Different approach to establish an armament system baseline

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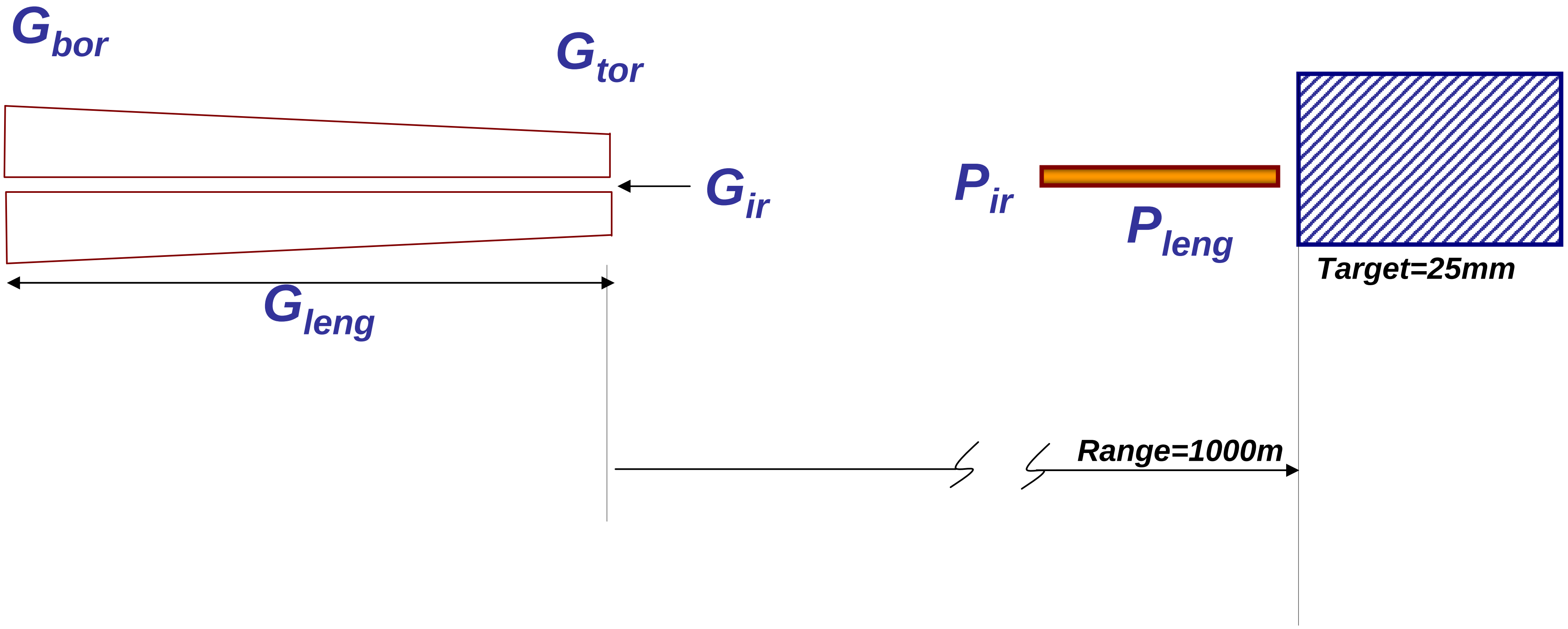
Overview

- Conventional design of new armament systems is not fully integrated
- Proposing an *integrated approach* to provide *first order estimate* of projectile and gun using optimization methods
  - Individual models of the projectile and gun are not the primary focus
  - Emphasis is on the framework for arriving at the baseline system
- The hope is to use this approach to:
  - Help systems developer narrow down the design space
  - Provide subject matter experts (projectile and gun) with starting point for further exploration of projectile and gun designs

Approach

- Simple Quasi static model set up in ANSYS with constraints imposed due to practical consideration for the bullet and weapon
    - Full Bore penetrator (base pushed; no sabots)
    - Simple tapered pressure vessel to simulate Weapon
  - Loads on model:
    - Normalized pressure travel curves from actual Large caliber & Small caliber data (no IB code coupled with the model)
- Design Optimization module in ANSYS is used for iterative design

