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Customer Success Is Our Mission

System Issues to Consider for Reducing Collateral Damage

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What Drives Collateral Damage?

- Accuracy
  - Siting
  - Targeting
  - MET quality
  - Mission planning

Crew, Fire Control, MET Support

- Precision
  - Reliability
  - Propellant quality
  - Projectile maneuverability
  - Range/super-elevation influences

Guidance, Architecture

- Lethality
  - Warhead size
  - Fuzing
  - Verticality

Verticality, Warhead, Fuzing

MET — Meteorological

Typical Long-Range Error Sources

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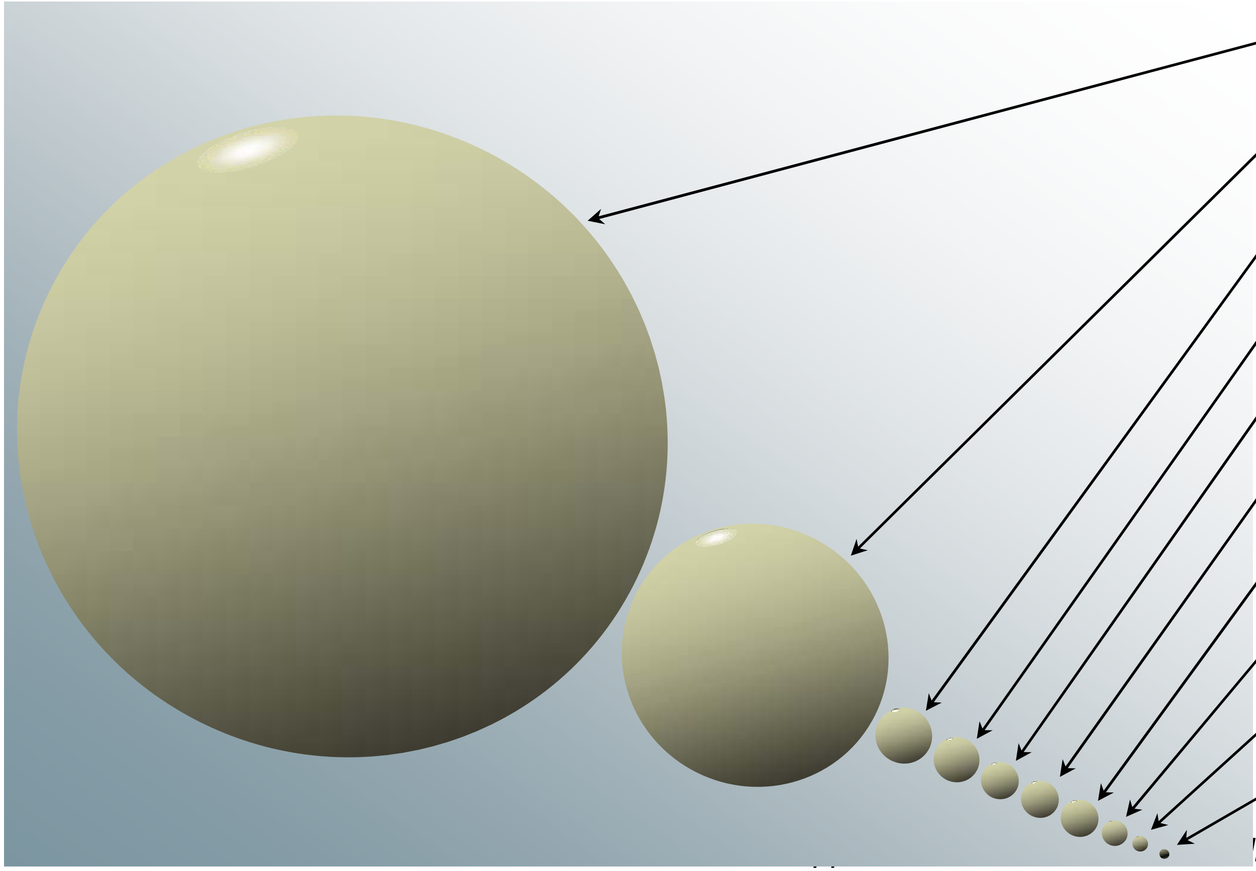
Ballistic Case = Ballistic projectile dispensing submunitions at 70 degree angle

$(MET^2 + Prop^2 + NORTH^2 + Site^2 + drift^2 + TLE^2 + Vert^2 + NAV^2 + Guide^2 + Control^2)^{1/2} = 317$ meters

Guided Case = Ballistic projectile dispensing submunitions at 70 degree angle

$(MET^2 + Prop^2 + NORTH^2 + Site^2 + drift^2 + TLE^2 + Vert^2 + NAV^2 + Guide^2 + Control^2)^{1/2} = 22$ meters



MET Error
100–1000 meters, typically 300

Propellant Error
50–300 meters, typically 100

Site NORTH Error
5–50 meters, typically 20

Submunition Drift Error
5–50 meters, typically 15

Target Location Error
5–100 meters, typically 30

Gun Site Error
5–50 meters, typically 10

Navigation Error
5–100 meters, typically 10

Projection Vertical Error
3–20 meters, typically 5

Guidance Miss Error
1–10 meters, typically 3

Control System Error
0.1–3 meters, typically 1

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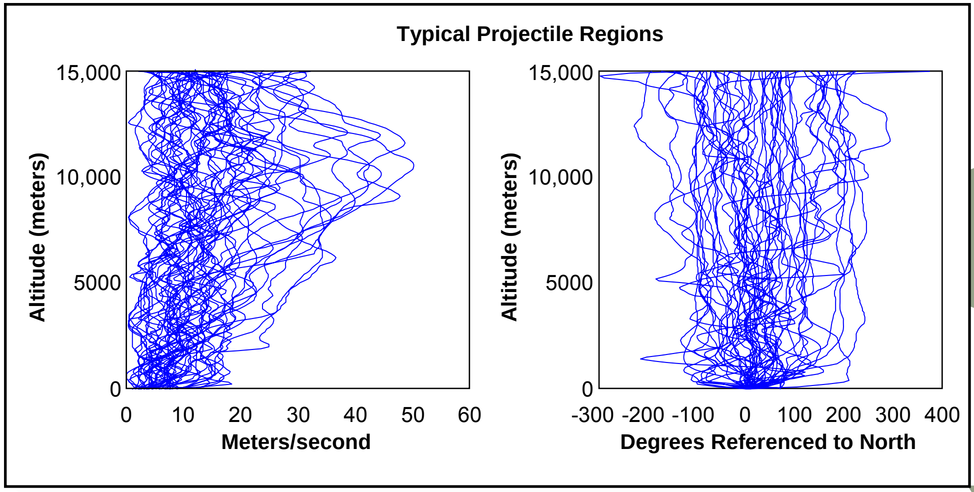
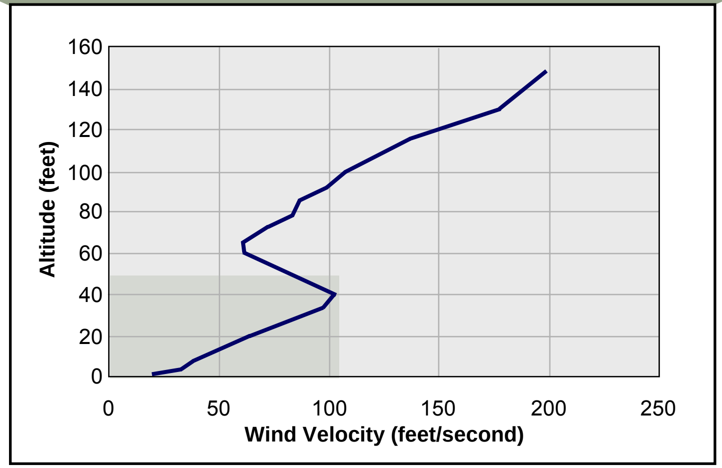
Winds Aloft

