Always a Step Ahead

ARDEC ARMAMENTS

ARDEC Terminal Performance Model

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Act like someone's life depends on what we do.

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SUMMARY

- Background
- Terminal Performance Model (TPM) Architecture & Inputs
- On-Screen Example
- Interactive Session; Q&A

BACKGROUND

- 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.

TPM CONCEPT

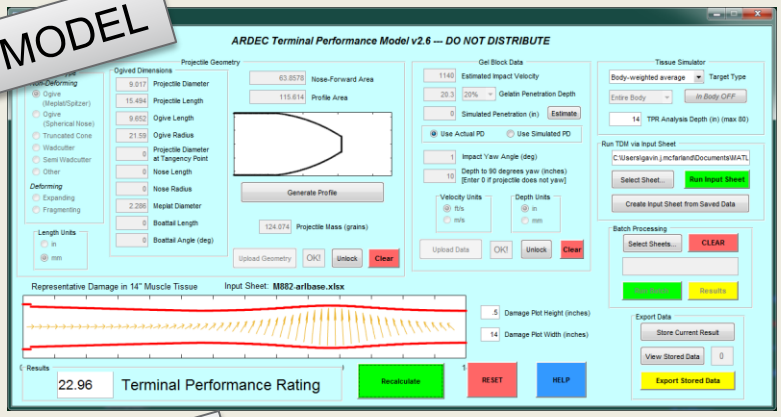
ARDEC has built an analysis tool intended for use by industry OGAs that estimates the amount of average tissue damage a given munition will create when impacting a human target. The Army ensures the tool aligns with user-established lethality requirements.

The ARDEC TPM currently…

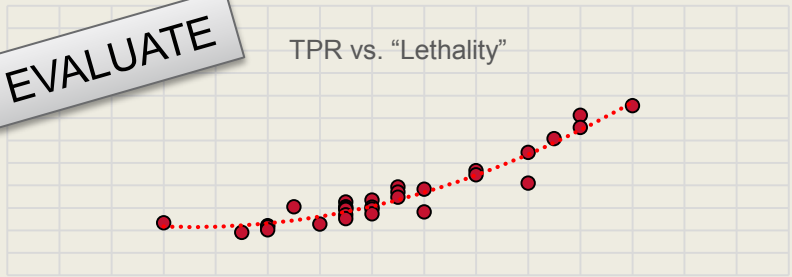
- Is a standalone application written in MATLAB; the final product will be a CAC-enabled web application.
- Operates via a "Test-Model-Evaluate" methodology.
- Assists with R&D design choices.
- Uses geometric characteristics of the fired projectile and data collected from an Army-standard gelatin block 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!***

