Raytheon

Customer Success Is Our Mission

2012 NDIA Joint Armaments Conference

Characterizing Precision with Radial Miss Distance

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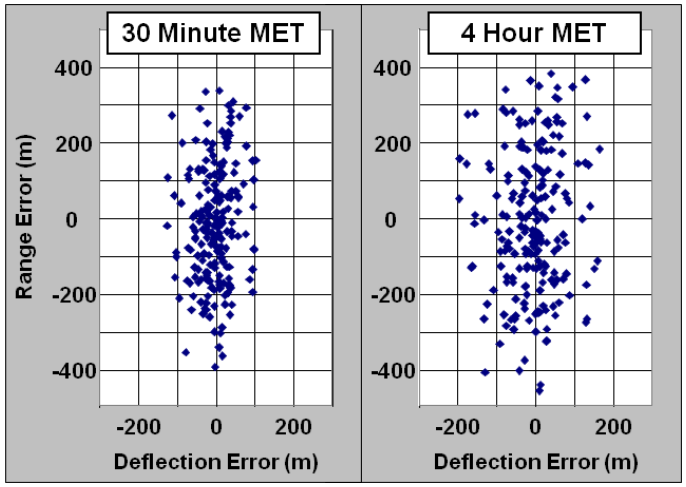
Agenda

- Radial Miss Distance
  - Categories of Accuracy
  - Explanation of Metric
  - Need for Metric
- Implementation
- Simulation Results

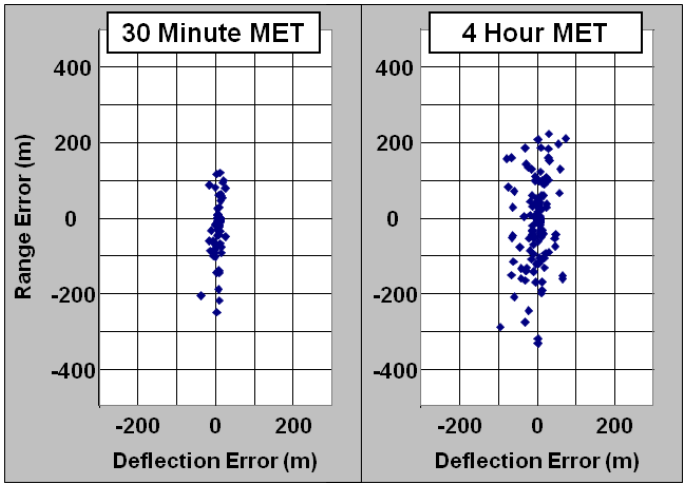
Categories of Accuracy

Area



- Conventional, ballistic projectile
  - Unguided
- Accuracy of projectile is very dependent on gun delivery and MET errors
- **Primary Use:** Area effects

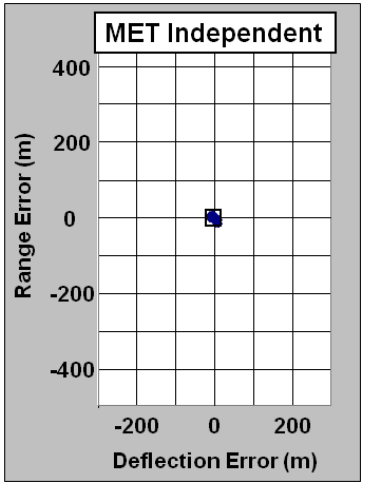
Ballistic Correction



- Guidance kits for area munitions
  - Guided but not highly maneuverable
- Kit can correct for some errors but can not adjust for major errors
  - Accurate MET and gun settings are still required for precision
- **Primary Use:** Reduces logistics for area munitions by reducing dispersion; collateral damage is not a concern

Results come from generic 6-dof modeling
Ballistic Correction results are from a nose + tailfin design

Precision

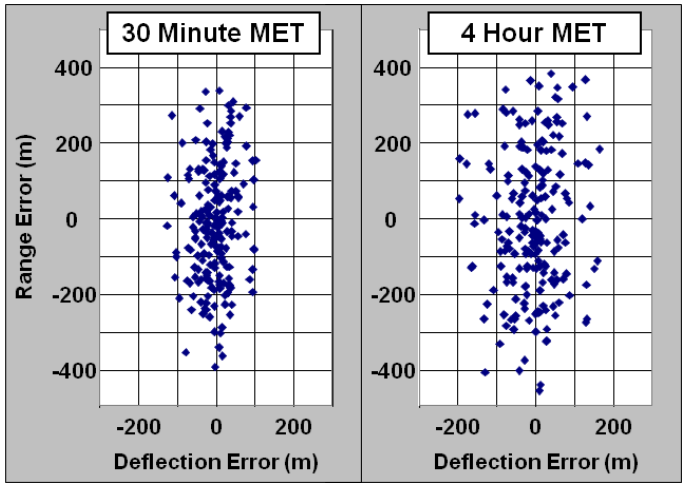


- Guided and highly maneuverable projectiles
- Corrects for all major errors
  - MET Independent
- **Primary Use:** Immediate effects or effects with friendlies or structures in close proximity

