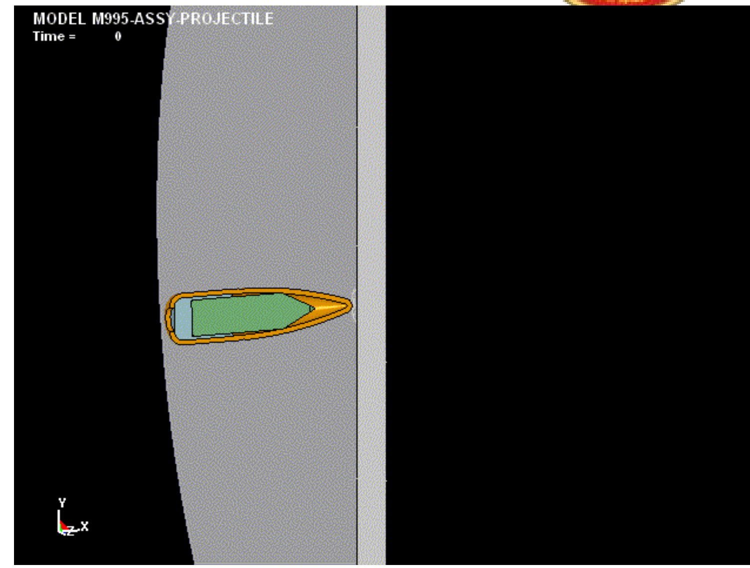


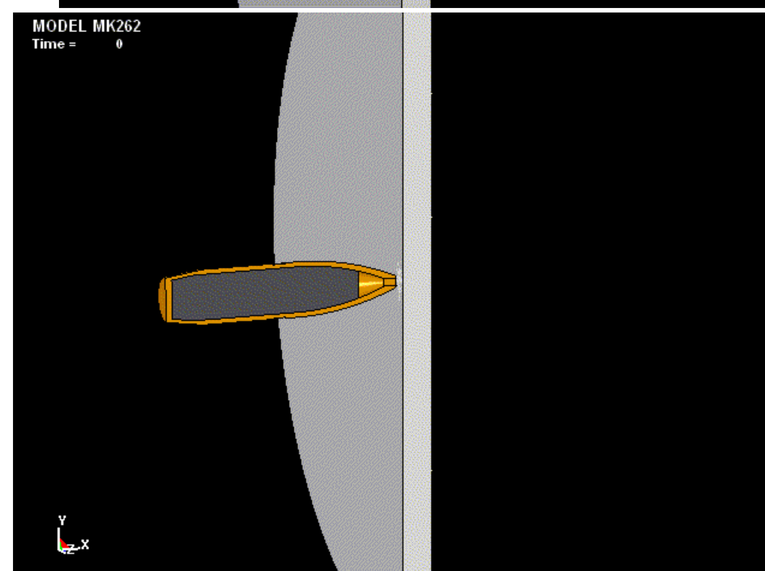
M995



Retained Mass