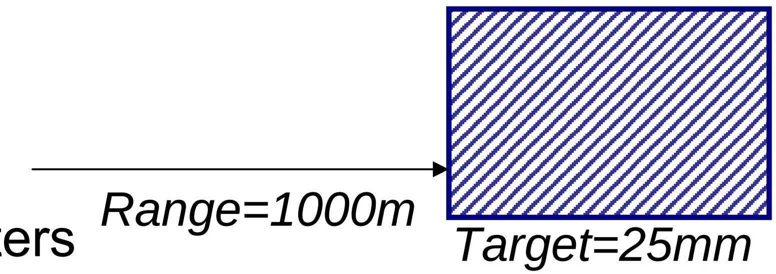
Projectile & Gun Parameters



Algorithm

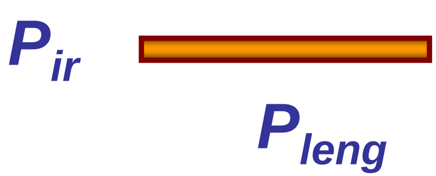
<u>*Working the problem backwards:*</u>

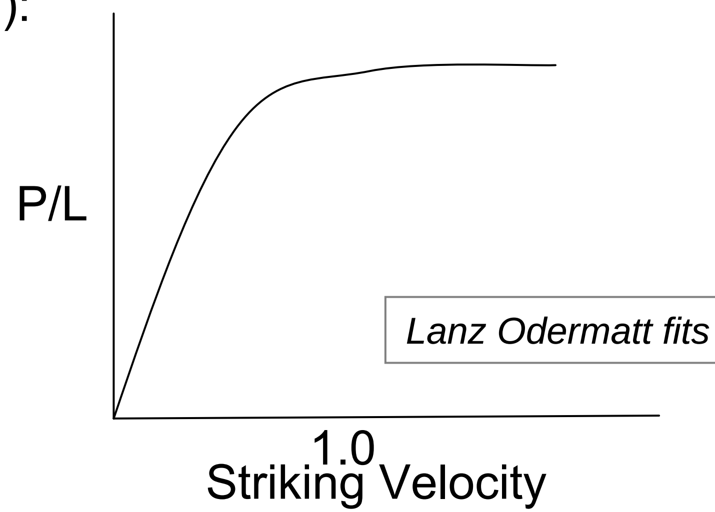
1. Begin with Target thickness and Range requirements (say 25mm at 1000m)



2. <u>*Projectile design space*</u>:

- Establish <u>*range*</u> of penetrator parameters
  - Establish length range such that penetration does not exceed 1.2 times the length (practical considerations):
    - example $0.85L<P_L<1.5L$
  - Establish diameter range such that:
    - Eg. L/D ratios in the range of 5<L/D<15





Algorithm

3. Calculate striking velocity for that penetrator configuration to defeat the target

4. Calculate velocity falloff, use point mass estimates (from diameter and mass).

5. Calculate muzzle velocity from velocity fall off and the defeat range.

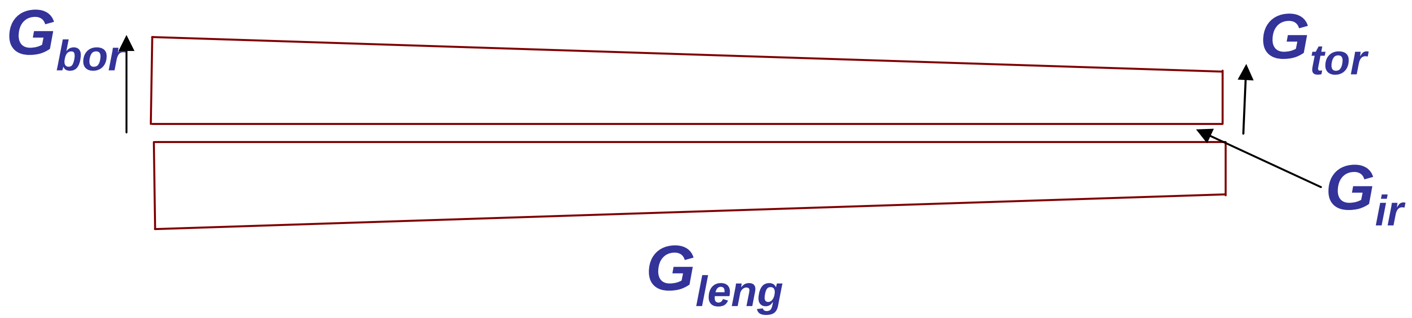
6. Calculate Muzzle energy (from projectile mass and muzzle velocity)

