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Effectiveness of Precision-guided Munitions on Armour Systems

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ABSTRACT

Simulation methodology has been used to analyse the effectiveness of multi-barrel rocket launcher system (MBRLs) delivering precision-guided munitions (PGMs) on armour force deployed in concentration areas under various terrain conditions. The methodology considers various aiming strategies, the effectiveness of the sensor and the imprecision in information available about the target to evaluate the effectiveness of the MBRL system.

Keywords: Precision-guided munitions, multi-barrel rocket launcher system, sensors, simulation, precision conventional strike, target acquisition

1. INTRODUCTION

With the advancements in technology, nations are building precision conventional strike (PCS) weapons which can attack selected targets with high accuracy and limited collateral damage. PCS is achieved by a variety of weapon systems collectively known as precision-guided munitions (PGMs). PCS can encompass targets at the tactical, operational, and strategic levels of war and can be conducted by force elements fielded by all the three Armed Services. Though it has been typically associated with deep attack, the association is not a necessary condition. Due to the PCS, future battlefield is becoming increasingly dynamic and nonlinear in nature, resulting in partitioning of the battle space into indistinct deep, close, and rear areas[1-3].

With the reach of artillery increasing up to 70-100 km and the induction of multi-barrel rocket launchers (MBRLs), capable of delivering large amount of explosives in short time span, artillery can now engage enemy deep inside its territory. That way, it can degrade its confidence even before the enemy is able to launch its attack.

A methodology for analysis of the effectiveness of PGMs delivered by MBRLs against armour force concentration has been discussed. As a case study, an example where two batteries of MBRL delivering PGMs to attack an armour force of one Brigade (180 tanks), in various operational modes, has been discussed. A simulation exercise has been carried out to evaluate the casualties suffered by the armour systems under attack by PGMs. The model also incorporates the inaccuracy in information about target in terms of geo location error. The effect of environment on the flight path of PGMs has been considered in the form of drift velocity.

2. PRECISION-GUIDED MUNITIONS IN ANTI-ARMOUR ROLE

In the modern day war, armour systems play a very decisive role in shaping the course of war in the battlefield, thus a large number of programmes

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for building PGMs for destroying armour are in existence in the world[2-4]. Some of these are low-cost anti-armour sub-munition (LOCAAS, USA), Army Tactical Missile System Block II/III or BOAR (ATCAMS, USA), Sensorfuzed Munitions (SMArt, Germany), BONUS smart 155 mm Artillery Round (Sweden, France), SPLAV 9A52 SMERCH with 9M55K1 warhead (Russia), etc.

The PGMs are delivered either by rockets or missiles. The PGMs are stored in its bus section which separates from the rocket at an appropriate altitude above the target area (Fig. 1). A non-contact target sensor monitors the descent altitude of the PGMs. It causes the (parachute-retarded, top-attack) sub-munitions to be dispensed at an optimum height for target acquisition by their integral sensors. On target detection, it activates the kinetic energy, self-forging, fragment warhead which defeats the target.

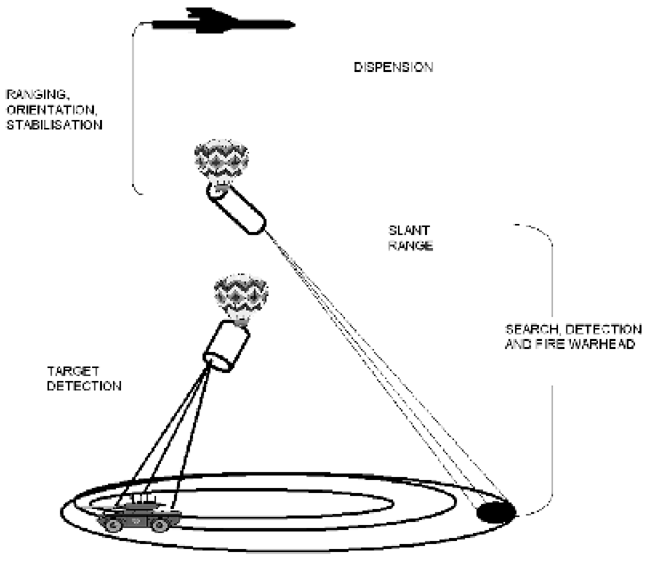

Figure 1. Precision-guided munitions in anti-armour role.