Radial Miss Distance

- CEP is traditional definition of accuracy and specifies that 50% of weapons will land within the stated radius
  - In simulation, a bi-variate normal distribution is assumed
- Radial Miss Distance (RMD) is a new measurement of accuracy that specifies 90% of weapons will land within the stated radius
  - RMD is used in conjunction with CEP; Both metrics of accuracy should be specified

Area

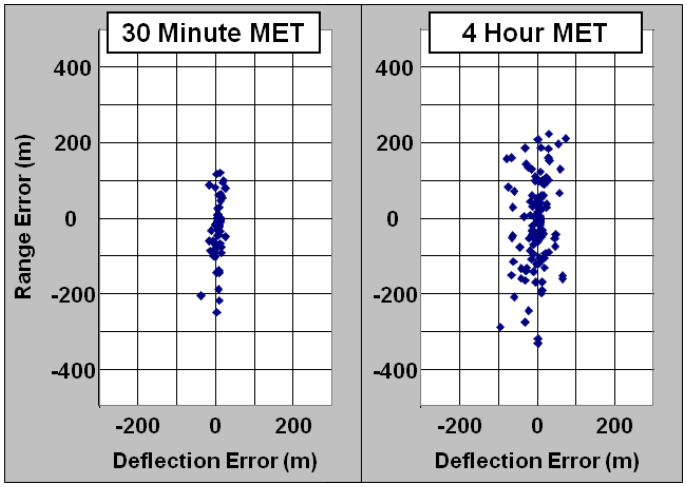


CEP = 130m
RMD = 257m

CEP = 166m
RMD = 306m

Roughly 2-3x CEP

Ballistic Correction

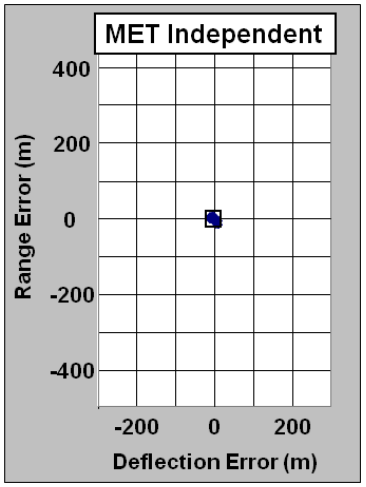


CEP = 7m
RMD = 74m

CEP = 28m
RMD = 166m

Roughly 6-10x CEP

Precision



CEP = 5m
RMD = 15m

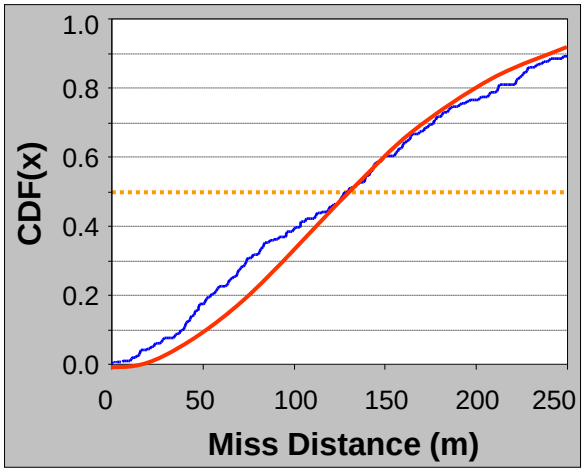
Roughly 2-3x CEP

Results come from generic 6-dof modeling
Ballistic Correction results are from a nose + tailfin design

The Need for RMD in Simulation

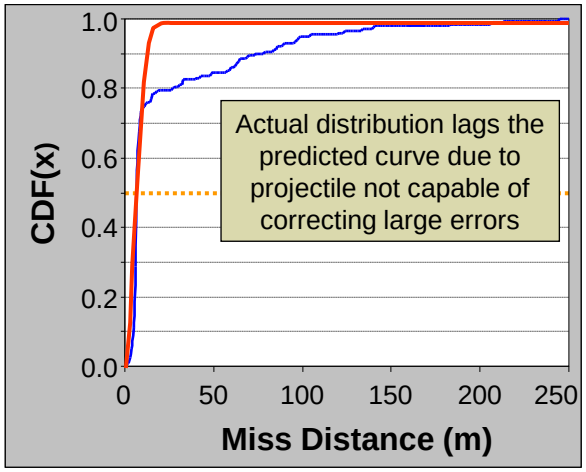
- Typical approach for playing artillery in simulation:
  1. Enter munition accuracy in either CEP or range and deflection (1-sigma errors)
  2. Assume circular bi-variate or normal distribution
  3. Pull random impact X and Y from distribution
- This approach does not accurately describe all munitions