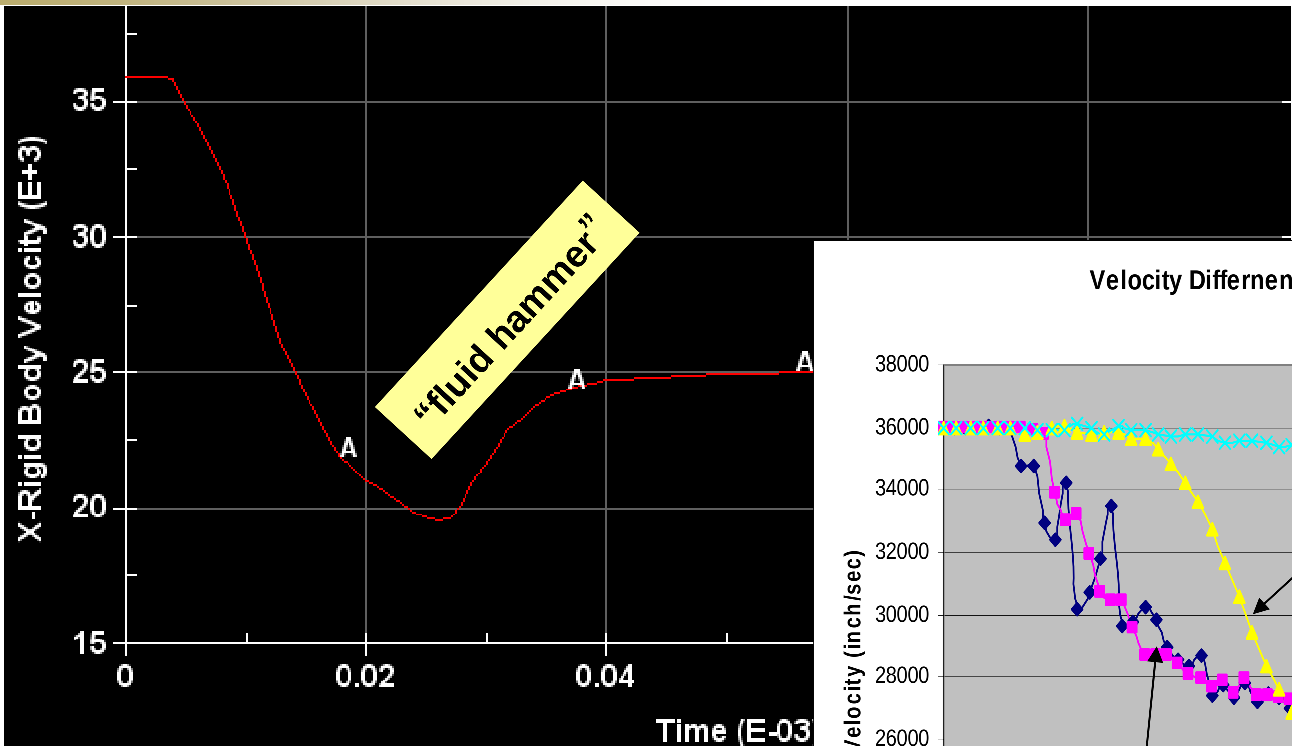


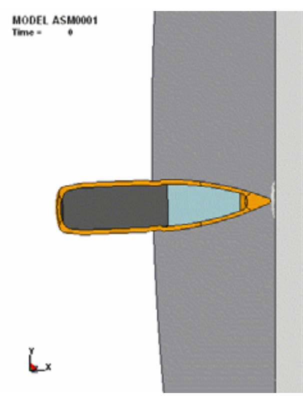
Recall…

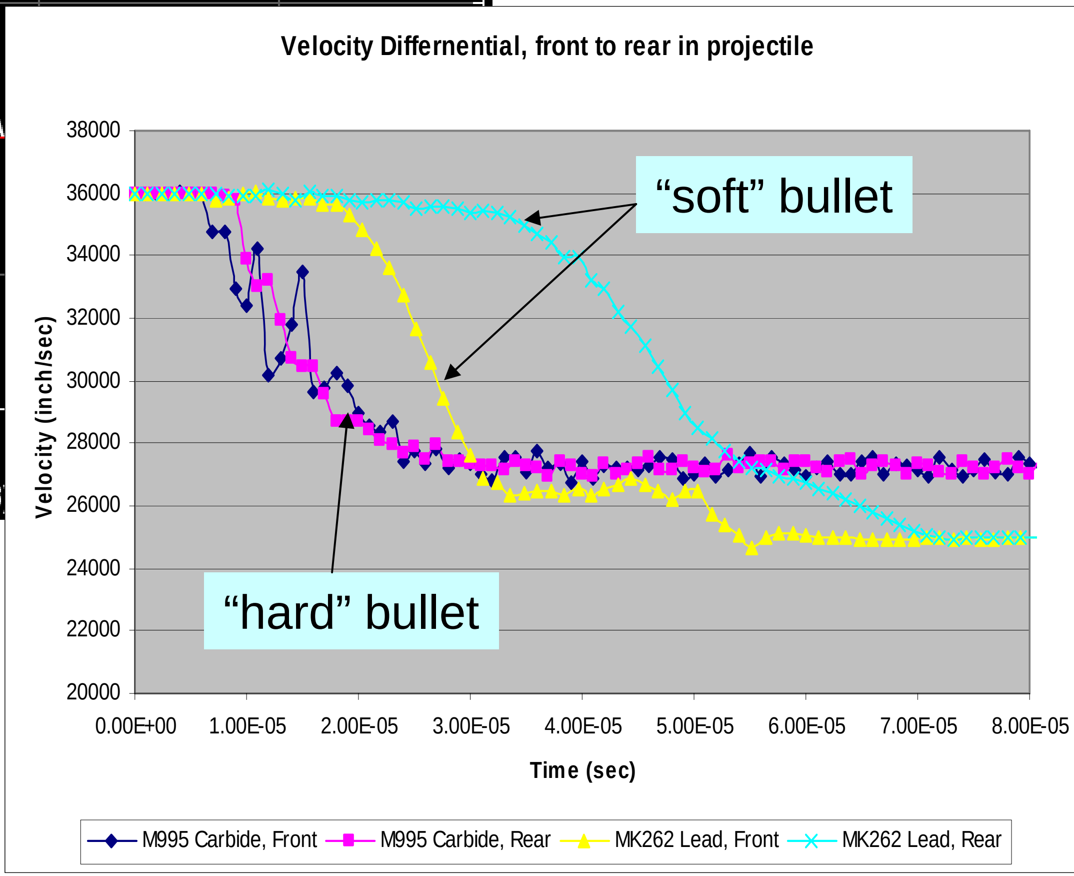