Algorithm

3. *Weapon Design Space*:

- Complex gun tube design considerations (auto frettage, critical velocity, thermal considerations etc) are not considered for this illustration.
- Chambrage and breech block features and recoil omitted for simplicity but could be added in other versions.

Since we have a full bore projectile, the gun bore is set as the projectile diameter + clearance



- Establish a range of acceptable gun tube lengths ***Gleng*** (in this model, its set equal to travel) that is acceptable to the customer (say from 0.5m to 2.0m)
- Optimization routine picks ***Gleng*** from the range

Algorithm

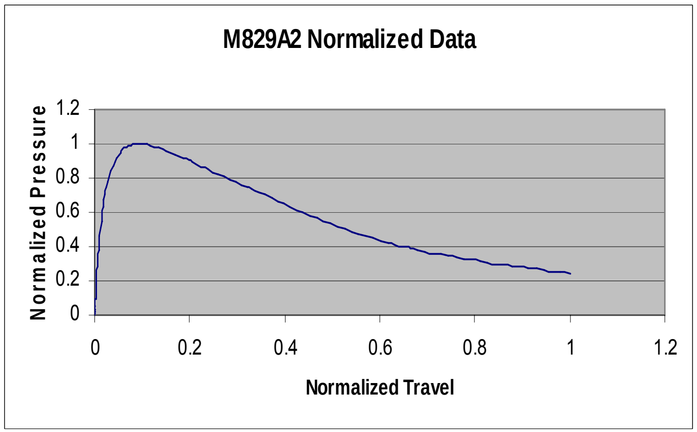
- Since required muzzle energy is now known, and Gleng is known, the mean base pressure can be calculated

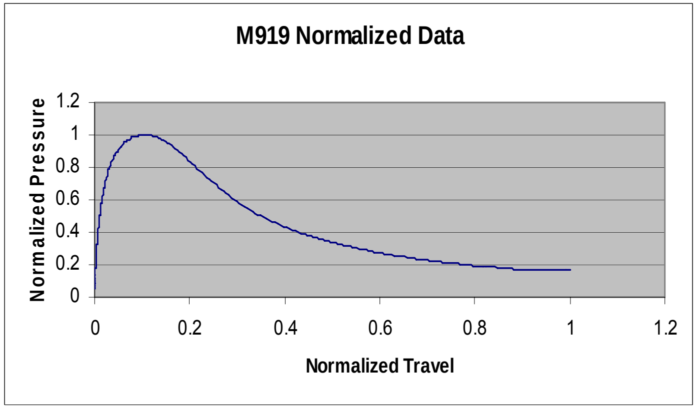
- Mean Base Pressure * Travel = $\frac{\text{Muzzle Energy}}{(\text{Area} * \text{Travel})}$