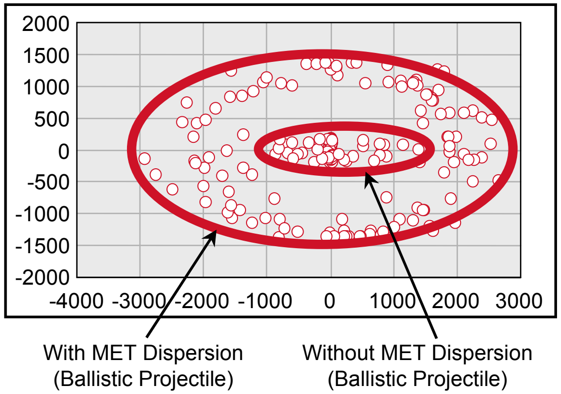
- Winds aloft a major determinant of system correction maneuver needed

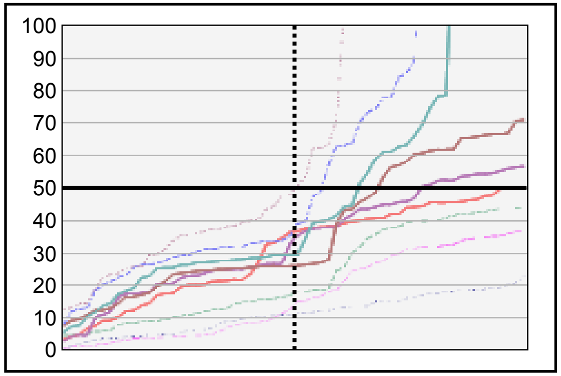
Examples of Winds Aloft Profiles (U.S. Air Force)





Winds aloft profiles will create large dispersions if systems are not robust





Rule:
Maneuverability must be greater than two times MPI to be MET tolerant

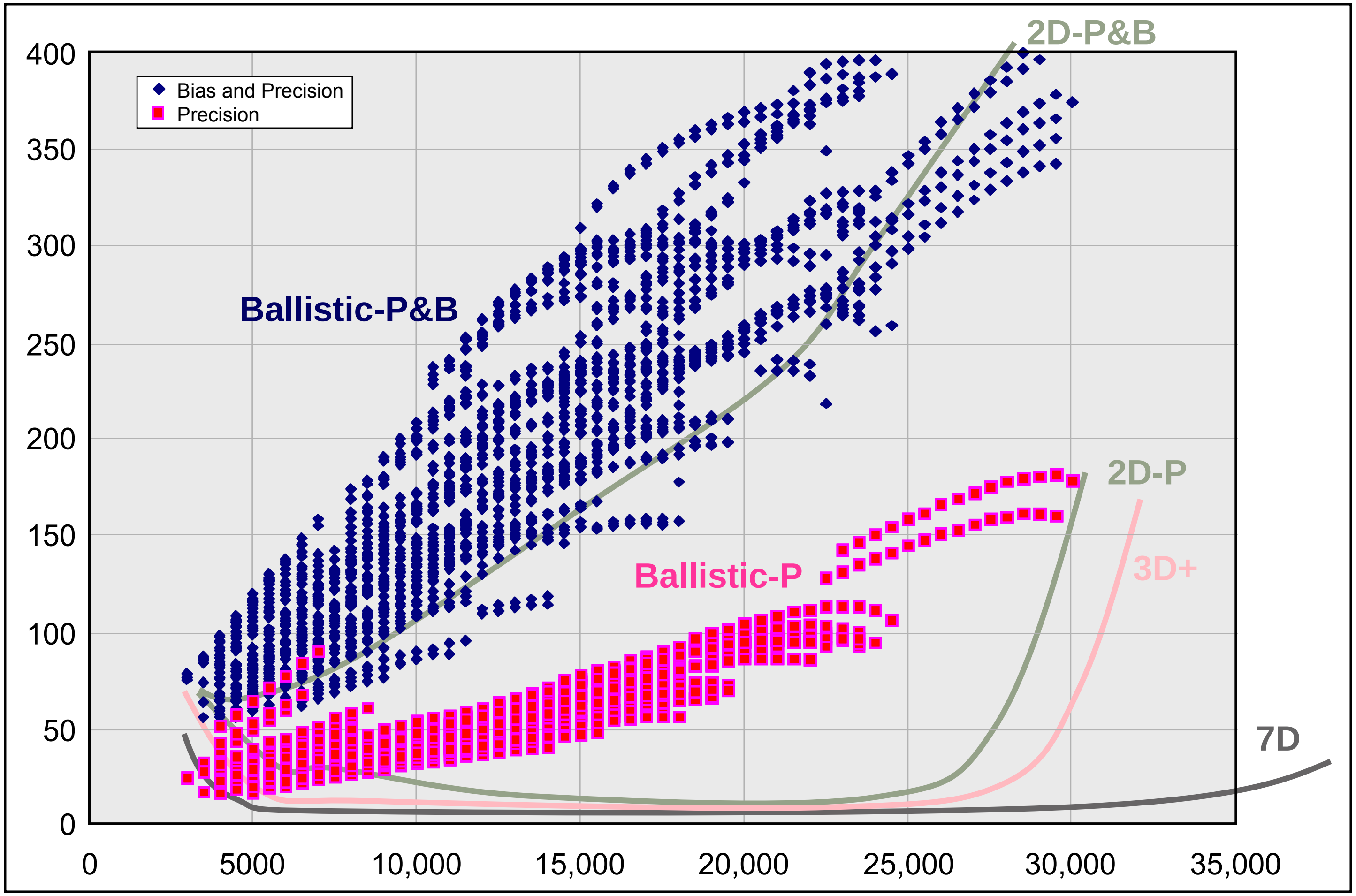
MPI — Mean Point of Impact

First Shot CEP

- First shot CEP drives collateral damage potential

MET dominates errors determining bias for ballistic

Depending on system maneuverability, MET errors may have minor or major collateral damage influence