$Mv^{3/2}$

$$F = \frac{1}{2} C_D \rho V^2 A$$

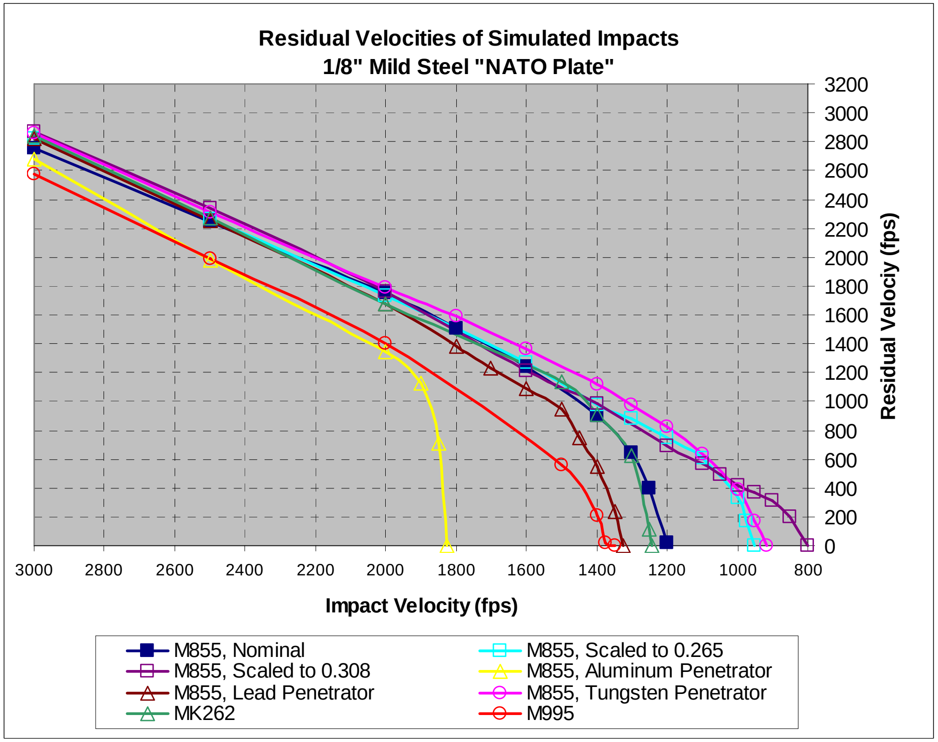
Velocity Increase?