3. METHODOLOGY

For the purpose of illustration of the analysis methodology, an armoured Brigade (135 tanks + 45 supporting AFVs) is considered to be under attack by 2 Batteries of SPLAV 9A52 SMERCH multiple-launch rocket system. Each Battery consists of 6 launchers each carrying 12 tubes. Each tube fires one rocket. Each rocket has 9M55K1 warheads containing five MOTIF-3M sub-munitions. These warheads form fragments which attack the tanks from the top.

In the above outlined process of operation of PGMs, following issues need to be modelled for analysis:

- Flight path or trajectory of the rocket
- The point of dispensing the PGMs by the rocket over the target area
- The spiral motion and descent of the PGMs retarded by the parachute
- The sensing system of the warhead and point of activation of fragmentation

The rockets or missiles will follow a certain trajectory and arrive in the target area. Here, it senses the targets by its sensors or is pre-programmed to release the PGMs after certain flight path/duration. This model considers that the pattern in which the rockets fired from the MBRLs reach the aim point, follows a circular normal distribution with mean co-incident with the aim point (A_x,A_y) and standard deviation σ, derived as a function of circular error probable (CEP). Thus, the dispensing point I_x, I_y wrt rocket are given by

$$I_x = R_x \sigma + A_x$$

$$I_y = R_y \sigma + A_y$$

where R_x, R_y are standard normal random numbers.

Each dispenser releases n number of PGMs, equipped with a parachute. The sub-munitions are dispensed in a direction ω (taken randomly from 18 directions or 20° angular sectors) around the flight path of the rocket. The PGMs are released at fixed intervals of distances (say d) along the flight path. Therefore, the release point of each sub-munition can be calculated as

$$Di_x = I_x + d^* \ i^* \cos(\alpha)$$

$$Di_y = I_y + d^* \ i^* \sin(\alpha) \quad \text{for } i = 1\ldots..n$$

where Di is the precise point of release and $\alpha = 20\ \omega$ is the angle of release.

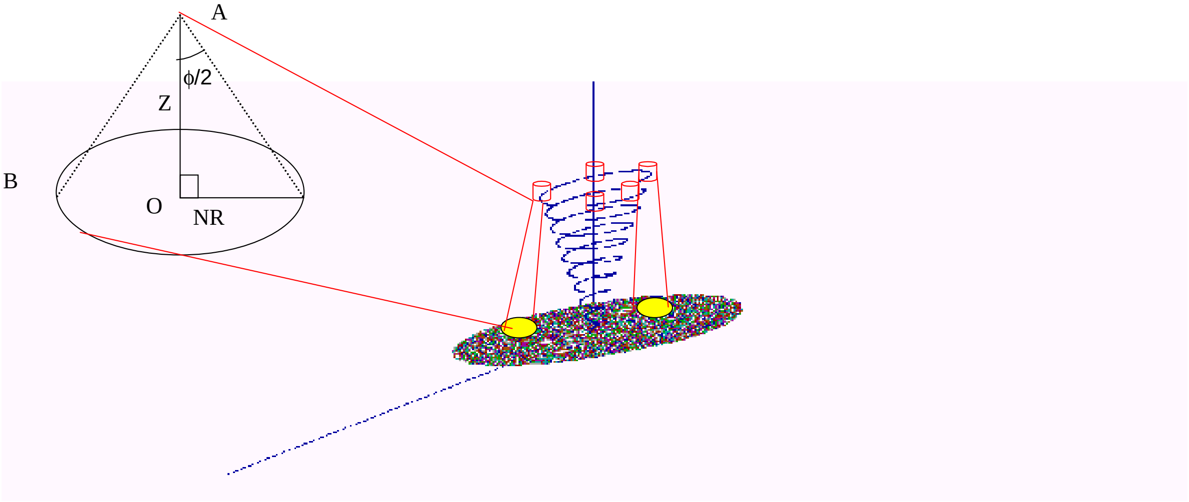

Figure 2. Sensor moving in spiral trajectory.

Each PGM is under influence of three forces at the time of release, firstly the forward motion of the rocket along its flight path, secondly, the resistance offered by parachute in the prevailing wind conditions; and thirdly, the gravitational pull. Consequently, it can be considered that each sub-munition describes an inward Archimedean spiral ($r = \theta$). The spiral motion starts from the release point with initial radius r_1 and initial angle $\theta = 20\pi$ which is assumed to reduce by 2π every second. The actual values 20π and 2π will depend on the specific system under study and have been assumed this way for analysis. Therefore, the radius r at any point of time in the spiral is given by

$$r = r_1 * \theta/20\pi$$

where θ is the refreshed value of the angle after initiation of descent.