CEP — Circle of Equal Probability

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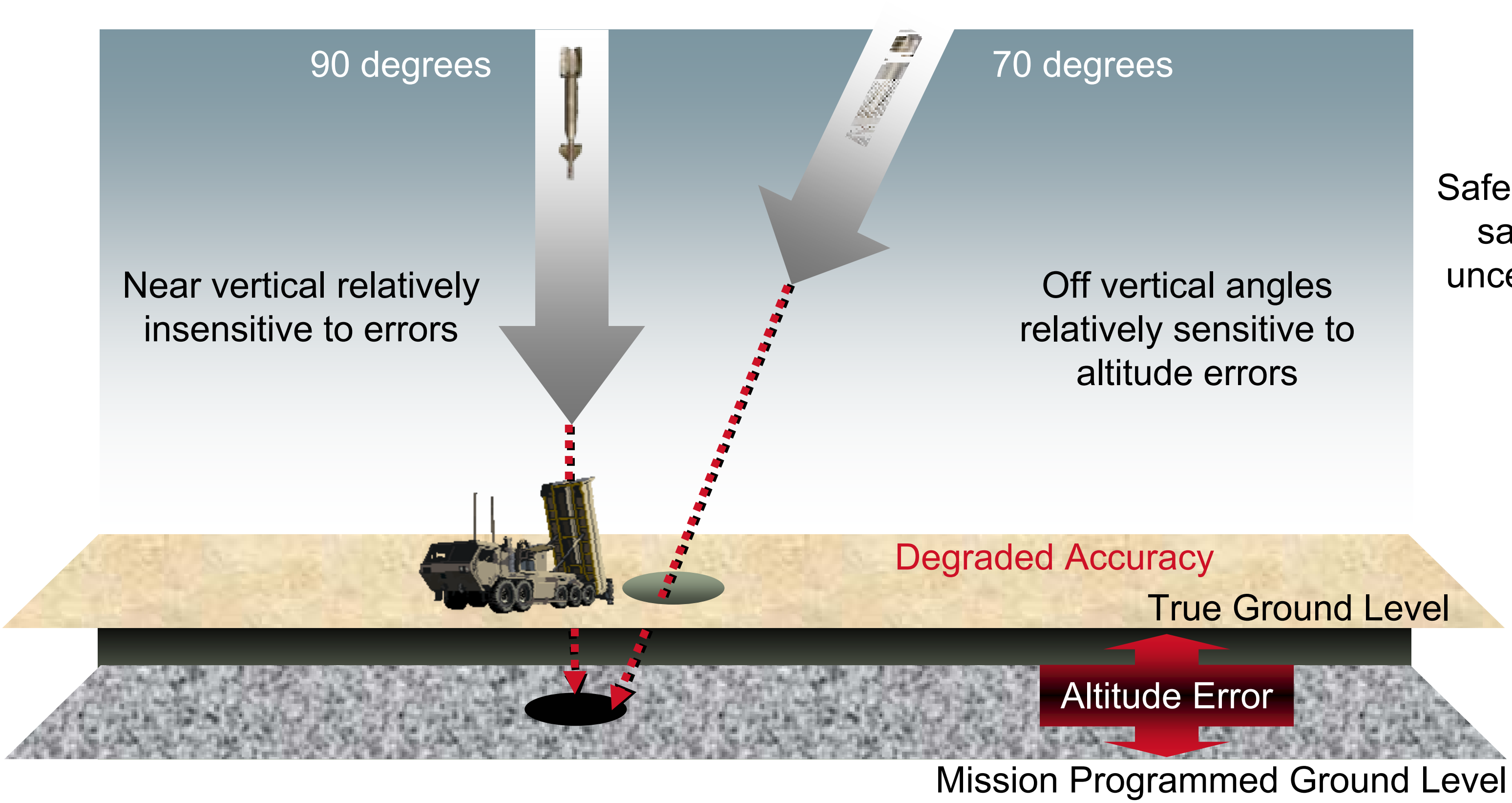
Vertical Errors

- Vertical errors causing horizontal miss

Horizontal Error Potential (70 degrees)

Source	Vertical (1s)	Horizontal (1s)
GPS	15.3 meters	5.1 meters
FO	10.0 meters	3.4 meters
DTED	18.8 meters	6.4 meters



Safe to shoot, safe with uncertainties

FO — Fixed Object
DTED — Digital Terrain Elevation Data

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Verticality of MOUT

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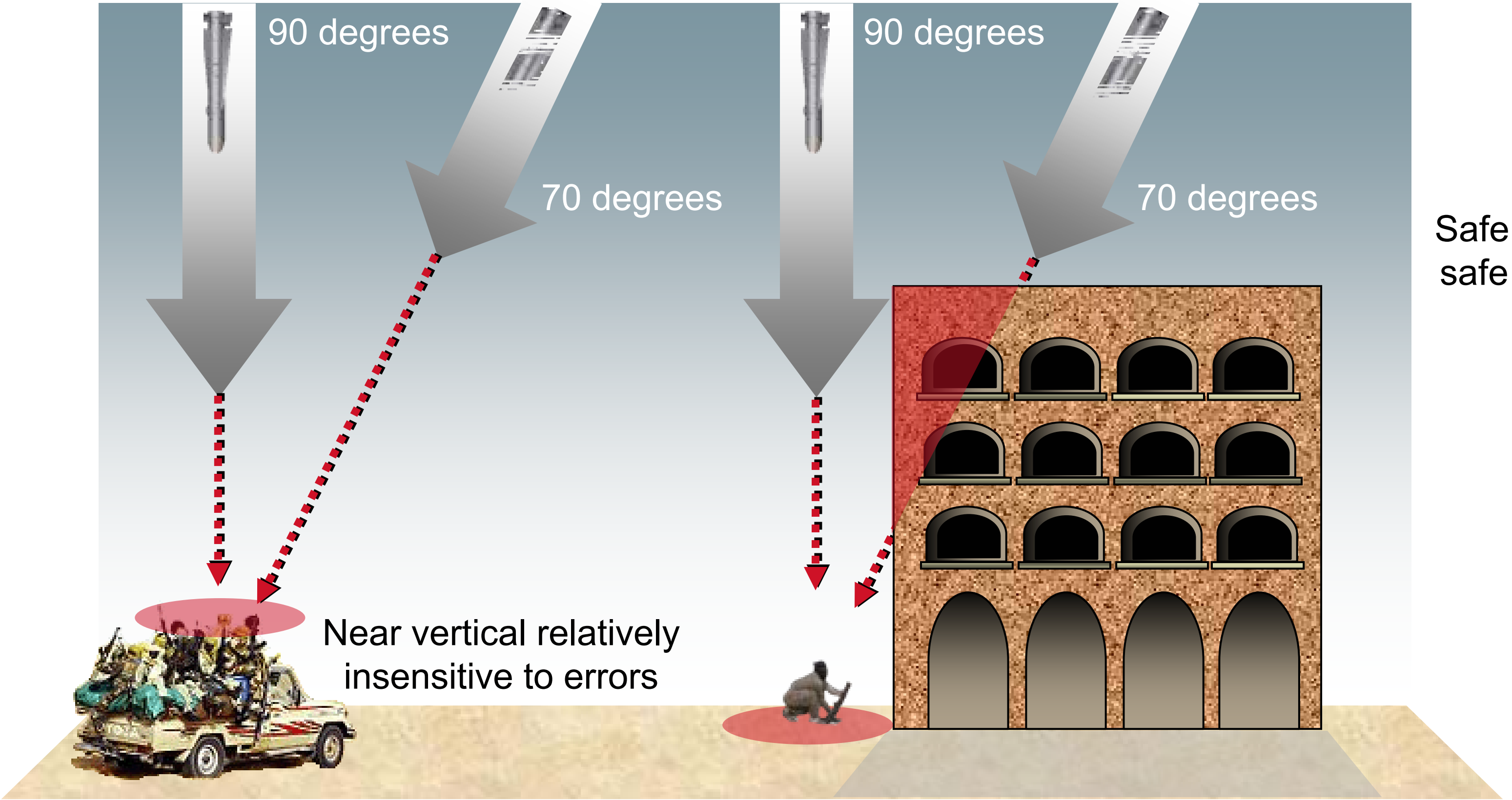
- Verticality — MOUT — Risk of building impact