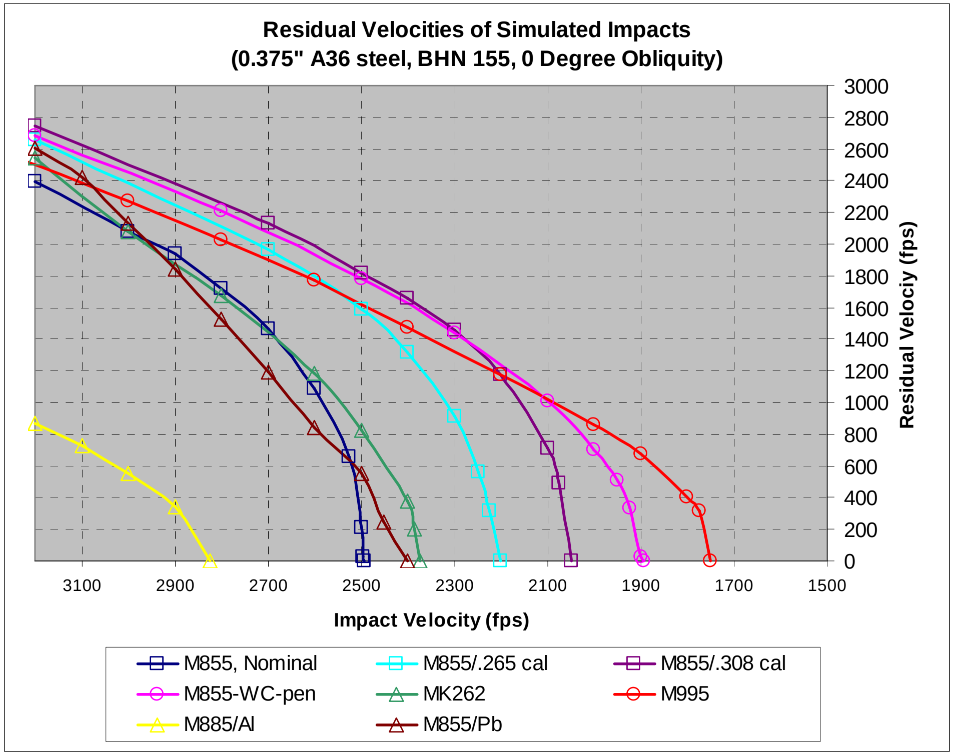






Compiling the Simulated Results





Heavier projectiles have lower V50's and carry more mass through lighter barriers

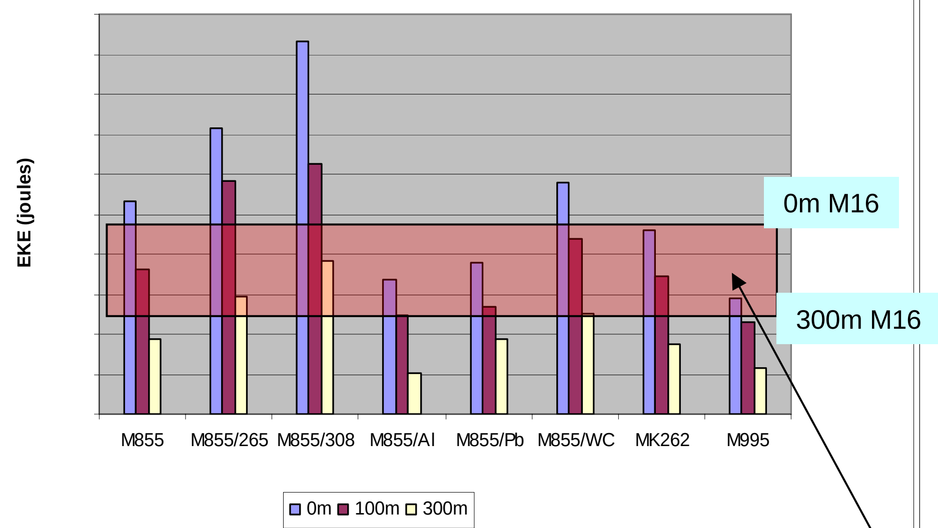
Harder targets to defeat will push user towards AP type ammo