The initial height (Z) at which the sensor starts its search over the spiral path also reduces by a descent rate Z_R. The new height of the sensor at any given time is given by $Z = Z–[Z_R * (20\pi–\theta)/2\pi]$.

The Cartesian coordinates X and Y are calculated from the polar coordinates r, θ and environment factors incorporated in the drift velocities by

$$X = \mathrm{r} * \cos(\theta) + D_x$$

$$\mathrm{Y} = r * \sin(\theta) + D_y$$

where D_x and D_y are the drift components of the drift velocity.

At each point (X,Y,Z) travelled by the PGM in space, the sensor searches the ground with a circle of radius NR given by

$$NR = Z/\tan(\pi/2 - \phi/2)$$

where ϕ is the lookdown angle of the sensor (Fig. 2).

One of the major factors in activation of warhead fragmentation is the time of attack. Probability of detection by the infrared detector of the PGMs depends upon how hot the tank is in the concentration area. The tank heat depends upon the duration t_d (in hours) after it's engine is stopped. Therefore, if the attack is immediately after tank move, it has better chances of success than the attack after long duration of assembly in the concentration area. The detection probability by the sensor can be evaluated as a function of t_d (Fig. 3) using the relation

$$P_d = \exp(-\lambda t_d) \text{ for } t_d \leq 12$$

where parameter λ is related to terrain. In plains, vegetation and built up areas affect the detection probability as compared to deserts. The detection probability fades and becomes nearly constant after 12 h.

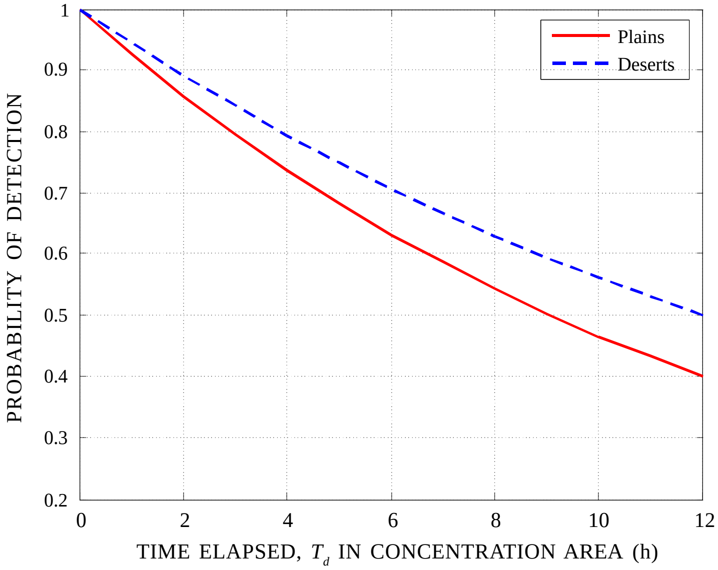

Figure 3. Detection probability of tank after its engine stopped.

A tank is detected if the tank lies in the circle described by the sensor of radius *NR*, i.e.,

$$\sqrt{\{(T_x - X)^2 + (T_y - Y)^2\}} \leq NR$$

where T_x, T_y are the tank coordinates.

Once a tank is detected by the sensor of the PGM, it activates the warhead to generate fragments for top attack on the target. A tank is killed if

$$R_1 < P_d \ , \ R_2 < P_{\text{hit}}, \text{ and } R_3 < P_{\text{Kill}}$$

where R_1, R_2 and R_3 are random numbers from uniform population.

4. CASE STUDY

As metioned earlier, this study considers an armoured Brigade (135 tanks + 45 supporting AFVs) under attack by 2 Batteries of SPLAV 9A52 SMERCH multiple-launch rocket system. Each Battery consists of 6 launchers each carrying 12 tubes. Each tube fires one rocket. Each rocket has 9M55K1 warheads containing 5 MOTIF-3M sub-munitions. Hence, a total of 2 x 6 x 12 = 144 rockets containing 144 x 5 = 720 sub-munitions are fired on the Brigade. The rocket acts as a dispensing unit which dispenses these sub-munitions at an optimum height over the target area (170-150 m). Following ejection, trajectory of each sub-munition is stabilised by a parachute. The sub-munition descends by a parachute at a speed of 15-17 m/s and detects targets by means of two-colour infrared sensor with 30° field of view.

