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Damage Assessment Software Program

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ABSTRACT

The software package described here deals with the assessment of damage inflicted by missiles carrying pre-fragmented, bomblet, incendiary, runway-denial penetration submunition (RDPS), smart munition, and terminally guided submunition warhead. The targets to be neutralised could be static, semistatic or mobile, like runways, bridges, bunkers, armoured tanks, soft-skinned vehicles, and personnel. This is graphical user interface(GUI)-based software, where the user can specify the target dimensions, target types, the number of missiles, its aim point, the type of warhead and the mode of operation. The software gives the number of targets that have been neutralised effectively, as the output. This GUI-based software has been developed using Microsoft Visual Basic, Version 6.0.

Keywords: Damage assessment, warhead, missile circular error probability, lethal radius, sub-munition, software program

1. INTRODUCTION

The basic function of any weapon is to deliver a destructive force on an enemy target. The targets include military bases, factories, bridges, ships, tanks, missile launching sites, artillery emplacements, fortifications, and troop concentrations. Since each type of target presents a different physical destruction problem, a variety of general and special-purpose warheads are required, within the bounds of cost and logistical availability, so that each target may be attacked with maximum effectiveness. The warhead is the primary element of the weapon; it accomplishes the desired end result, i.e, effective damage to the target. The damage assessment study[1] of various kinds of warheads is important for their efficient usage on the appropriate targets. Various softwares[2-4] and end game models[5-6] have been developed by research groups to study this problem.

In a war scenario, in a given zone for a surface-to-surface missile, targets that can be destroyed by its warhead, are varied, and so are their characteristics. To assess the damage effectively, both the target as well as weapon characteristics have to be known. In this application software, the characteristics of each target type, and that of the warheads capable of inflicting damage on that particular type of target, have been taken into account. The software also serves as a tool for effective planning, giving the number of missiles required and the type of the warhead to be used based on the damage to be inflicted on the area. The user has the flexibility to assess the damage on a particular target area, given the missile inventory and also obtain the minimum number of missiles required to cause a desired damage on a given area. The targets that have been considered are runway, bridge, tank, armored vehicle and men. The different types of warheads that have been included are pre-fragmented warhead, bomblet warhead, incendiary warhead, RDPS warhead, smart munition, and terminally-guided smart munition.

2. GRAPHICAL USER INTERFACE FEATURES

The graphical user interface (GUI) derives the user inputs on a step-by-step basis. Only four of the main screen shots have been provided in this paper. Firstly, the user is asked to specify the dimensions of the target area. Then the 'data of target elements' window appears following which the user is asked to enter the details of the aim points. Based on the number of aim-points, the number of missiles to be taken for each aim-point is also queried for. Categorically, when the user enters the data, it is saved in the software's memory and used whenever required. When all the necessary data has been entered, the software computes the results and gives a graphical display of the same. The screens have been designed as various forms and they are coded using event-driven programming.

In the GUI, the user can specify the target area as a rectangle or circle with desired dimension. The 'data of target elements' (Fig. 1) form contains various frames and text boxes to get the dimensions of the element, namely the length, breadth, and its centroid. It also has a provision for the user to enter the nature of the target, viz, tanks, men, and B-class vehicles, apart from the option from selecting between kinds of tank distributions.

The next form, (Fig. 2) gets the number of aim-points, their respective centroid, the confidence level and the number of missiles required to be deployed for each aim-point and the type of warhead of the missile can be specified. The

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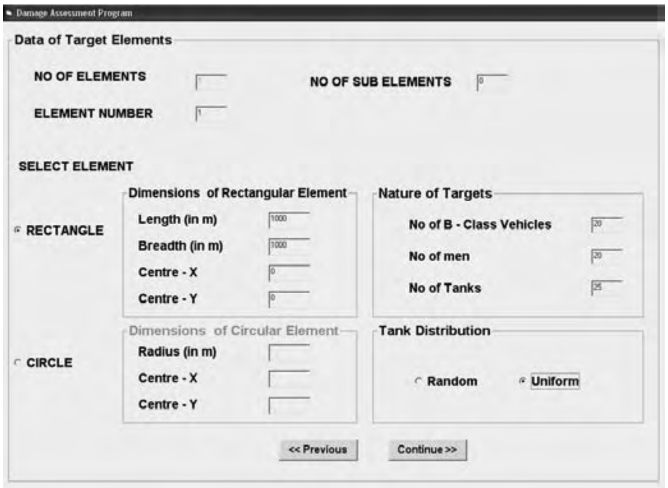


Figure 1. Data of target elements screenshot.

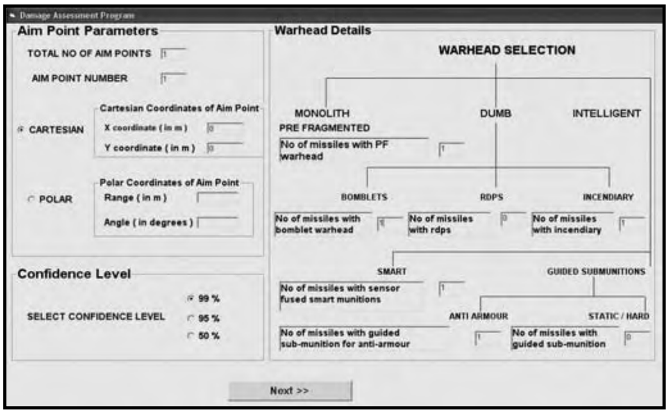


Figure 2. Aim-point parameters specification.

warhead details are classified into Monolith, dumb, and intelligent, respectively. If there is more than one aim-point, the same screen appears again to get the required input corresponding to it. For dumb sub-munitions, users have a choice to use the existing database of dumb munition specifications, or new specifications can be given on the screen (Fig.3). For smart munitions the height of operation, detection range, probability of detection, hit, and kill is to be entered. Here the user has a choice of smart munition distribution among random, uniform and geometric. For terminally guided sub-munition (TGSM), there is only geometric distribution to choose from. Also the deployment option of the TGSM can be selected from directional and omni-directional deployments. (Fig.4).