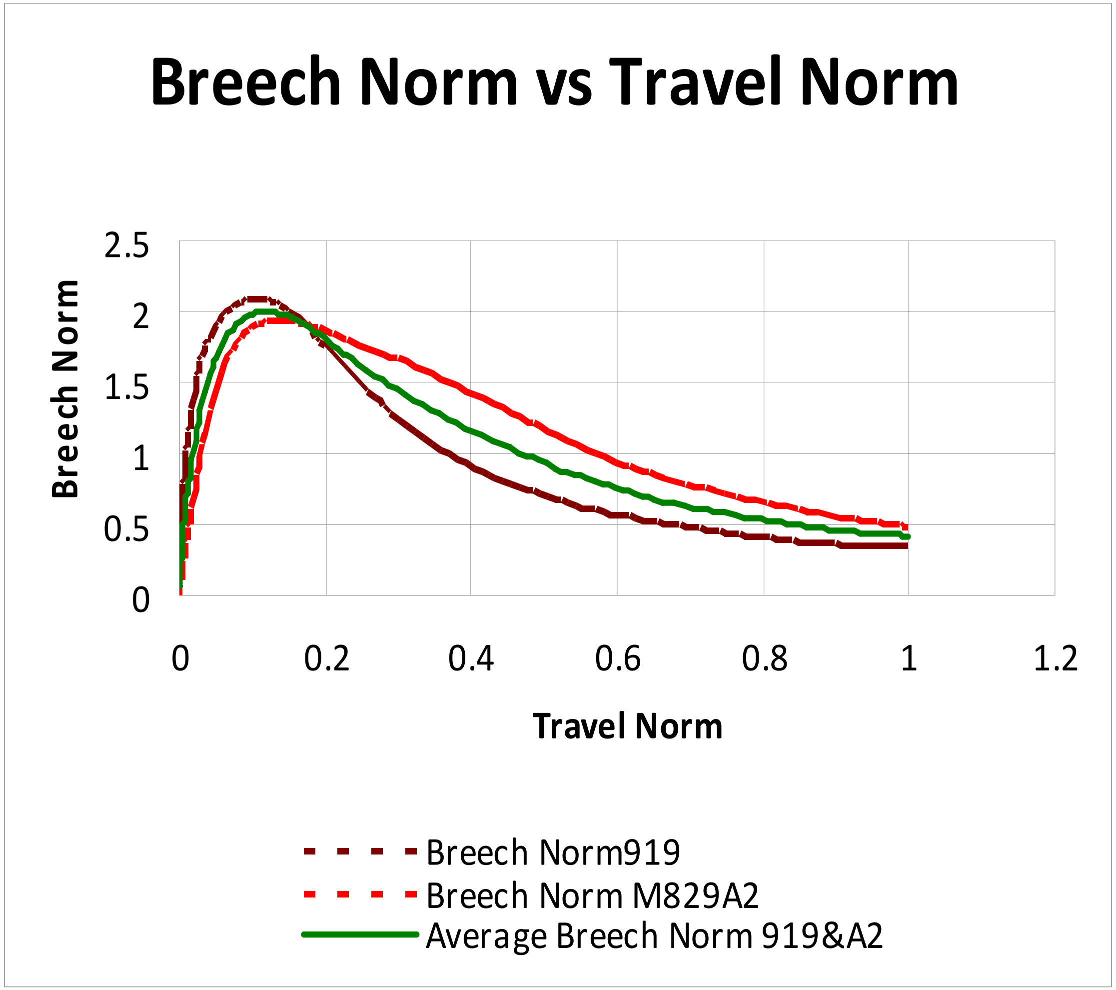
- Breech pressure can then be calculated, since it is on the order of 2/3rd breech pressure (no Lagrange here; no IB code used)

- Factor in energy losses (projectile kinetic energy about 29% of chemical energy)

Pressurization Model







Tube pressurization data generated from the average of normalized breech pressures

Optimization Scheme

Optimization Routine Structure

Design Variable Constraints:

- Projectile Length constraints (penetration cannot exceed 1.2 times length)
- Projectile length to Diameter constraints (5 <≤ LD ≤15)
- Gun Tube length constraint (set by practical restrictions)
- Tube outer diameter constraint (set by practical restrictions)
- Tube muzzle diameter constraint (set by practical restrictions)