Evaluating the Results by **RANGE**

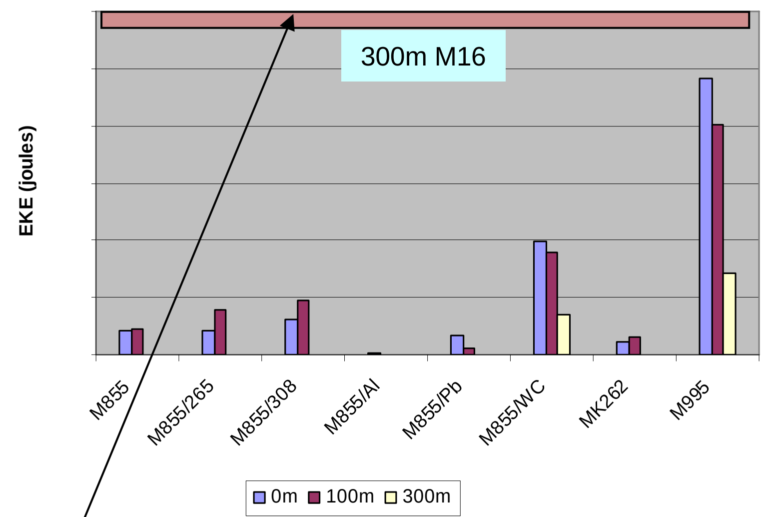
Effectiveness at a given RANGE is more useful to the user…

M995 penetrates when others cant…
…but how effective is it after the barrier?

Effectiveness after 1/8" Mild Steel
Zero to 300m



Effectiveness after 3/8" Mild Steel
Zero to 300m

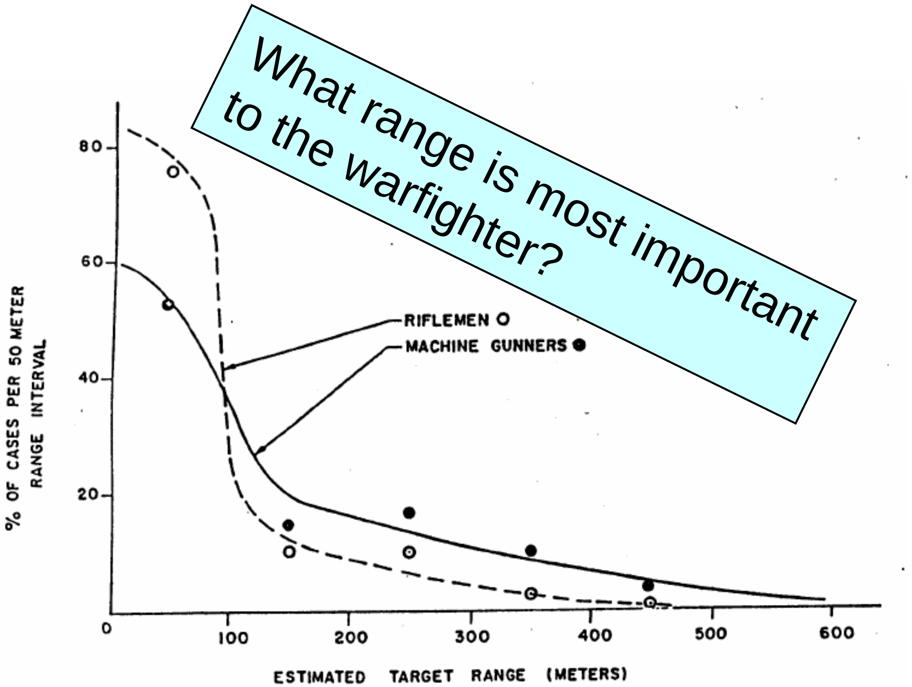


M855 better thru plate than on bare at close range?