TEST

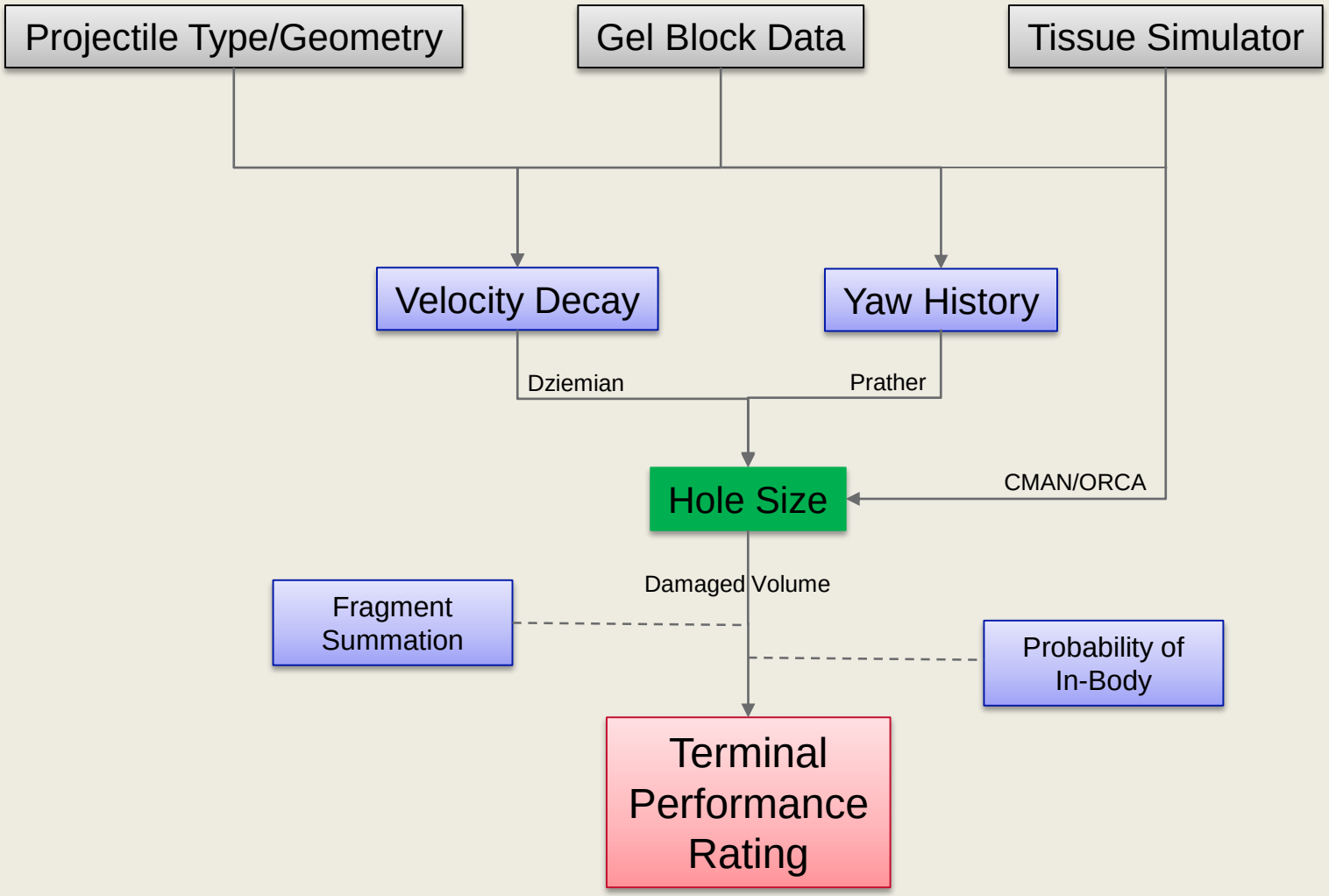
MODEL



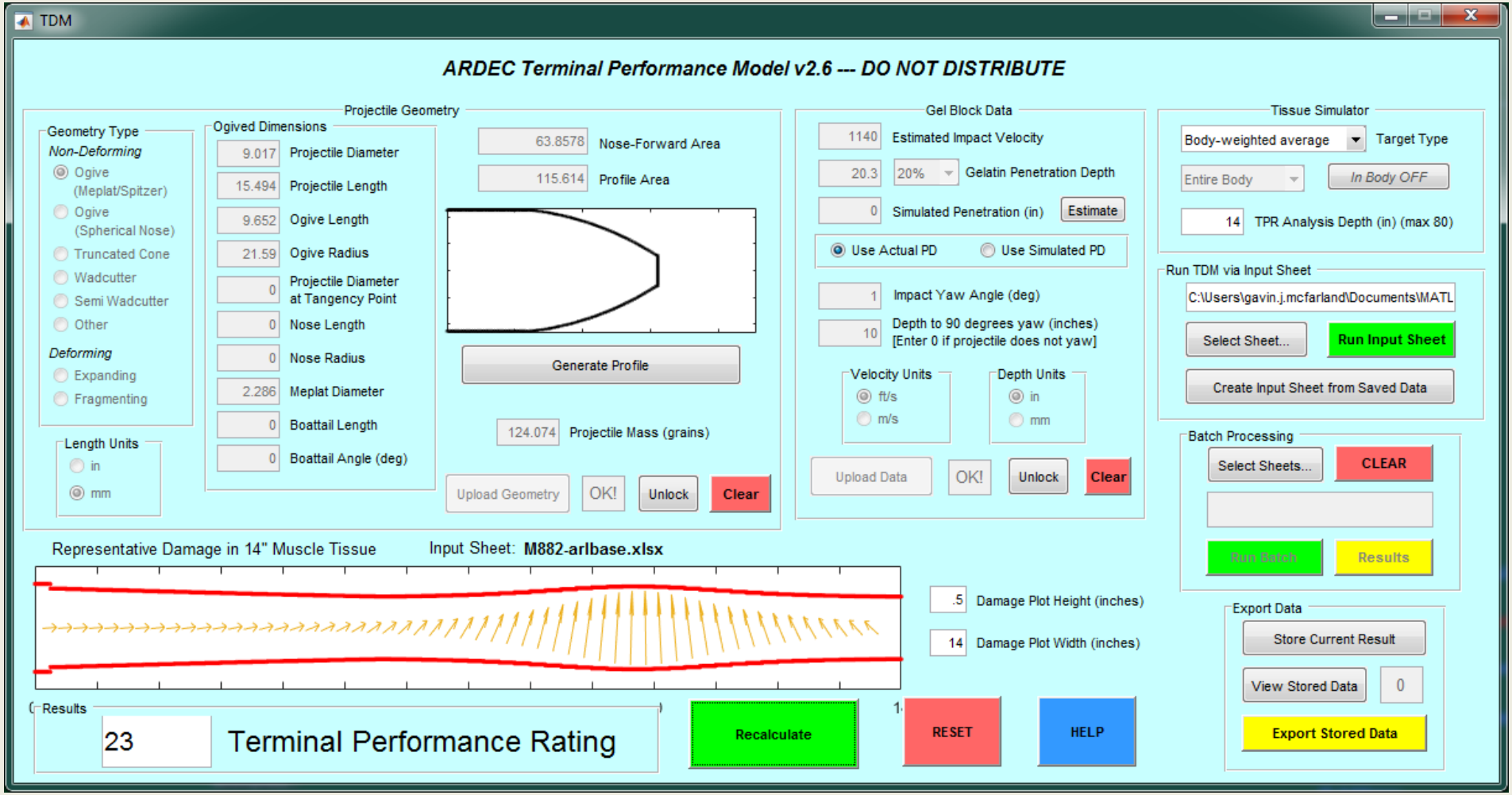
EVALUATE



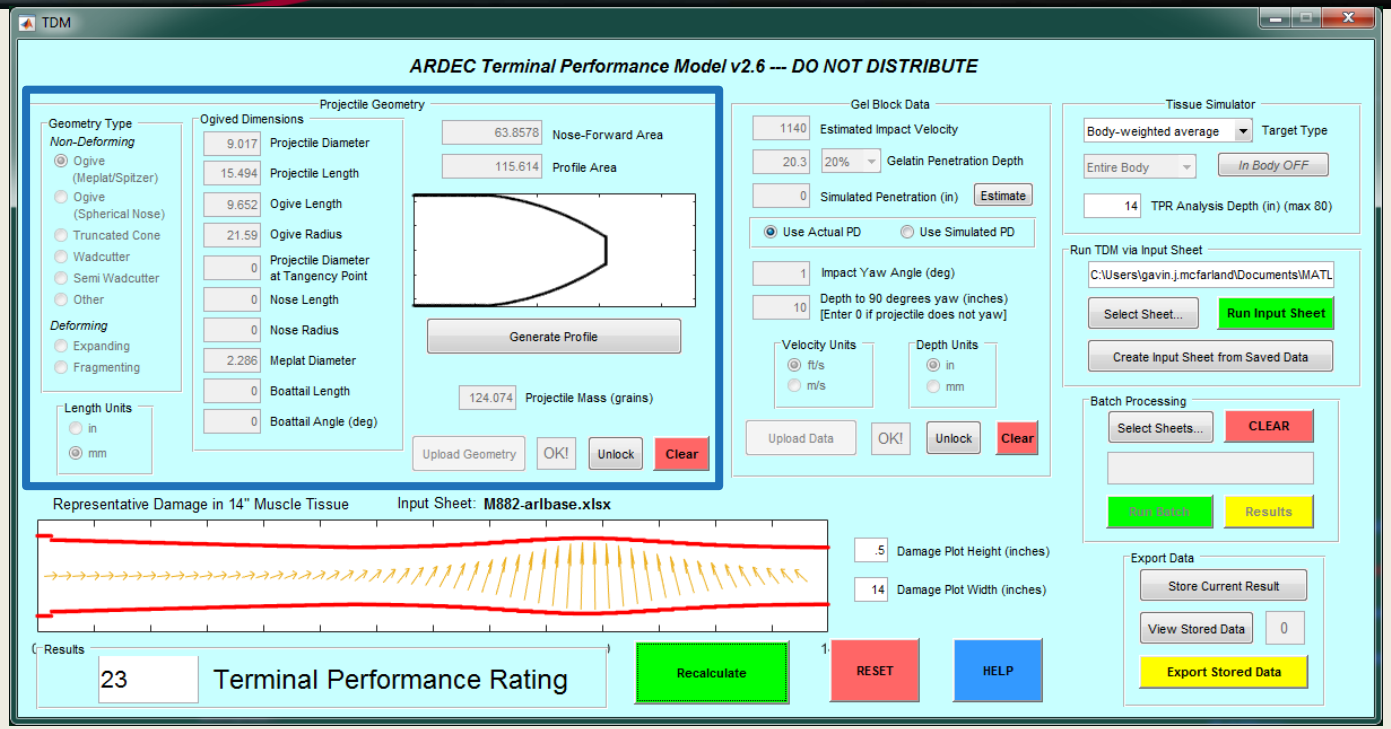
TPM ARCHITECTURE



TPM GUI v2.6


TDM
ARDEC Terminal Performance Model v2.6 --- DO NOT DISTRIBUTE
Projectile Geometry
Geometry Type
Non-Deforming
Ogive (Meplat/Spitzer)
Ogive (Spherical Nose)
Truncated Cone
Wadcutter
Semi Wadcutter
Other
Deforming
Expanding
Fragmenting
Length Units
in
mm
Ogived Dimensions
9.017 Projectile Diameter
15.494 Projectile Length
9.652 Ogive Length
21.59 Ogive Radius
