Tissue Damage Model for Estimating Terminal Performance
Pistol Bullet Impacting Gelatin
• Background & Objective

• Army Lethality

• What the Tissue Damage Model (TDM) is and how it works (top level)

• Comparative examples of commercial product

• TDM interactive session

• Task/Schedule

• Summary
Background

• Upcoming requirements documents have performance evaluations in terms of Probability of Incapacitation, P(i).

• Neither industry, nor most of government, has the ability to evaluate P(i) to the current ORCA/SDF standard.

• A “screening” process or “bridge” model to allow more efficient collaboration between industry/OGA and Army, has been discussed between ARDEC and ARL numerous times over the past 10 years.

• Ammunition Industry interviewed to understand how they guide their ammunition development and compared to how the Army does.

• Heavy reliance on FBI methodology by industry which evaluates hit and damage separately, at the technical level. These are later combined at the programmatic level.

• Both industry and FBI are in agreement that industry needs a way of evaluating its developmental product in correlation to the buyer’s requirements.

• ARDEC has developed a validated model for “pistol-class” ammunition; working on rifle
Current Analysis Philosophies for small arms effectiveness evaluation

Fall into 3 categories...

1. Probabilistic
2. Ballistic Measurables
3. Individual / Anecdotal Experiences
Q: At what level do you make a decision on which system (A, B or C) is best for the soldier?

A: depends on your role in the organization

Ballistics (measureables)
- Velocity
- Mass
- Lethal Mech
- Recoil
- Flight Mech etc...

Probabilistic Effects
- \( P(h) \)

Probabilistic Target Reaction
- \( P(i) \)

Statistical Loss exchange Ratio
- Force on Force

The whole picture

Assume C is much more costly than A.
C will be the system you need, once in a while; is it worth the cost?
(depending if you’re the one who needs it, or the one who rights the check)

Error bar on any one predicative value

A: depends on your role in the organization
Penetration Model Summary

1. Penetration depth of deepest portion of projectile
   a. They want to see 12-18” and assign point accordingly as established by medical professionals

2. Standard deviation of the penetration depth
   a. This speaks to their desire to have consistent performance. Large SD’s result in significant point deductions.

3. Projectile retained weight
   a. They want to see 100% weight retained and award accordingly.

4. Projectile expansion
   a. They want to see the greatest expansion, optimized to seek maximum diameter that will achieve the 12 – 18” of penetration.

5. The number of shots that penetrated less than 12 inches
   a. This again speaks to consistency. The more shots that penetrate less than 12, the more points you lose.
ARMY Lethality
ORCA Static-Dynamic Framework (SDF)

The framework is composed of three stages: (1) Delivery, (2) Damage to Target (injury) and (3) the ability to assess the target’s reduced capability to accomplish tasks (incapacitation). Each one of these stages requires an in depth understanding of the rifle and the projectile’s characteristics in terms of aerodynamics and terminal effects.
Lethal Mechanisms

Non-Deforming
FMJ (Yaw)

Designed Expansion
(JHP/EFMJ etc...)

Velocity/Design Induced Fracture
(Fragmenting, Frangible, etc...)

Example gelatin block effects
Evidence of yaw

Immediate reaction
projectile

Example gelatin block effects
fragments
Army Lethality, simplified

Probability of Hit, $P(h)$

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Probability of Incapacitation Given a Hit, $P(i/h)$

"damage equivalence"

Probability of Incapacitation, $P(i)$

(Not exactly, but adequate for discussion)

- Accuracy (Total System)
- Dispersion (Total System)
- Environment
- Target Size / Actions

- Impact Energy
- Lethal Mechanism
- Target Composition
- Hit Location on Target
- Target Task
TDM Concept/Objective

ARDEC has built an analysis tool for industry that allows them to estimate the amount of average tissue damage a given munition will create when impacting a human target. U.S. Army will ensure the tool aligns with lethality requirements established by their users.

Payoff (when complete):

- Increases the number of R&D organizations and efforts working towards accurately meeting the users needs
- Save cost to the U.S. Army in terms of time investigating commercial concepts with sub-standard terminal performance
- Save cost to industry in terms of prototyping and submissions
- Strengthen technical bonds between gov’t tech community, OGA and industry counterparts

Recent Events (2nd QTR FY16):

- Evaluated first gen concept
- Began technical code development for version 2
- Gather OGA/SME feedback and working into model
How the Tissue Damage model (TDM) works...

1. **Projectile Type/Geometry**
   - Velocity Decay
     - Dziemian
   - Fragment Summation

2. **Gel Block Data**
   - Yaw History
     - Prather
   - Damaged Volume

3. **Tissue Simulator**
   - CMAN/ORCA

- Terminal Performance Rating
“Lethality” vs. Average Wound Volume

Why we are using it...

