ARDEC Terminal Performance Model

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• Background
• Terminal Performance Model (TPM) Architecture & Inputs
• On-Screen Example
• Interactive Session; Q&A
• Requirements documents evaluate terminal performance in terms of Probability of Incapacitation, P(i).

• Neither industry nor most of government can evaluate P(i) to the current SDF standard.

• A “bridge” model, intended to allow more efficient collaboration between industry, OGAs, and the Army, has been discussed between ARL and ARDEC.

• Ammunition industry has been interviewed to understand how their ammunition development is guided and how it compares to Army standards.

• There is heavy reliance on the FBI’s methodology which evaluates hit and damage separately in the technical assessment.

• Industry needs a way to evaluate developmental products before submission to correlate to buyer requirements.

• ARDEC has developed a calibrated model for pistol-class ammunition, with further testing on other rifle, shotgun, and other types of ammunition.
ARDEC has built an analysis tool intended for use by industry OGAs that estimates the amount of average tissue damage a given munition will create when impacting a human target. The Army ensures the tool aligns with user-established lethality requirements.

The ARDEC TPM currently…

- Is a standalone application written in MATLAB; the final product will be a CAC-enabled web application.
- Operates via a “Test-Model-Evaluate” methodology.
- Assists with R&D design choices.
- Uses geometric characteristics of the fired projectile and data collected from an Army-standard gelatin block test event as inputs.
- Simulates the test event occurring against a variety of monolithic human tissue types, a body-weighted average of six common tissue types, or a “complex shotline” consisting of multiple tissue types.
- Produces a Terminal Performance Rating (TPR) output for the test event, intended to be used as a comparative tool against a baseline or competitor system.
- Requires feedback from industry, OGAs, other SMEs to refine model – we need your help!
ARDEC Terminal Performance Model v2.6 --- DO NOT DISTRIBUTE

Geometry Type
- Non-Deloring
  - Ogive (Meplat/Spitzer)
  - Ogive (Spherical Nose)
  - Truncated Cone
  - Wadcutter
  - Semi Wadcutter
  - Other

Ogived Dimensions
- Projectile Diameter
- Projectile Length
- Ogive Length
- Ogive Radius
- Projectile Diameter at Tangency Point
- Nose Length
- Nose Radius
- Meplat Diameter
- Boat Tail Length
- Boat Tail Angle (deg)

Profile Area
- 63.857
- 115.814

Gel Block Data
- Estimated Impact Velocity
  - 1140 ft/s
  - 20% Depth
  - 20% Goldin Penetration Depth
  - 0 Simulated Penetration (in)

Tissue Simulator
- Body-weighted average
- Target Type
  - Entire Body
  - In Body OFF
- TPR Analysis Depth (in) (max 30)
  - 14

Run TDM via Input Sheet
- C:\Users\gavin.mcelrath\Documents\WATL
- Select Sheet...
- Run Input Sheet

Batch Processing
- Select Sheets...

TPM GUI v2.6

Terminal Performance Rating
- 23

Damage Plot Height (inches)
- 5

Damage Plot Width (inches)
- 14

Results

Export Data
- Store Current Result
- View Stored Data

Export Stored Data
TPM can handle monolithic, expanding, and fragmenting round types. Each requires different geometric data:

**Monolithic yawing projectiles…**
- Nose type (single ogive, double ogive, truncated cone, etc.)
- Diameter & length
- Ogive characteristics
- Boattail characteristics
- Mass

**Expanding projectiles…**
- Pre-expansion diameter & length
- Post-expansion diameter & length
- Mass

**Fragmenting projectiles…**
- Fragment mass, shape, density
- Wound track start and stop “depths”
- Fragment velocities at start and stop depths (can be estimated)
- See backup slides for more info
Expanding round example – profile sketch shows expanded projectile
A fragmenting bullet is fired into gel at an impact velocity of 3000 ft/s. The bullet fragments at initiation point #1 (measured at 1.5” depth), where an irregular piece of copper material breaks away and the rest of the bullet continues on. At initiation point #2 (6.5” depth), the bullet fragments again; this time, a cylindrical piece tumbles upwards and out of the block, while a cone-shaped piece continues moving more or less forward, stopping near the end of the block. After the shoot, the fragments' locations are probed to find their resting depth, after which the fragments are excised and weighed. Fragment velocities at the initiation points and where Frag #2 leaves the block are obtained via high speed video analysis.

The resultant TPM input sheet from this gel block shoot is shown below:
Gel Block data is collected from Army-standard gelatin shooting:

- Projectile velocity upon gel block impact
- Maximum penetration depth of projectile in 20% gel
  - 10% gel may be used instead, but 20% is Army standard
- Total projectile yaw upon gel block impact (can be estimated)
- Depth to maximum total projectile yaw (90° or 270°)

TPM can simulate penetration depth – this feature is still in development
Select simulated target in the tissue simulator:

- Body-weighted average of six different tissue types (muscle, subcutaneous, bone, lung, heart, liver)
- Monolithic “blocks” of tissue
- Complex shotlines of multiple sequential tissue types (two presets or user-defined)
- Maximum analysis depth can be adjusted as required up to 80 inches
- Probability of being in a region of the body at a given depth
TPM output is Terminal Performance Rating (TPR), a scaled representation of the volumetric damage done to the selected target.
• Specially-formatted Excel sheets can be used as “input sheets” to save and rapidly enter frequently-used TPM geometry and gel block inputs.

• Input sheets can be run in batch mode to quickly generate TPR values.

• TPR values can be saved and exported to an Excel file.

• Other features are currently in development…
  • Sturdivan “in body” probability values, fragment hazard analyses, etc.
Terminal Performance Rating Scale

Weapons Systems:
- Handguns
- SMGs
- Shotguns
- Low-Energy Rifles
- High-Energy Rifles

ALL VALUES ARE APPROXIMATE

Terminal Performance Rating

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