Vertical Error Potential (70 degrees)

Source	Vertical (1s)
GPS	15.3 meters
FO	10.0 meters
DTED	18.8 meters

Off vertical angles also sensitive to altitude errors



Safe to shoot, safe if MOUT

No Vertical Errors

True Ground Level

MOUT — Military Operations on Urban Terrain

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MOUT/Complex Terrain — Fire Line

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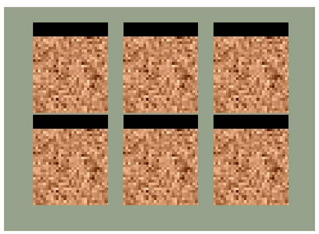
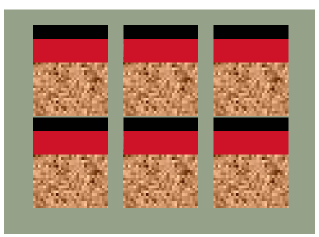
- Management of target shadowing versus threats of collateral damage caused by structure strikes

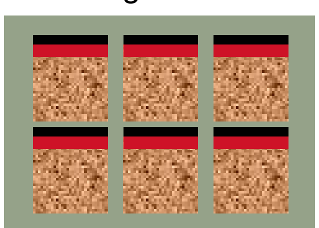
Best Case
(Gun is parallel with roads)



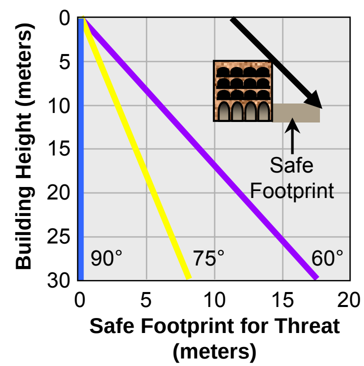
Risk of Building Strike 60 degrees



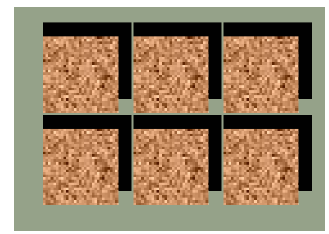
Risk of Building Strike 90 degrees



- Open area that can be engaged by indirect fire
- Open area that cannot be engaged because of building
- Collateral risk area



Worst Case
(Gun is 45 degrees to buildings)



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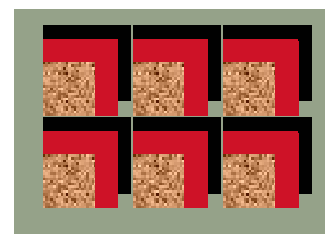
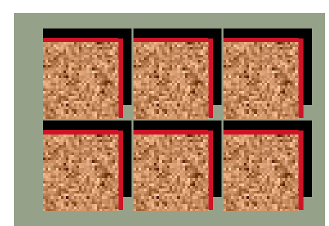
Risk of Building Strike 60 degrees