- Correlates well to “Lethality” values divorced from hit probability
- Ammo that deviates from line is typically explainable

Representative examples of “lower velocity” projectiles

Why we are using it...
That Energy Thing…

Everything above the KE fit line has an efficient tissue damaging mechanism.

Efficient Lethal Mechanism

Inefficient Lethal Mechanism

Poor expansion, no yaw

Calibrated with “lower velocity” projectiles
TDM Usage Example
Tissue Damage Estimation Tool

Example: .40 cal JHP

- Projectile geometry (nose shape or expanding/fragmenting)
- Projectile dimensions for area calculation entered here
- Red line: Wound diameter
- Green arrows: Yaw angle
- Tissue definition - preset (e.g., all muscle) or specify tissue for each depth increment

Terminal Performance Rating: 37.29

Wound volume output

Input sheet: EX_40FederalJHP.xlsx

Graphical representation of projectile

Input sheets can be used to recall previous models

UNCLASSIFIED
5 commonly used commercial cartridges chosen solely to evaluate the range of the model's capability:

1. .50 AE, FMJ, 325 grains, 1305 ft/sec, TPR = 60.5
2. .40 cal S&W, JHP, 180 grains, 1110 ft/sec, TPR = 47.4
3. .45 ACP+P, FMJ, 185 grains, 1130 ft/sec, TPR = 30.1
4. .45 ACP, FMJ, 230 grains, 890 ft/sec, TPR = 27.0
5. 9mm Parabellum, FMJ, 124 grains, 1140 ft/sec, TPR = 20.6
6. .22LR, FMJ, 40 grains, 1200 ft/sec, TPR = 8.6

TPR = Terminal Performance Rating
Comparative Model Output: Muscle/Gelatin

.50 AE

TPR = 60.5

.40 S&W JHP

TPR = 47.4

.45 ACP +P

TPR = 30.1

.45 ACP

TPR = 27.0

9mm Para

TPR = 20.6

.22 LR

TPR = 8.6

Data generated with current version of TDM
2 Discrete Shot lines

Simulated by current version of TDM

Frontal shot through center chest

- .50 AE
- .40 Cal JHP
- .45 ACP
- 9mm Para
- .22 LR

Side shot through Shoulders

Data generated with current version of TDM
Single-tissue targets

Numbers made with current version of TDM

9mm Para

Muscle

Subcutaneous

Bone

Liver

.40 cal S&W JHP

Liver

Lung

Bone

Muscle

Subcutaneous
Displayed bands of performance were determined by:

- Error budget calculations to determine the precision of the model
- Comparison to historical P(i) precision (.3 pts)
- Comparison to products used by OGA and deemed “effective”
Interactive Trial

Run audience-fed examples

(AT RDECOM BOOTH)
<table>
<thead>
<tr>
<th>Tasks / Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yaw History</strong></td>
</tr>
<tr>
<td>2nd QTR FY16</td>
</tr>
<tr>
<td>3rd QTR FY16</td>
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<td>1st QTR FY17</td>
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<td>2nd QTR FY17</td>
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<tr>
<td>3rd QTR FY17</td>
</tr>
<tr>
<td>4th QTR FY17</td>
</tr>
<tr>
<td><strong>Hole size validation</strong></td>
</tr>
<tr>
<td>Low velocity hole size</td>
</tr>
<tr>
<td>High velocity hole size</td>
</tr>
<tr>
<td><strong>Fragmentation vs Expansion (validation)</strong></td>
</tr>
<tr>
<td><strong>Rifle velocity spectrum calibration &amp; validation</strong></td>
</tr>
<tr>
<td>Higher velocity impact</td>
</tr>
<tr>
<td>Fragmentation</td>
</tr>
<tr>
<td><strong>Packaging</strong></td>
</tr>
<tr>
<td>Software Language &amp; Interface Design</td>
</tr>
<tr>
<td>Security &amp; Distribution</td>
</tr>
</tbody>
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Summary

- Objective: Create a model that allows industry to estimate terminal performance in a manner that separates hit from damage, while maintaining adequate correlation to Army requirements.

- Current Tissue Damage Model (TDM) version is validated for “lower velocity” projectiles only.

- Version two is intended to work in all mass/velocity/Lethal mechanism regions.

- JSSAP funding the creation of version 2.

- 1 year effort lead by ARDEC and supported by ARL to end 4th QTR 2016 to finalize TDM model.

- Seeking release to industry by 3rd QTR 2017.

- Hit probability, among other system characteristics, need to be evaluated in any selection process. This model is for terminal performance, ONLY. The author suggests a quality requirement document contain damage, hit and probabilistic metrics, tied together.

- Seeking participants to assist in validation and comparison to other standards.