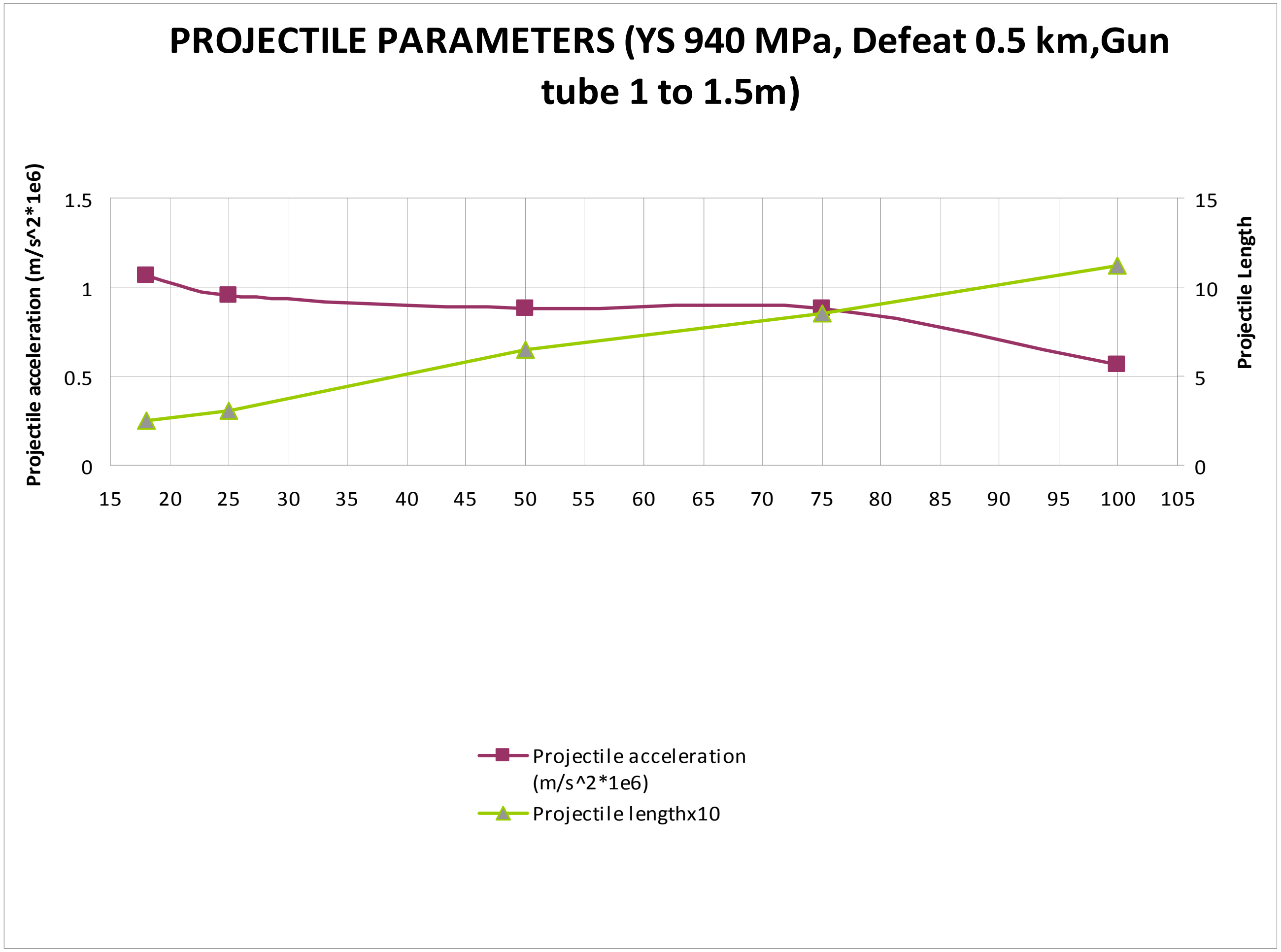
State Variables Constraints:

- Projectile axial stress at base not to exceed
- Projectile von mises stress not to exceed
- von Mises stress at Chamber area not to exceed limit
- von Mises stress at Muzzle area not to exceed limit

OBJECTIVE Function:

- Minimize Volume of Gun Tube (or weight of tube)