0 Projectile Diameter at Tangency Point
0 Nose Length
0 Nose Radius
2.286 Meplat Diameter
0 Boattail Length
0 Boattail Angle (deg)
63.8578 Nose-Forward Area
115.614 Profile Area
Generate Profile
124.074 Projectile Mass (grains)
Upload Geometry
OK!
Unlock
Clear
Gel Block Data
1140 Estimated Impact Velocity
20.3 20% Gelatin Penetration Depth
0 Simulated Penetration (in)
Estimate
Use Actual PD
Use Simulated PD
1 Impact Yaw Angle (deg)
10 Depth to 90 degrees yaw (inches)
[Enter 0 if projectile does not yaw]
Velocity Units
ft/s
m/s
Depth Units
in
mm
Upload Data
OK!
Unlock
Clear
Tissue Simulator
Body-weighted average
Target Type
Entire Body
In Body OFF
14 TPR Analysis Depth (in) (max 80)
Run TDM via Input Sheet
C:\Users\gavin.j.mcfarland\Documents\MATL
Select Sheet...
Run Input Sheet
Create Input Sheet from Saved Data
Batch Processing
Select Sheets...
CLEAR
Run Batch
Results
Export Data
Store Current Result
View Stored Data
0
Export Stored Data
Representative Damage in 14" Muscle Tissue
Input Sheet: M882-arlbase.xlsx
.5 Damage Plot Height (inches)
14 Damage Plot Width (inches)
Results
23
Terminal Performance Rating
Recalculate
RESET
HELP