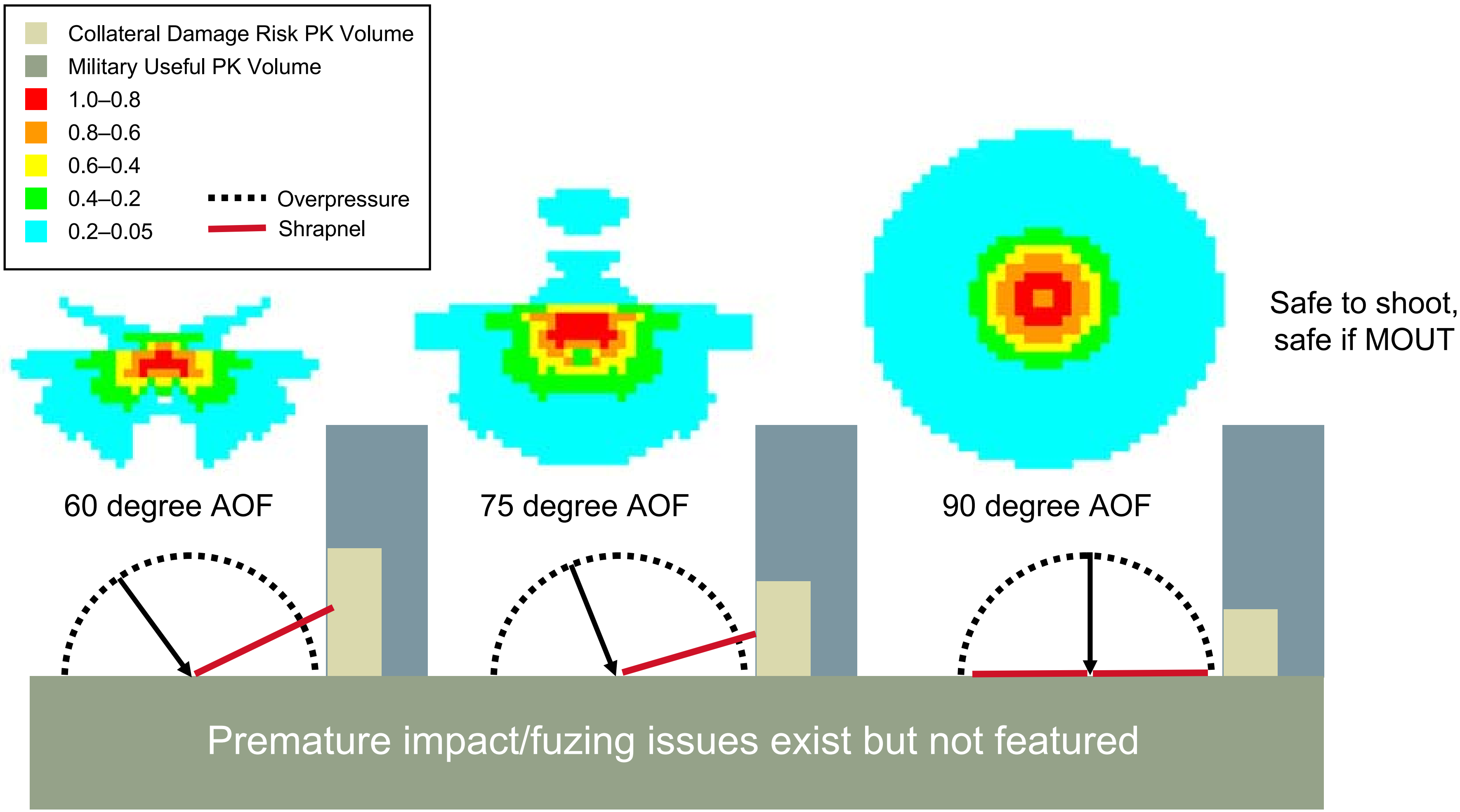
Risk of Building Strike 90 degrees



Note — with 7D, terminal azimuth angles can be aligned to obstructions

Urban Terrains — Verticality/Lethality

- Management of impact angle of where fragments might go



AOF — Azimuth of Fire
PK — Probability of Kill

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Payload Lethality

Joules required to damage target

Target	Light Damage	Moderate Damage	Heavy Damage
Personnel	0.1	1	4
Aircraft	4	10	20
Armor	10	500	1000

Initial Fragment Velocity

The theoretical result for fragment velocity using the Gurney constant (2ΔE) for TNT is 2328 m/s:

$$v = \sqrt{2\Delta E}\sqrt{\frac{C/M}{1+K(C/M)}}$$

where:

C/M is the charge-to-metal ratio

K depends on the configuration:
Flat plate: K = 1/3
Cylinder: K = 1/2
Sphere: K = 3/5

Probability of Kill

$$N_{hits} = A(N_o/4\pi R^2)$$

where:

N_{hits} is the expected number of fragments hitting

N_o is the initial number of fragments from the warhead

A is the frontal area of the target presented to the warhead

R is the range of the target to the warhead

For multiple hits the overall P_k is found from

$P_k = 1 - (1-P_K|_{hit})^{Nhits}$, if $N_{hits} > 1$, or MISSING TEXT?

Fragment Velocity at Range

$$V(s) = V_o * e^{-\rho C_d As/2M}$$

ρ = The density of air. Normally 1.2 Kg/m3

V_o = The fragment velocity

C_d = The coefficient of drag[1]

A = The cross-sectional area of the fragment

M = Mass of fragment

s = Distance traveled

1 Depends on shape of the fragment and velocity

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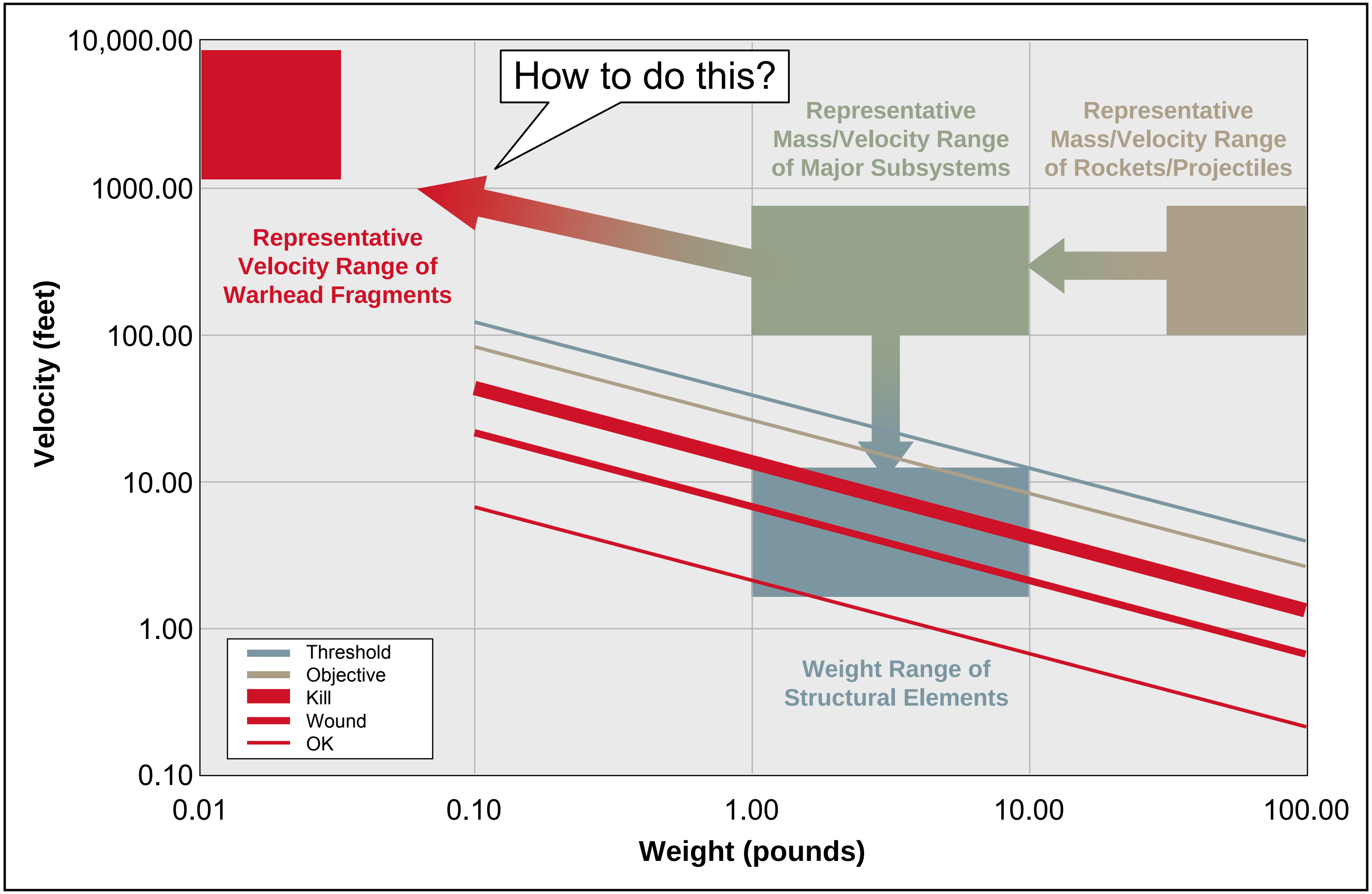
Warheads Too Big