The purpose of this study is to illustrate the utility of the model in analysing multiple issues namely

- Deployment strategies for tanks
- Optimum aiming strategies
- Difference in performance due to terrain
- Effect of geo-location errors in aiming, consequent tank casualties, and permissible allowances regarding precise target locations, while firing such munitions

Other input regarding the munitions and target considered in the study are enumerated.

4.1 Input Parameters of the PGM

Rocket range = 20 to 70 km

Rocket weight = 800 kg

System error

Probable error in accuracy = 0.35 – 0.45 per cent of range

Probable error in consistency = 0.20 – 0.25 per cent of range

Area coverage

12 Rockets 650 m x 650 m at 40 km
800 m x 800 m at 70 km

Kill probability = 70 per cent

Clustered homing sub-munition 9M55k1: 5 sub-munitions are ejected at 150 m and stabilised at 150 m. It self destructs after 45 s.

4.2 Parameters of the Target (Armoured Brigade Deployment)

Armoured Brigade deployment in concentration area of 9 km x 9 km has been considered for the following two scenarios, i.e.,

- Plains where line of sight available is up to 500 m and hence inter-tank distance (ITD) of 300 m, 400 m and 500 m have been considered
- Desert where line of sight up to 800 m is available, and hence inter tank distance can vary from 300 m to 800 m. However, results relating to 300 m, 400 m, and 500 m have only been analysed to present a comparative picture in performance over the two terrain conditions.

4.3 Aim Points on the Target

While conducting the simulation, multiple aim-point approach has been considered. Each launcher fires on respective aim points generating a better target coverage. The various strategies analysed in the study are:

- Aim point at Regiment centres each engaged by 3 launchers each
- Aim point at Squadron centre each engaged by 1 launcher
- Triangulated aim point over concentration area, each point engaged by 1 launcher (Fig. 4)

5. RESULTS AND CONCLUSIONS

Three sets of results, tank casualties in plains (Fig. 5) and deserts (Fig. 6) with different aiming strategies and a set of tank casualties with different geo-location errors (Fig. 7) have been generated. Figures 5 and 6 indicate that aiming at Squadron centres gives best possible performance in different situations.

The analysis shows that by increasing the inter-tank distances within the fixed concentration areas

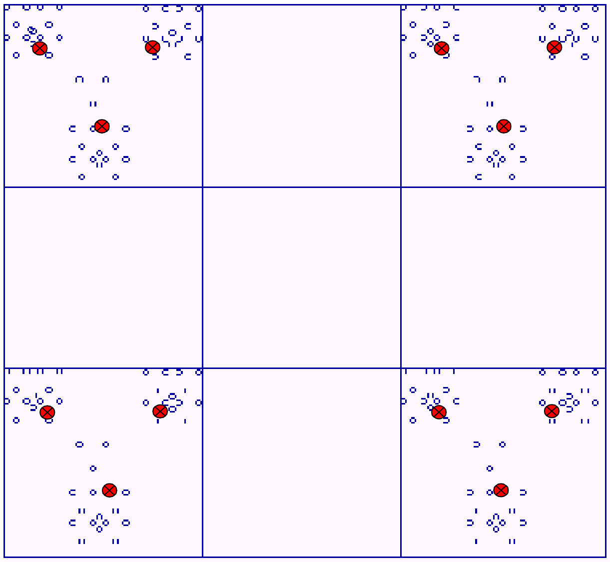

Figure 4. Triangulated aim point strategy.