TPM Input – Geometry



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

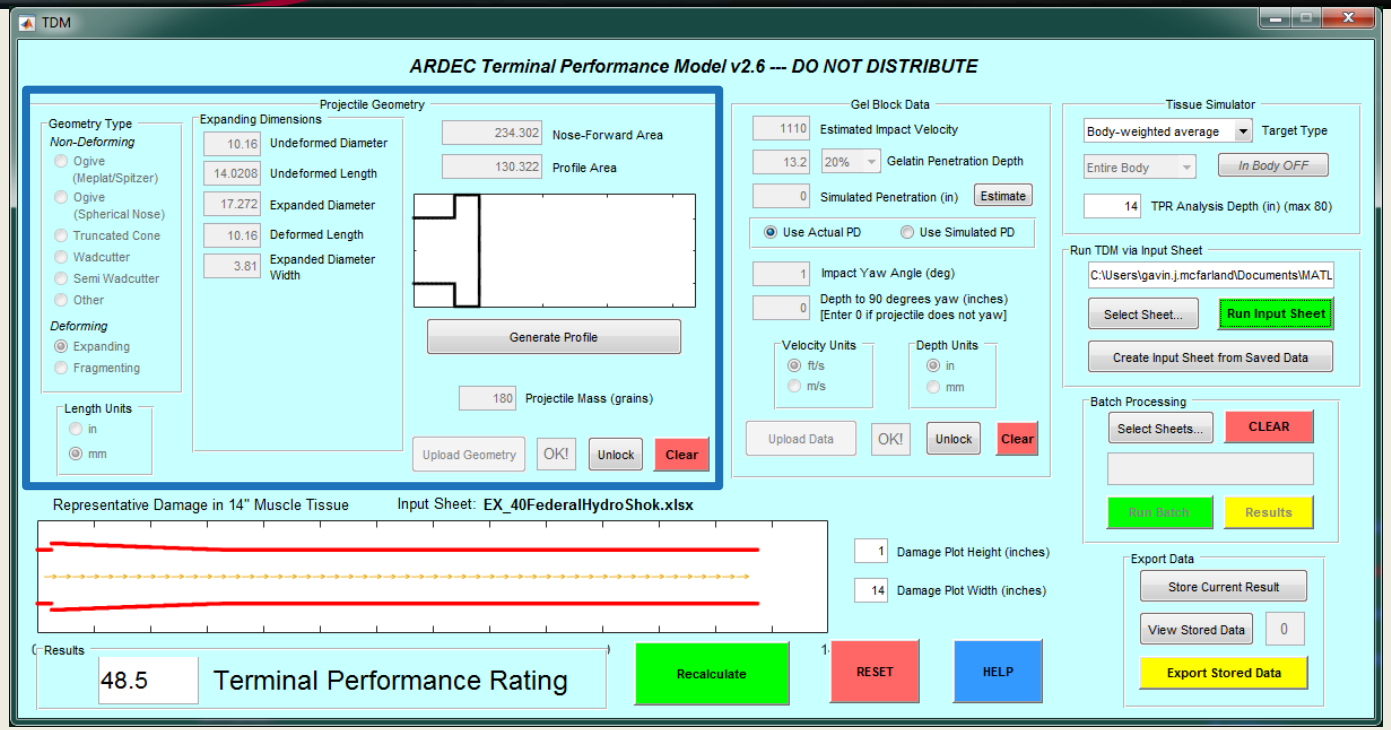
Expanding projectiles…

- Pre-expansion diameter & length
- Post-expansion diameter & length
- Mass

Fragmenting projectiles…

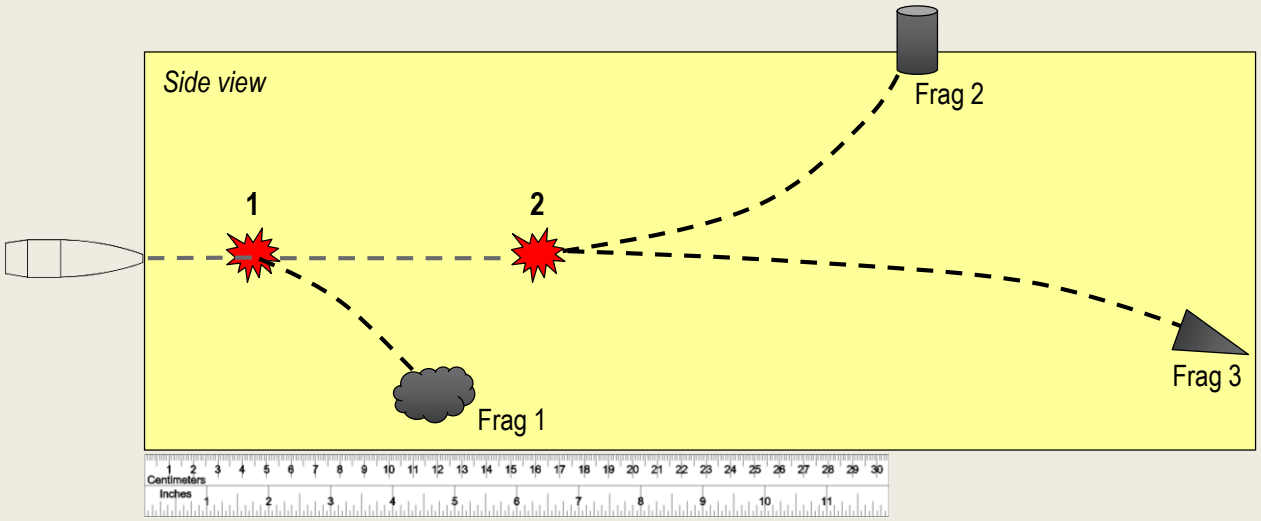
- Fragment mass, shape, density
- Wound track start and stop "depths"
- Fragment velocities at start and stop depths (can be estimated)
- *See backup slides for more info*