Sample Results



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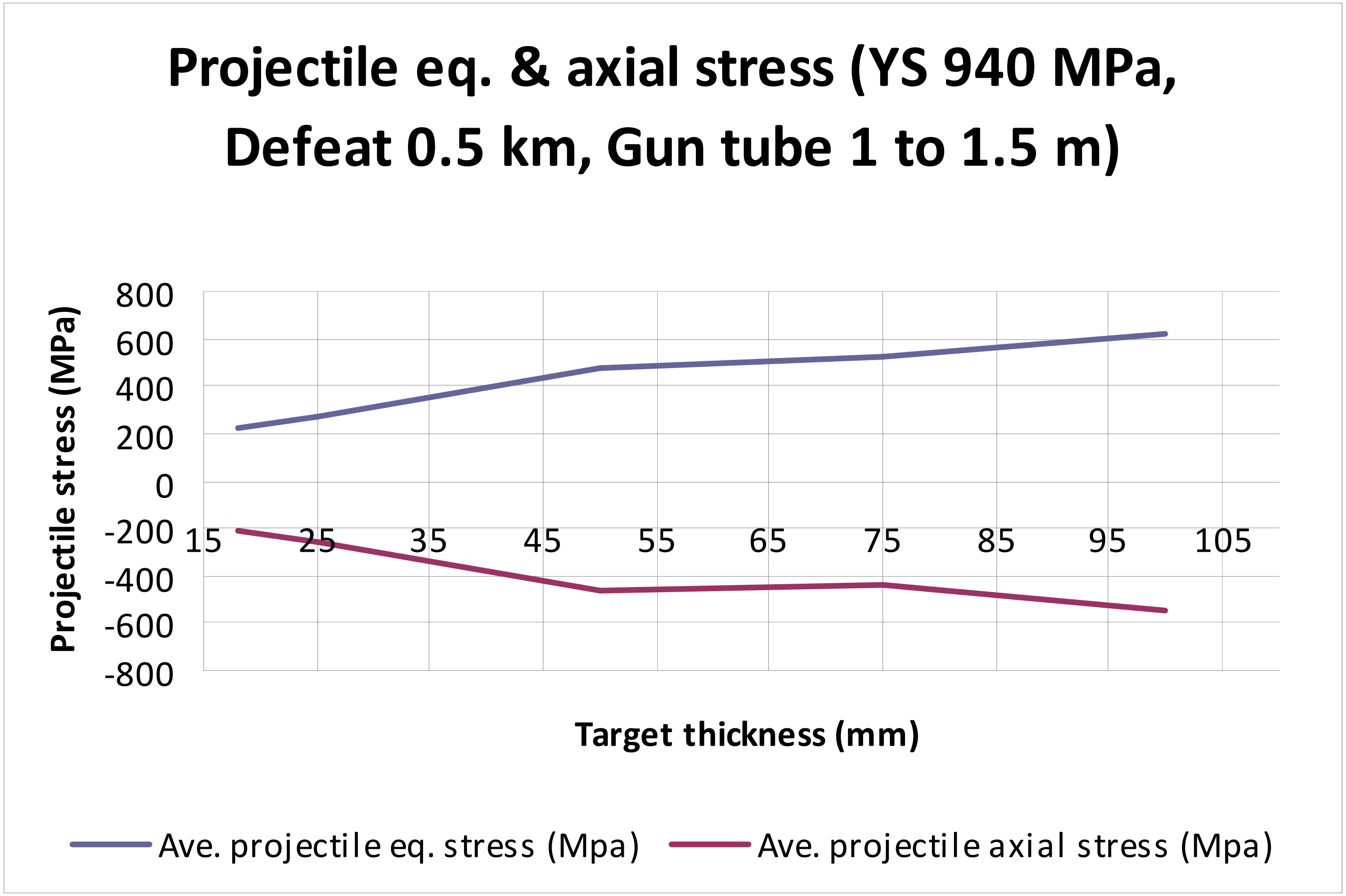