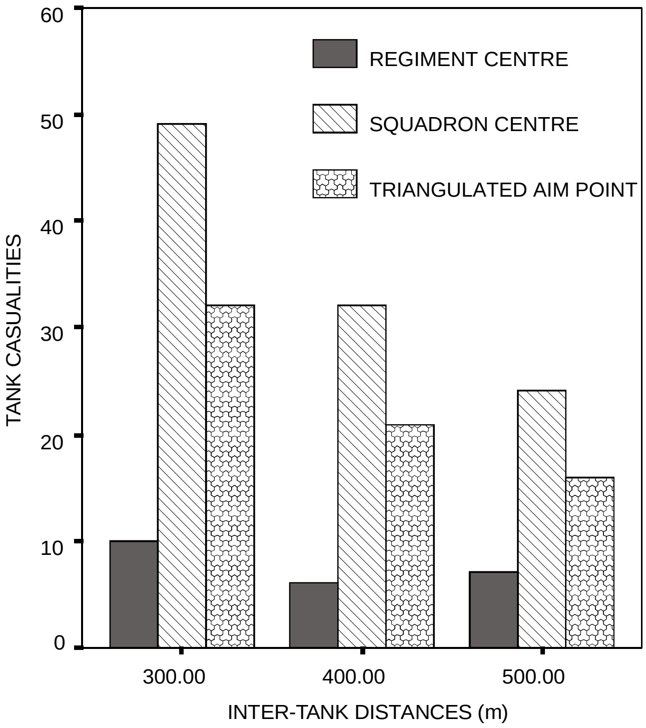

Figure 5. Inter-tank distances versus tank casualties engagement range = 40 km.

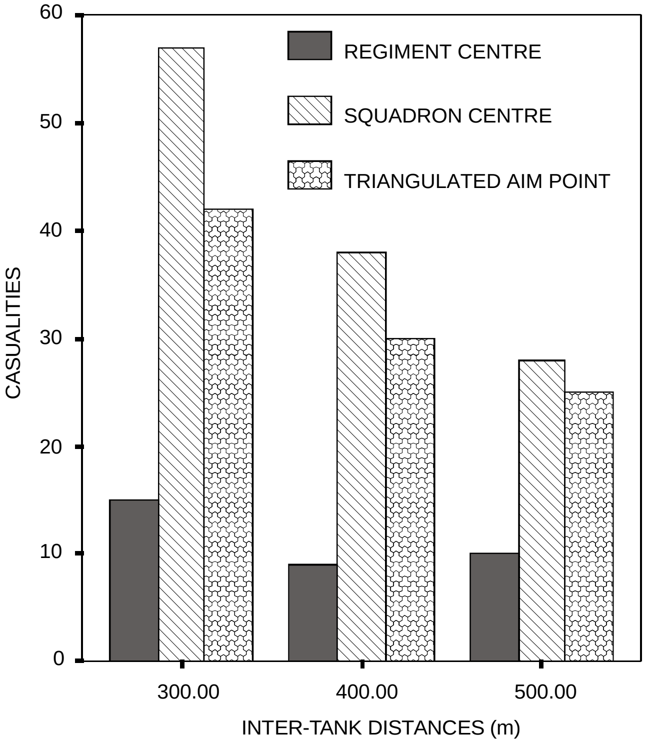

Figure 6. Inter-tank distances versus tank casualties engagement range = 70 km

the casualties can be reduced. The penalty in increasing the inter-tank distance is loss of command and control. The results in case of firing on Regimental centres show some bit of awkwardness (tank-to-tank distance: 400 m) mainly because in other aiming strategies, aim points are better spread over the target area, generating better area coverage.

Another important issue in PGM firing is the availability of target coordinates. In Fig. 7, it has been observed that even with 10 per cent error in the information about the target, the PGMs have been able to inflict sizeable casualties. However, quantitatively, the casualties reduce to about 60 per cent in deserts, and 40 per cent in plains, while moving from ideal conditions (zero error) to 10 per cent error. The further drop is much sharper. Therefore, 10 per cent geo-location error can be considered as a permissible allowance in aiming.

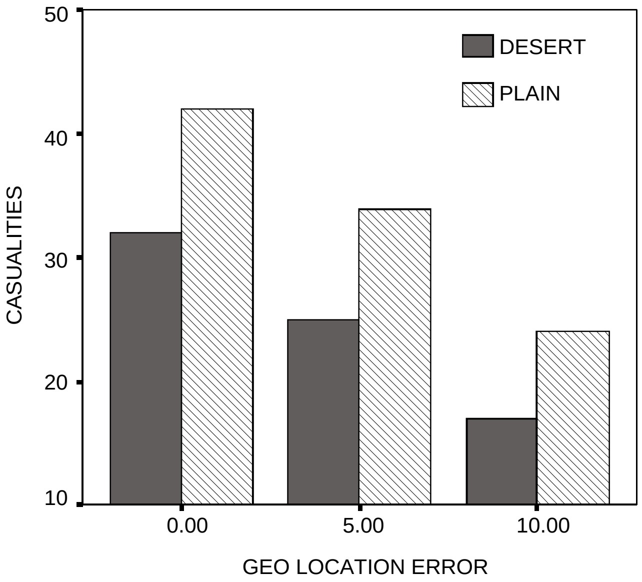

Figure 7. Geo-location versus tank casualties for triangulated aim point.

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