EXPANDING ROUND EXAMPLE



Expanding round example – profile sketch shows expanded projectile

FRAGMENTATION – A PRIMER



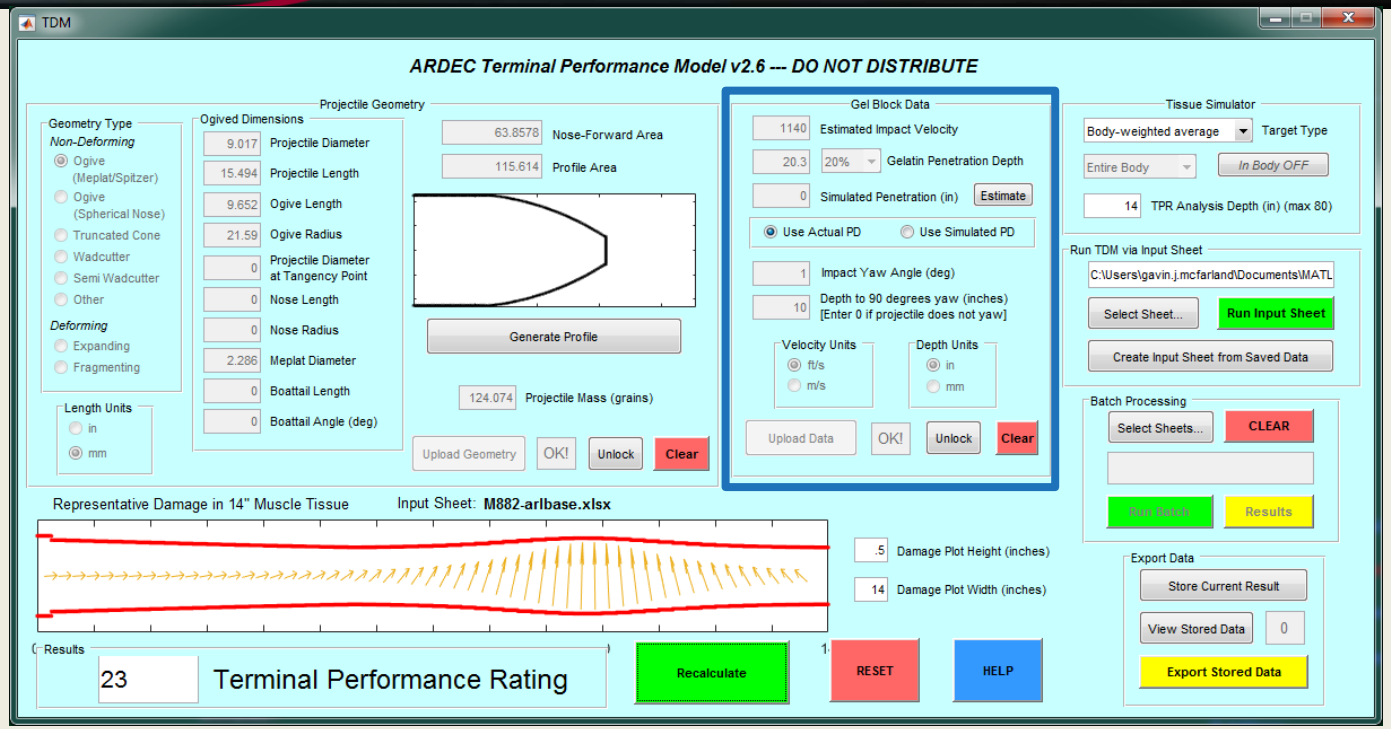
A fragmenting bullet is fired into gel at an impact velocity of 3000 ft/s. The bullet fragments at initiation point #1 (measured at 1.5" depth), where an irregular piece of copper material breaks away and the rest of the bullet continues on. At initiation point #2 (5.5" depth), the bullet fragments again; 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:

FRAGMENTING

# of Fragment Types	5							
			grains	g/cc	in	in	ft/s	ft/s
Fragment Name	**Fragment Shape**	**# Fragments**	**Mass**	**Density**	**Start Depth**	**Stop Depth**	**Initial Velocity**	**Ending Velocity**
Bullet	Rifle Bullet	1	67	8.6	0	1.5	3000	2850
Fragment 1	Chunky Frag	1	19.5	8.96	1.5	5.5	2850	0
Combined 2+3	Cone	1	47.5	8.6	1.5	6.5	2850	1800
Fragment 2	Cylinder	1	23.5	8.96	6.5	14	1800	100
Fragment 3	Cone	1	24	7.7	6.5	17.5	1800	0