- Collateral damage can be managed only with precision and attitude



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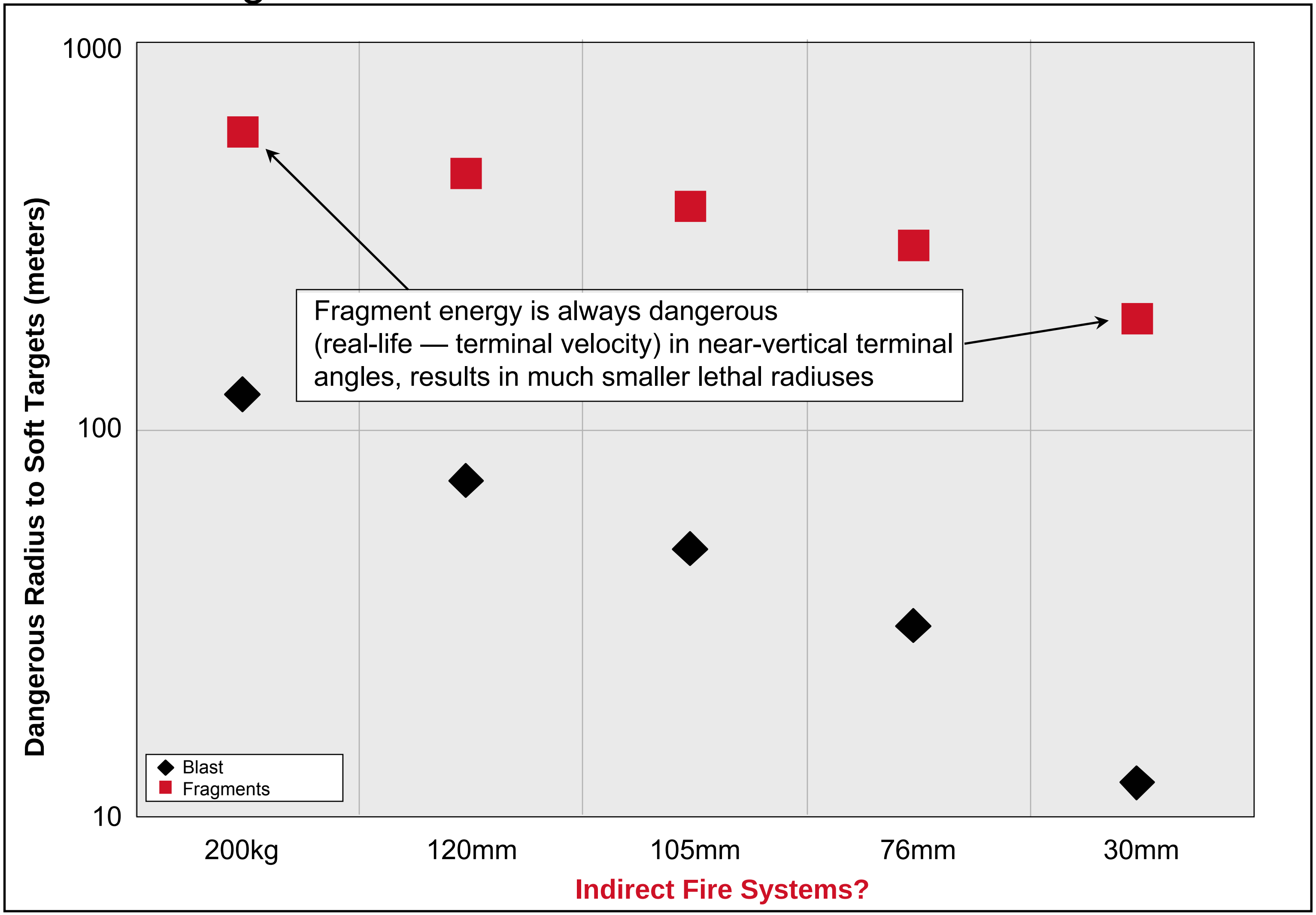
Warhead Size Lethality