Area



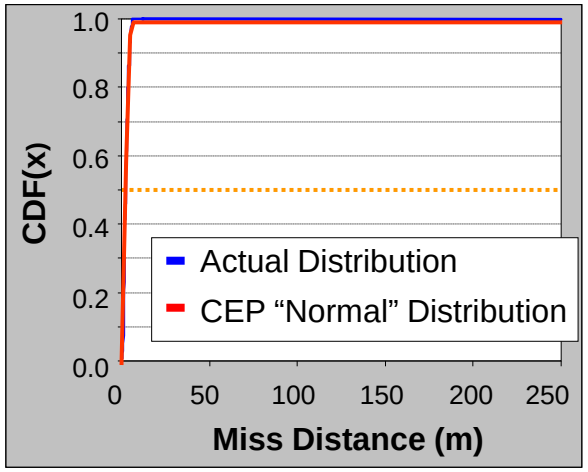
Area projectiles roughly follow normal distribution

Ballistic Correction



Normal curve does not match the actual data at the upper end

Precision

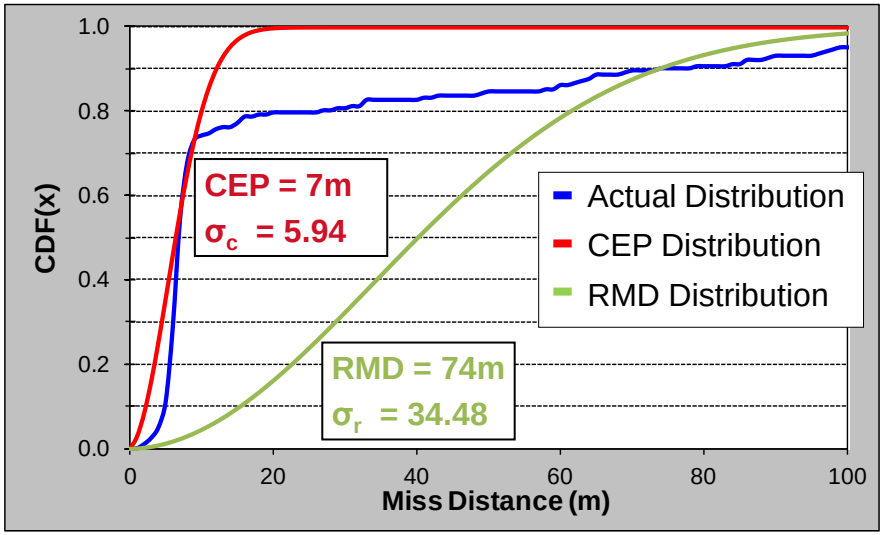


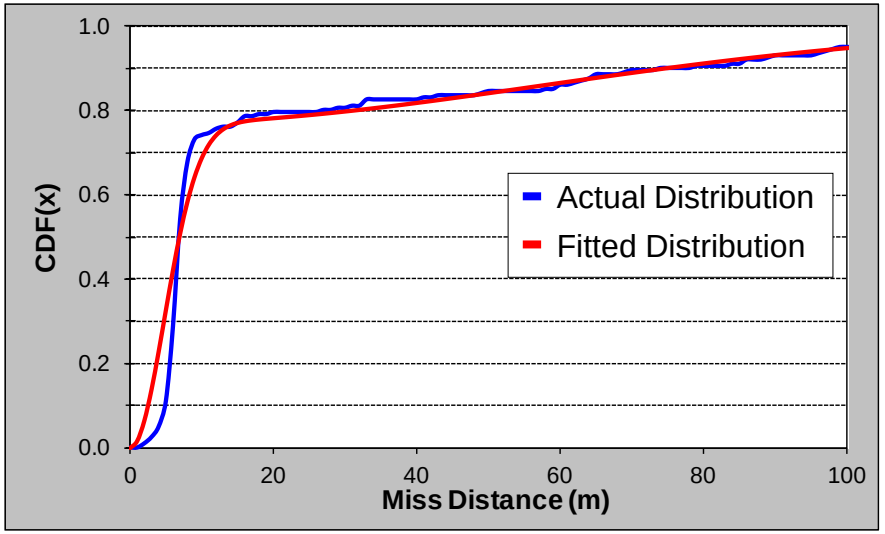
Precision projectiles roughly follows the normal distribution

Using just CEP to characterize all projectiles is misleading and does not adequately describe true accuracy