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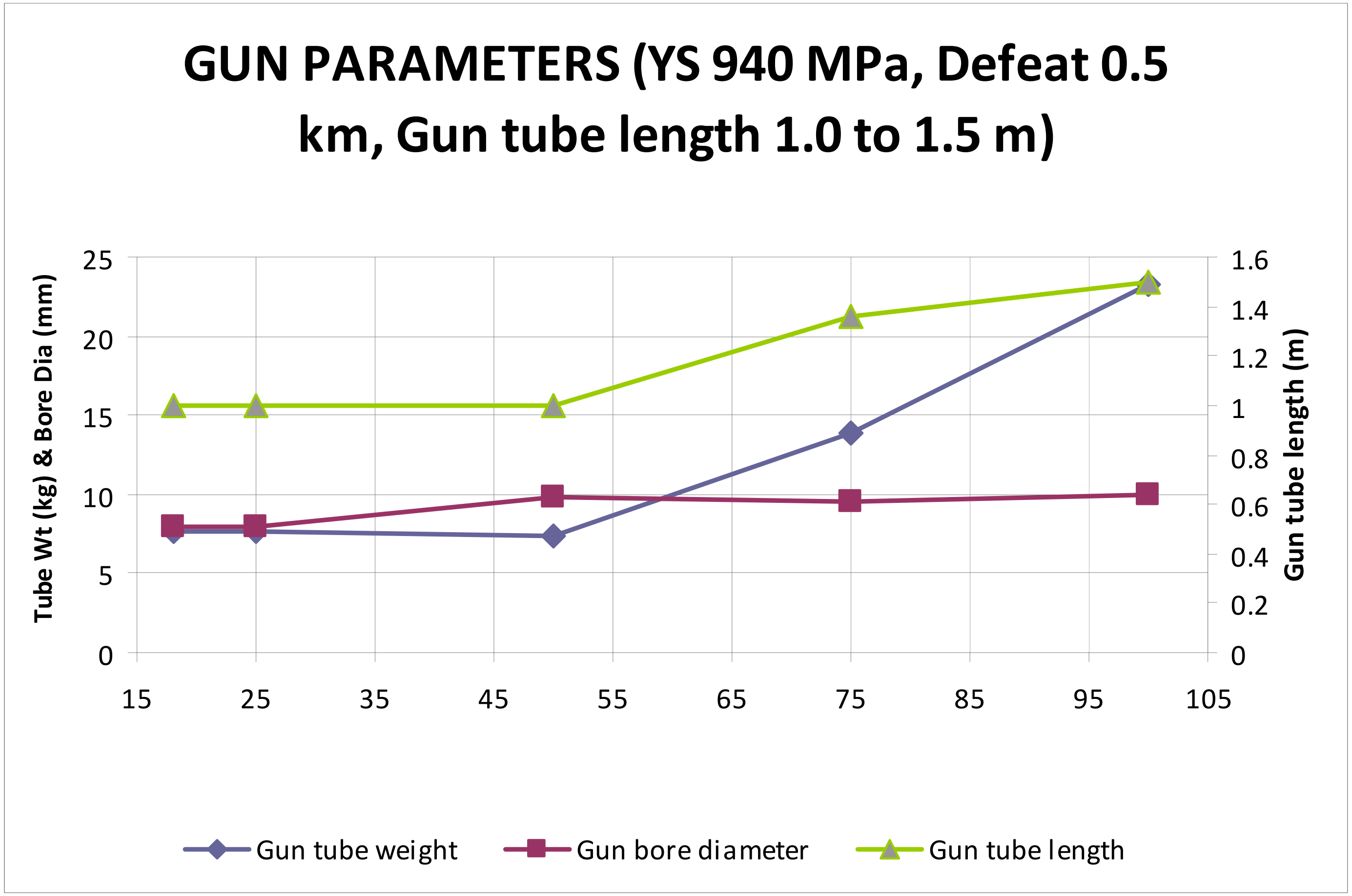

Summary

- A simple model of projectile and gun in an optimization framework has been used to arrive at a first order estimate of the armament system
- Future attempts will be focused adding more features to the projectile and gun model to observe if the approach is still feasible for exploring new armament systems