- Collateral damage radius



Projectile Type

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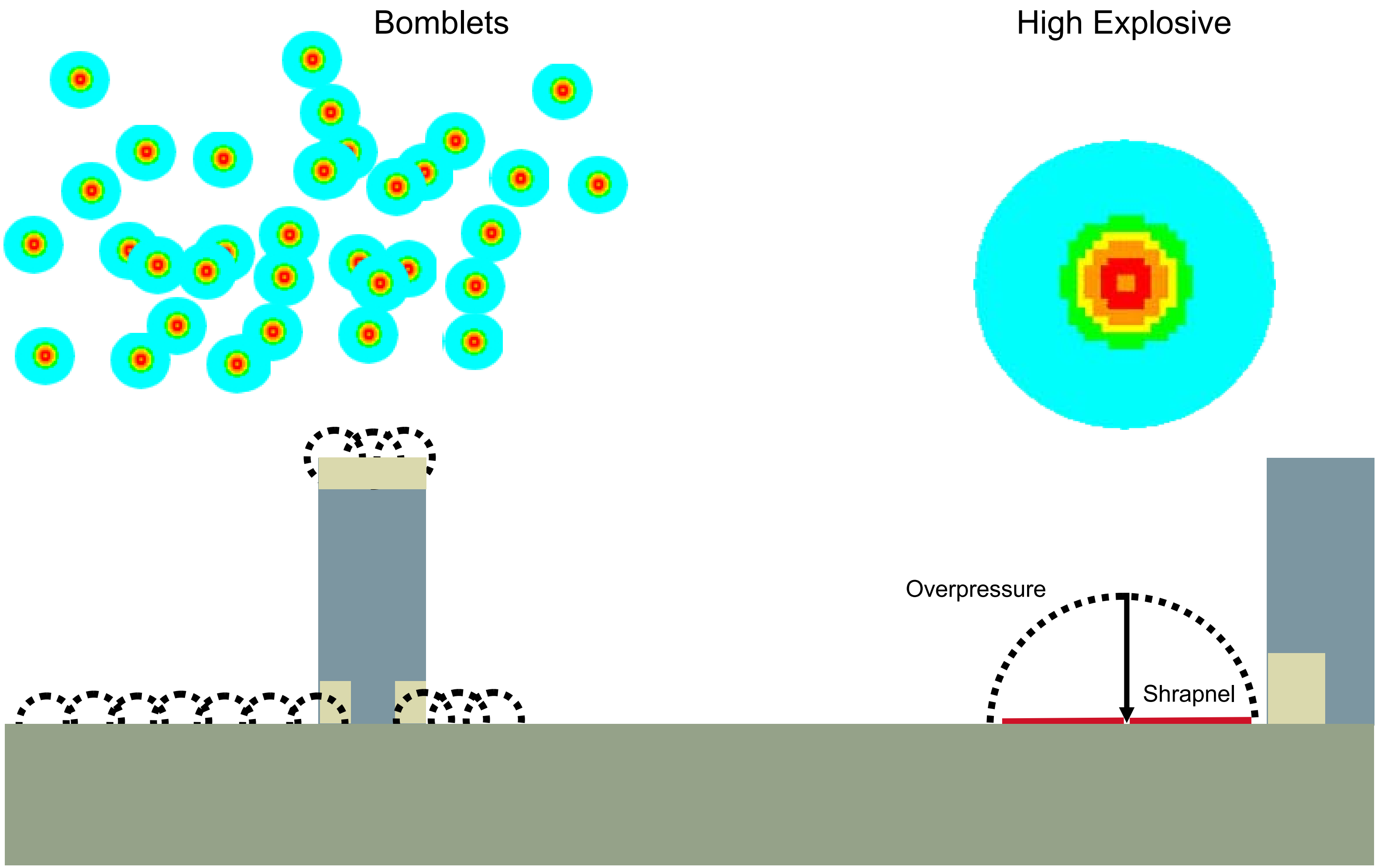
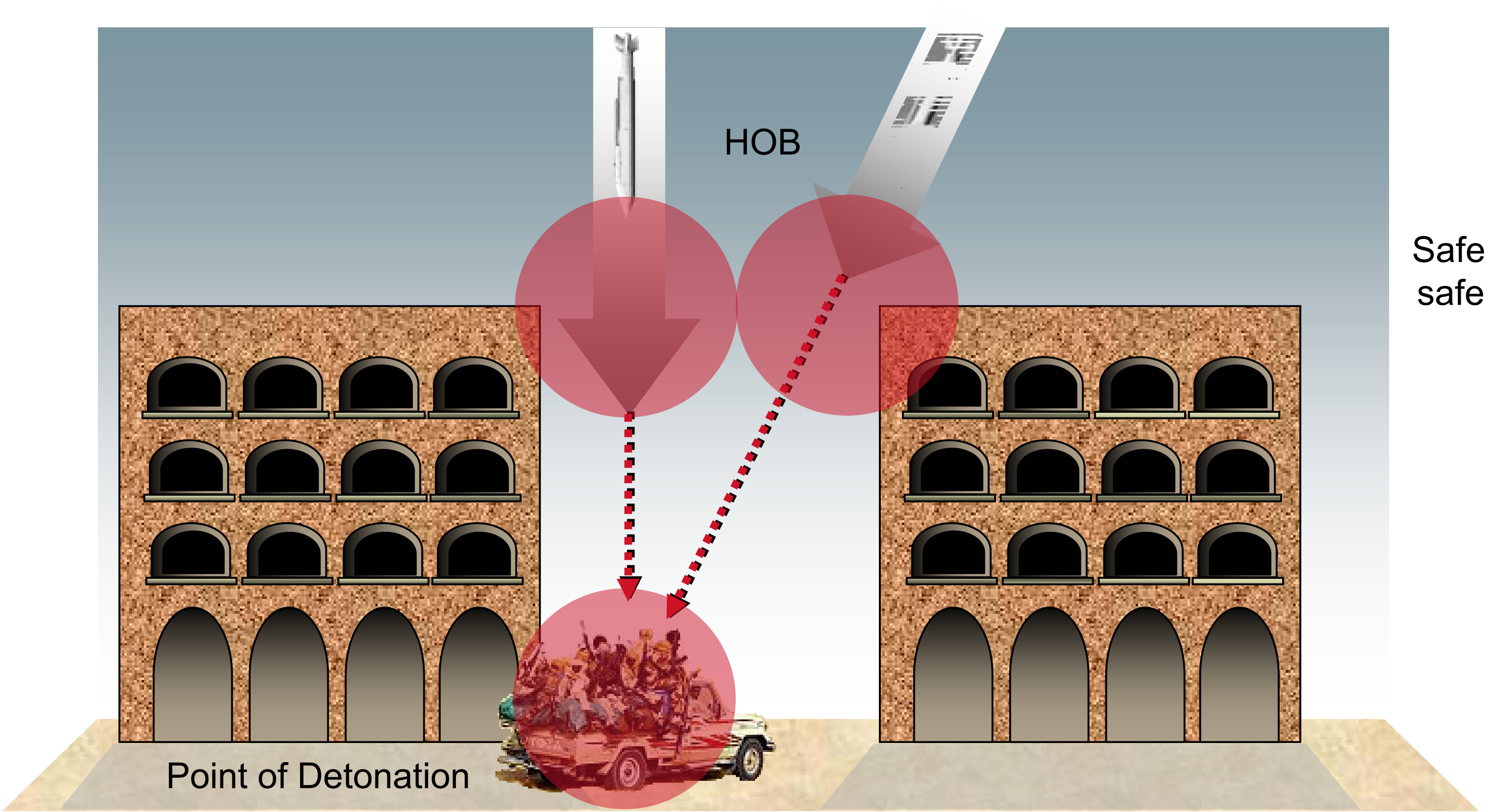
- Management of collateral damage area