A Better Method

- A better approach for simulation is to break away from the bi-variate or normal distribution assumption
  - Enter both CEP and RMD values
  - Curve-fit to match entered data points
- The Algorithm:





- Find the curves for the actual CEP and RMD values
- Calculate the sigma values

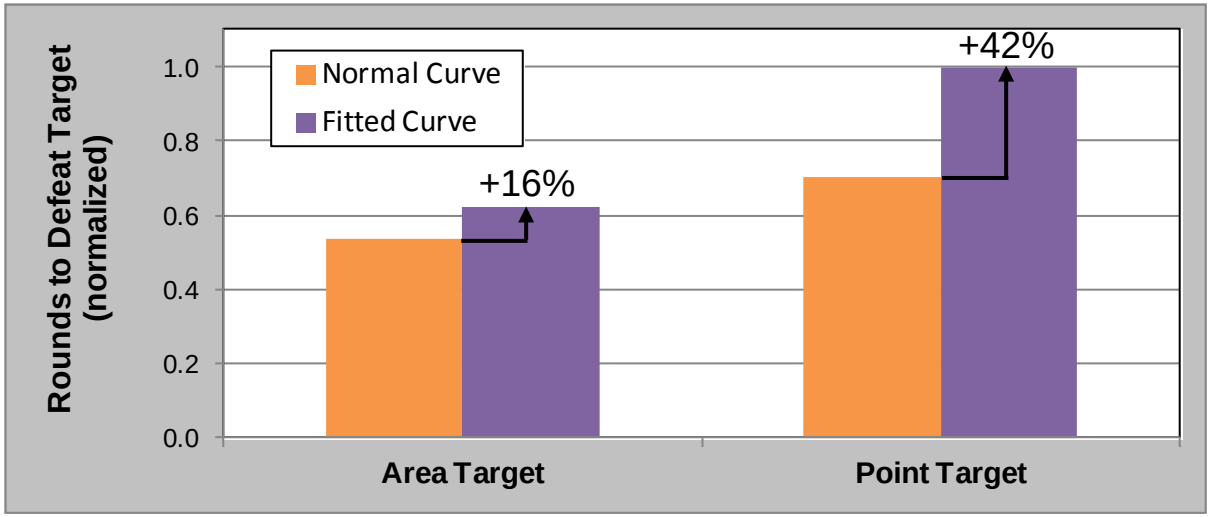
New methodology allows for actual distributions to be fit more closely

- Solve $CDF = \delta F(x, \alpha\sigma_c) + (1-\delta)F(x, \beta\sigma_r)$
- The full equations; solve for α and β

$$0.5 = \delta F(x_c, \alpha\sigma_c) + (1-\delta)F(x_c, \beta\sigma_r)$$
$$0.9 = \delta F(x_r, \alpha\sigma_c) + (1-\delta)F(x_r, \beta\sigma_r)$$

Implementation Results

- Implemented curve-fitting algorithm in Raytheon Salvo Effectiveness Model (SEM)
  - SEM is similar to ARTQUICK
  - Calculates number of rounds necessary to defeat targets



Cases

Normal Curve
- Only CEP entered into SEM
- Distribution assumed to be normal

Fitted Curve
- Both CEP and RMD entered
- Distributions fit to the two data points

- From just a simple algorithm change, number of rounds required to defeat the target increases by as much as 42%

Playing the projectile's distribution correctly in simulation can significantly effect the results

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Why it Matters

- Evaluation of munitions
  - Slight difference in results become significant when looking at larger campaigns
  - If ballistic-correction munitions are being compared to other munitions in simulation, they could be receiving an unintended benefit
- Results for firing munition at 100 area and 100 point targets:
  - Assume $10K per round and weight of 50kg

	Rounds Fired	Munition Cost	Weight of munitions to resupply
Normal Curve	524	$5.24M	26,200 kg
Fitted Curve	685	$6.85M	34,250 kg
Difference	+161	+$1.61M	+8,050 kg

Evaluation of a portfolio of munitions requires that all munitions are accurately represented

Summary

- Examination of artillery projectiles shows that distribution patterns can drastically change from munition to munition
- Long-standing simulation assumption that artillery has a normal distribution is often very inaccurate for ballistic correction munitions
- Very simple method to correct this involves entering both a 50% CEP and 90% radial miss-distance (RMD)
  - A distribution curve can then be fit to the two data points
- Implementation in lethality model prove that results can change considerably
  - This has implications for any analysis that compares different projectiles against one another
- Methodology has been submitted to and reviewed by AMSAA
  - AMSAA agrees there is an issue
  - They are evaluating solutions to the problem and how data can be collected

Radial Miss Distance allows for all projectiles to be accurately represented in simulation and evaluated in analysis

Questions?

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