M16/M855 EKE, no barrier

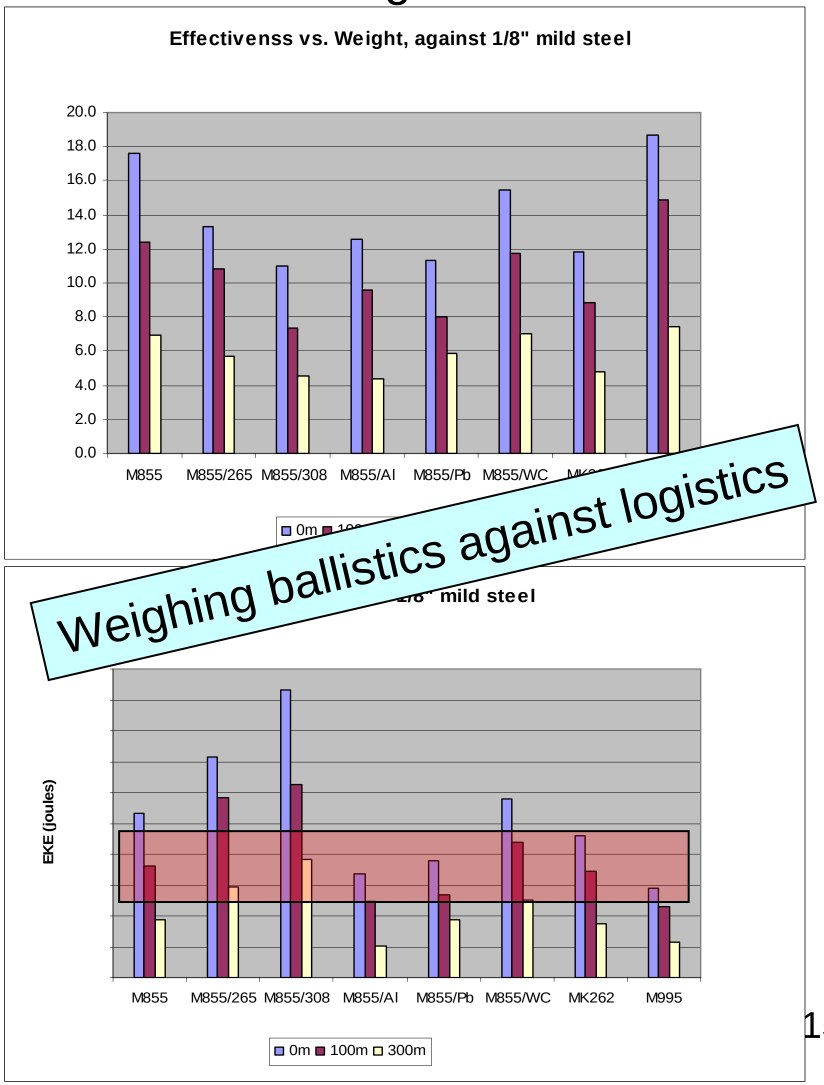
Trade Offs

Requirement



Frequency distribution of ranges in small arms firings estimated from Vietnam War combat film.

Weight



Summary

Qualitative look at top 4 candidates against each target

1/8” Mild Steel	**3/8” Mild Steel**	**¼” RHA**
M855-.308 caliber	M995	M995
M855-.265 caliber	**M855-WC-pen**	**M855-WC-pen**
M855-WC-pen	M855-308.cal	M855-.265cal
M855	M855-.265 cal	M855

MK262, M855-AL, M855-PB all significantly lower overall

Requirements + Performance + Trade-space + logistics = Choice

Conclusions

- Simulations correlate well, in most cases, to test data
  - Limit velocities for M855 against RHA, and Mils Steel matched ARL test data
  - All lead bullets may require fine-tune
  - ¼" RHA material properties may require fine-tune

- Simulations can be used to improve the projectile development process
  - Simulations show sensitivity to geometric and material property changes
  - **Simulations enable comparative, scientific analysis**
  - 100% predictive capability still difficult without calibrating test data
  - **Simulations reduce product development time**
  - **Simulations improve product quality**

- Putting a harder penetrator in the M855 is a good overall improvement

- Intermediate caliber can balance range with penetration capability effectively