Fusing

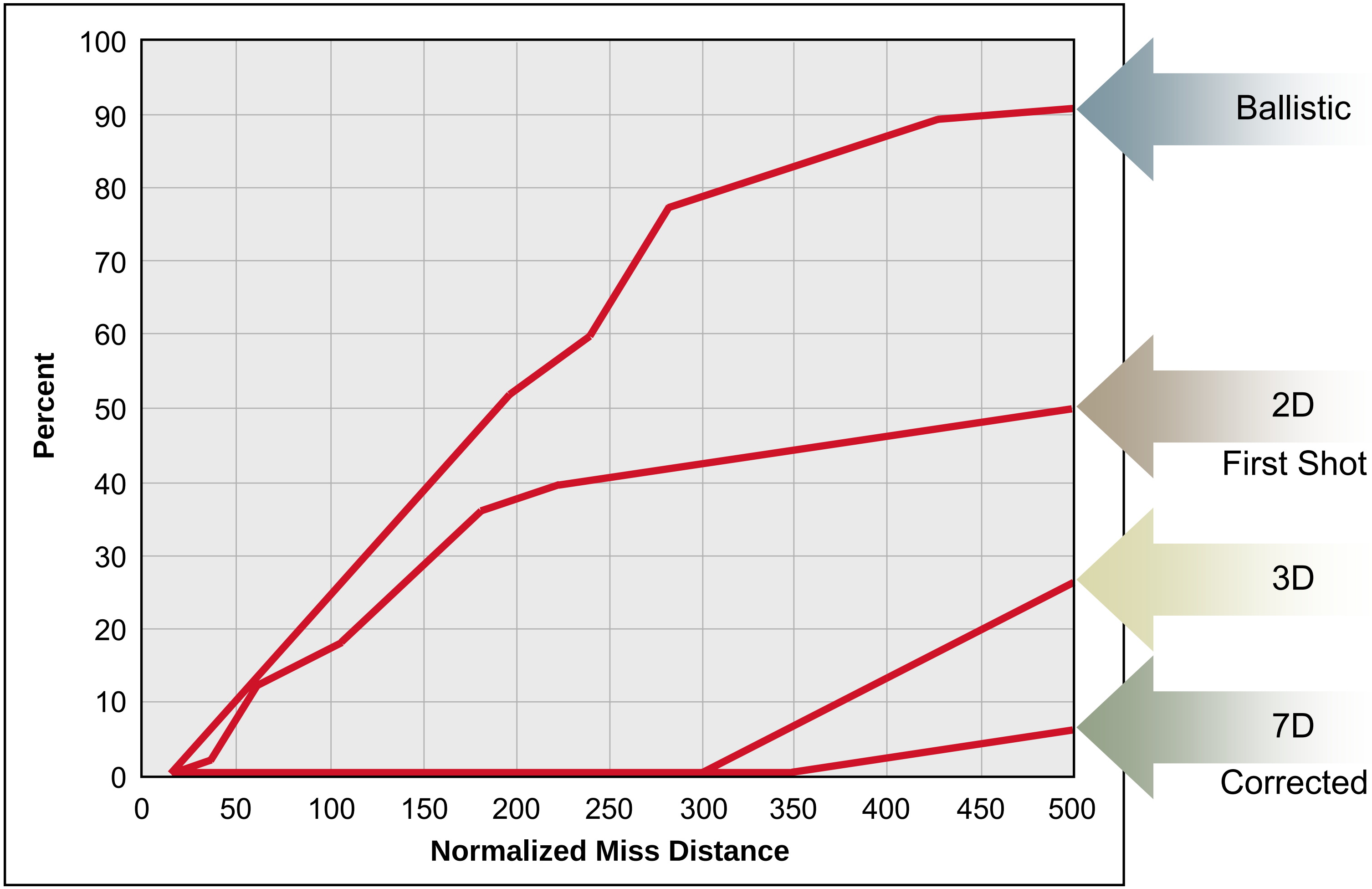
- Clutter induced pre-detonation



Safe to shoot,
safe if MOUT

Probability of Collateral Damage

- Probability of causing collateral damage inducing miss



Safe to shoot, safe if MET/Gun bad

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Projectile Maneuverability

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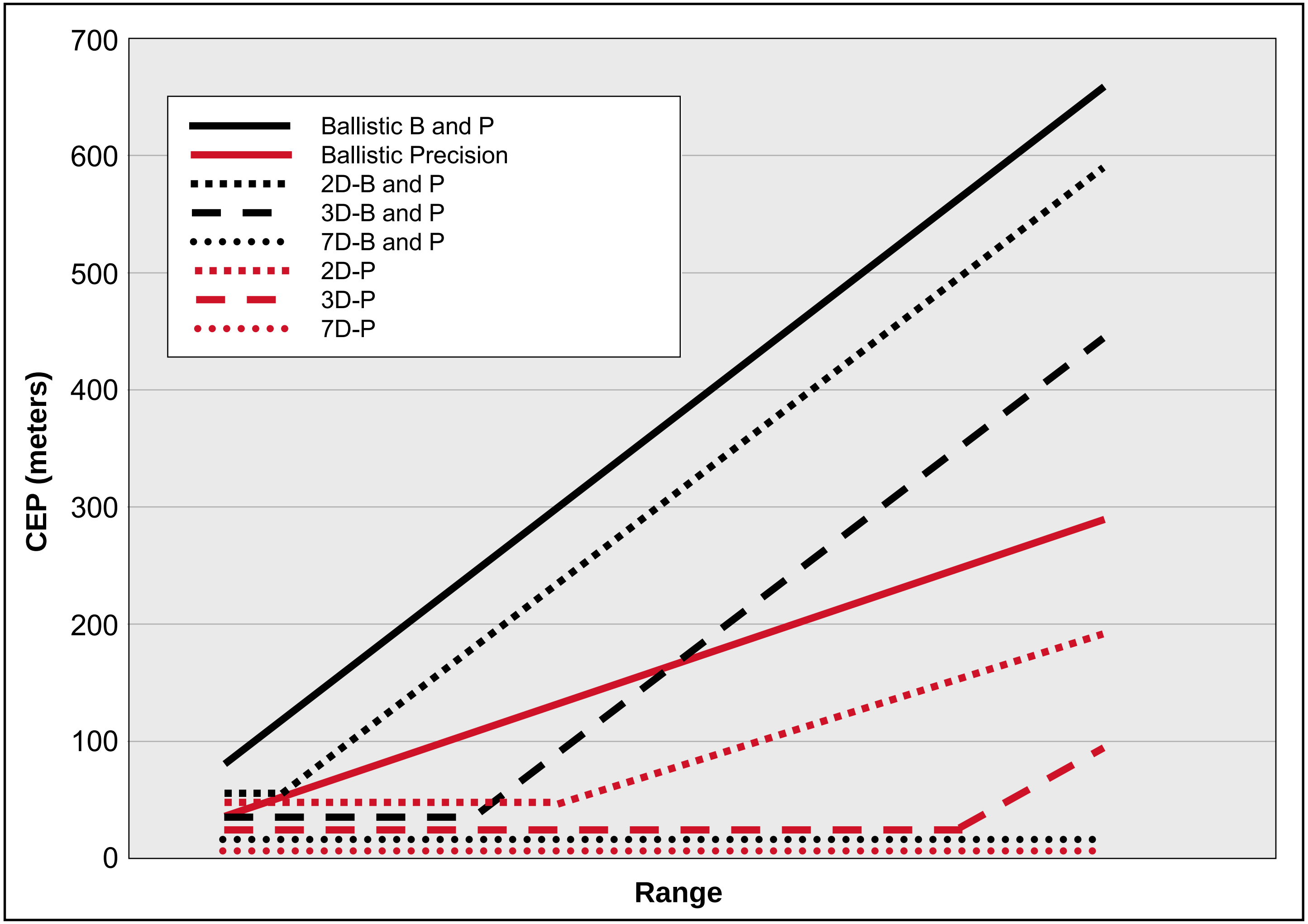
- How much aiming error to remove or provide safety margin



Safe to shoot, safe if MET/Gun bad

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Summary

- Precision is the key
  - Highest leverage – hit what you aimed out
  - Permits considering smaller warhead energy
    - Not yet a major factor — fractional damage per shot still rules
    - At least opens the door to softer warheads
  - Elimination of large potential kinematic hazards
- Matching of MET/GUN uncertainties to weapon maneuver potential
- Control of Delivery is very important
  - Verticality to avoid horizontal errors
  - Off axis to minimize shadowing and obstacles
- Fuzing must consider real world
  - Multiple options to avoid pre-detonations
  - Terminal trajectory to minimize pre-detonation
- Warheads presently design to maximize lethality
  - Size of fragments
  - Type (unitary, penetrator or submunitions)

Questions

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