TPM Input – Gel Block

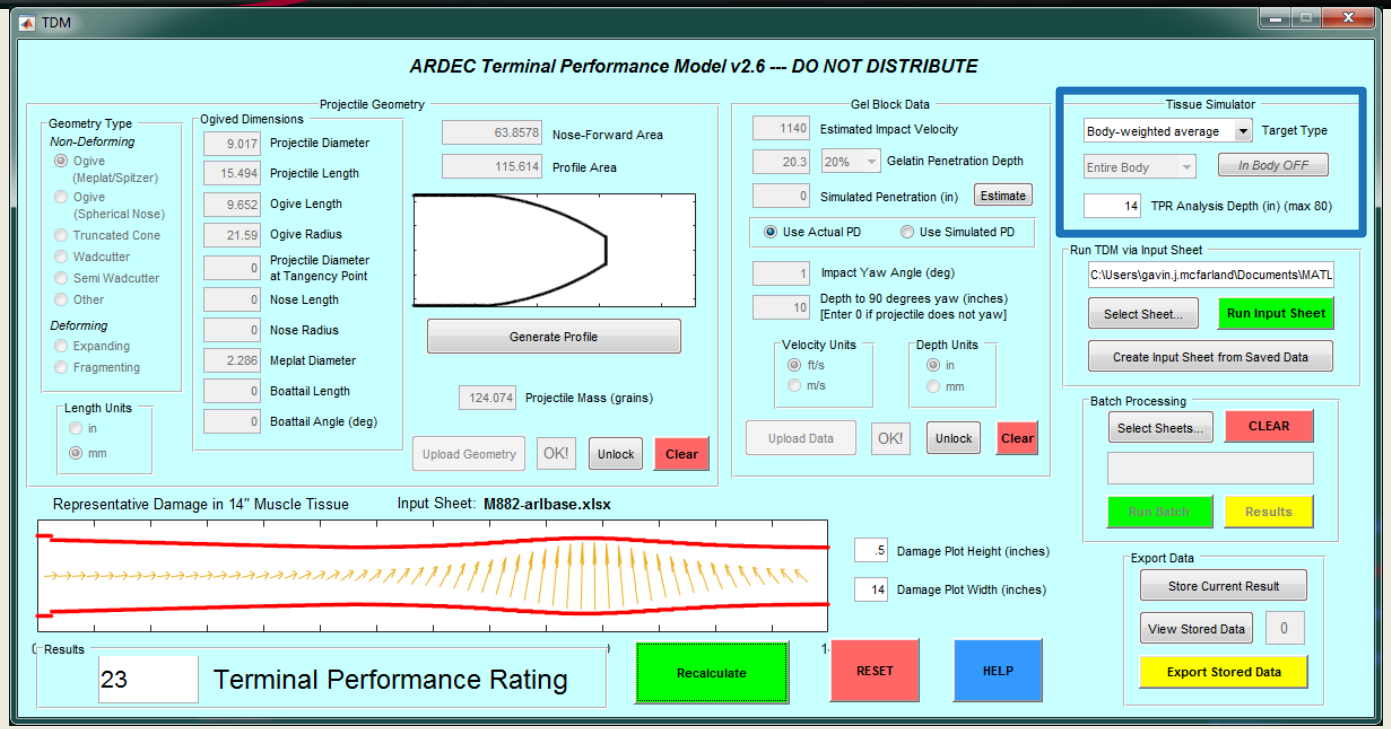


Gel Block data is collected from Army-standard gelatin shooting:

- 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

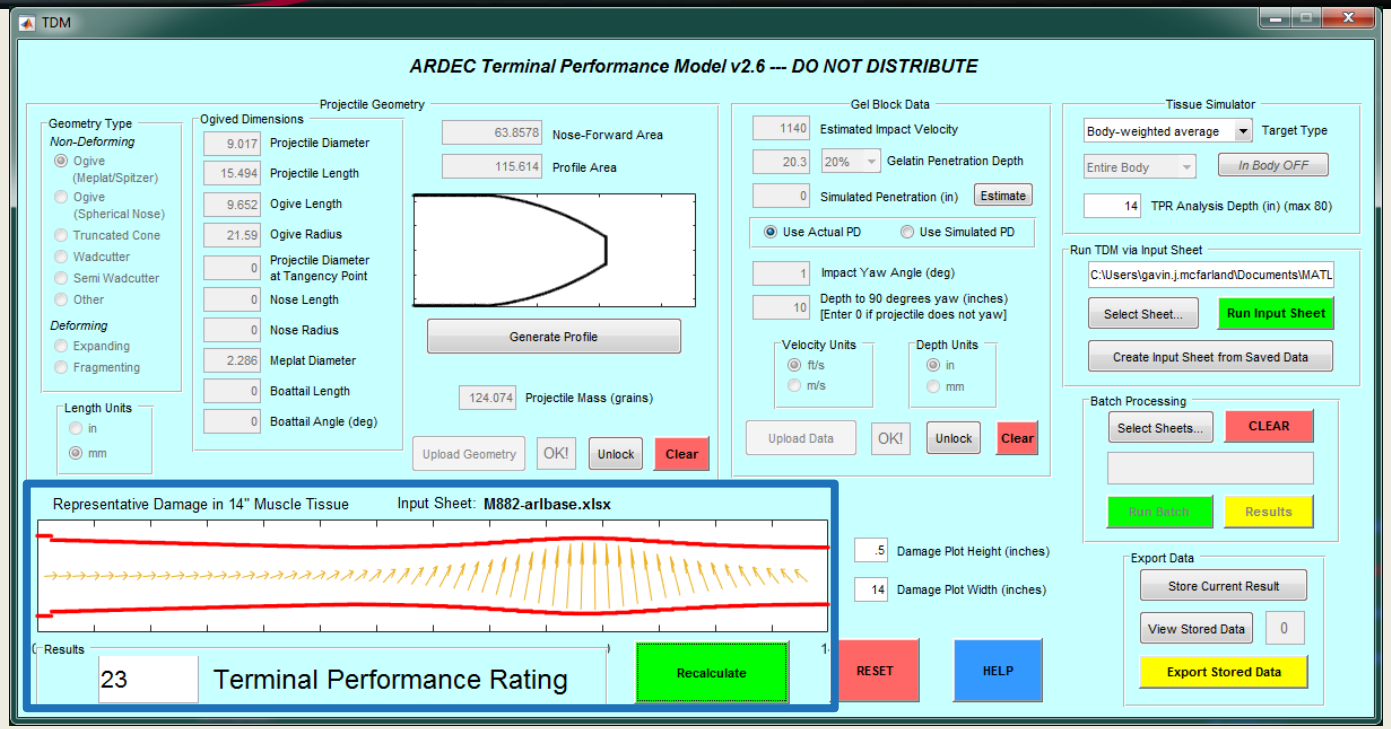
TPM Input – Tissue Simulator



Select simulated target in the tissue simulator:

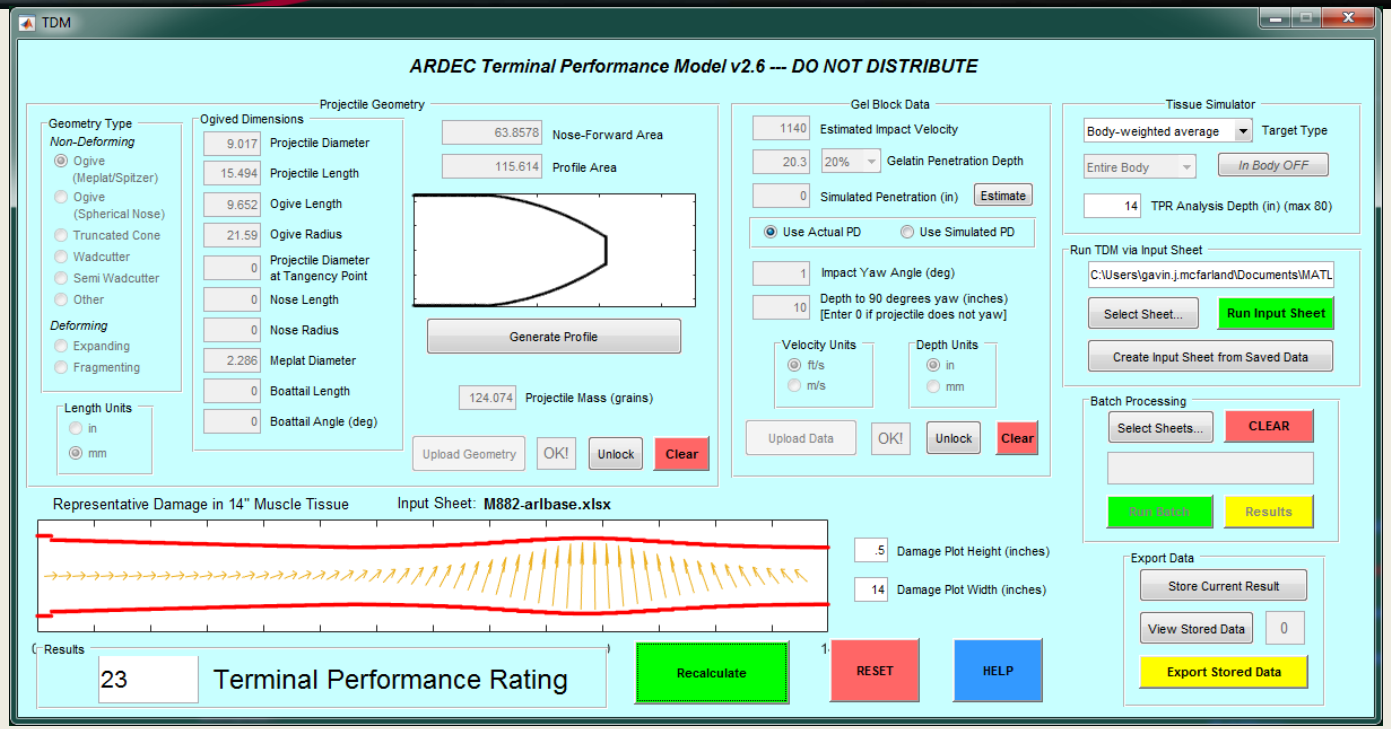
- Body-weighted average of six different tissue types (muscle, subcutaneous, bone, lung, heart, liver)
- Monolithic “blocks” of tissue
- Complex shotlines of multiple sequential tissue types (two presets or user-defined)
- Maximum analysis depth can be adjusted as required up to 80 inches
- Probability of being in a region of the body at a given depth

TPM Output – TPR



TPM output is Terminal Performance Rating (TPR), a scaled representation of the volumetric damage done to the selected target.

TPM Other Features



- 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