Text boxes and command buttons are used to design the various forms and are linked using codes. When the command button in each form is clicked, the inputs are stored and the next action is taken accordingly. The forms are self-explanatory in nature and they have been designed in such a way, that they are very easy to use by users. This software can be installed in any personal computer and used whenever required.

3. METHODOLOGY

Broadly, a two-step method has been followed to assess

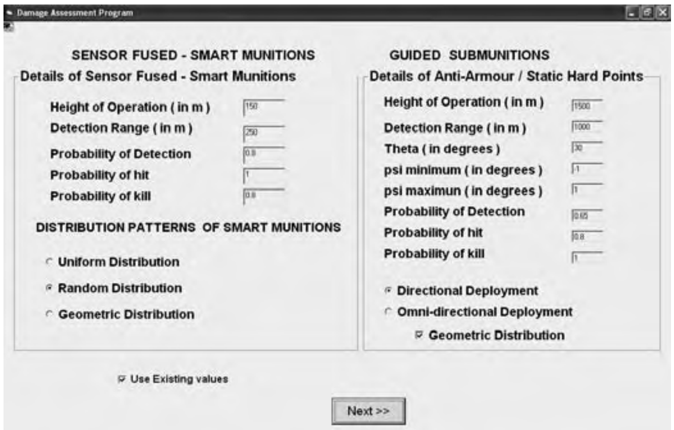


Figure 3. Smart munition and TGSM characteristics.

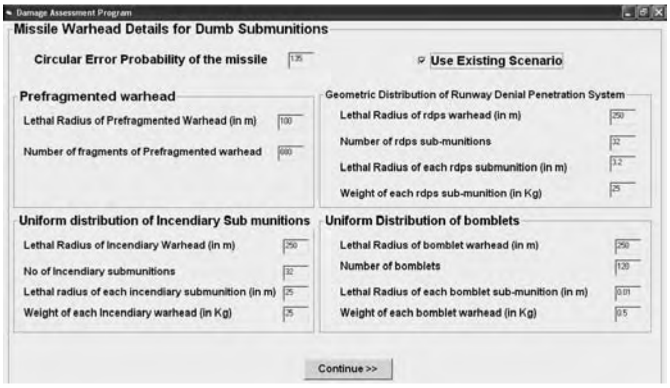


Figure 4. Dumb submunition details.

damage in the target area. The target area is divided into a sub-category called elements to distinguish the concentration of the target. Elements are sub-areas within the main target area where the targets are stationed. This is done so as to:

- Distribute the targets (men, tanks, B-class vehicles) randomly in the specified area.
- Delimit the concentration of targets in the target area.
- For better display of the attack scenario.

For each of the target elements, the aim-point of the missiles and the warhead type need to be specified. Then, as per the damage criteria, the extent of damage is assessed, calculating the mean percentage of damage and standard deviation of damage. In this software the damage is given in terms of the effective number of men, B-class vehicles, and tanks that have been damaged. The output that is displayed gives an idea of the total area damaged.

Though the area is divided into elements, the damage is given in terms of the number of targets individually damaged. The number of elements that have been damaged has no significance. It is for the user to classify the target area for a precise aim-point calculation.

3.1 Display of Targets and Weapons

The user is required to define the dimensions of target area, the elements, and their centroids. This is done, so as to scale down the target area corresponding to the user's screen for a relatively realistic display.

Then the user needs to specify the number of aim points, their coordinates, number of missiles for each aim-point, and type of warheads carried by each missile. Here, the user has an option to choose the confidence level, 99 per cent, 95 per cent and 50 per cent. Using Monte Carlo Simulation the run numbers are determined as per confidence level.

Monte Carlo simulation specifications:

The number of simulation runs n is given by

$$n \geq (z_y s_N / \varepsilon)^2 \qquad (1)$$

where z_y is the critical value corresponding to the confidence level; S_N is the standard error; and ε is the error corresponding to confidence level.

For a 95 per cent confidence level, with ε = 0.05,

Initial estimation: s_N = 0.5891 and z_y = 1.96

The no of simulation runs are

$$n \geq (z_y s_N / \varepsilon)^2 = 534$$

Pre-fragmented warhead neutralises the whole area of the lethal radius whereas bomblet warhead has several bomblet modules each having a defined lethal radius. For the display of pre-fragmented warhead and bomblet warhead, the lethal radius (r) and number of fragments or bomblets is taken as input from the user. Then, the point where the missile is likely to be impacted is derived from a random number generated using Gaussian distribution of the aim-point.

The circular error probability of the missile and the standard deviation (σ), are related as shown[7]. Here, it is assumed that σ_x and σ_y are equal, because in case of missile specification only CEP is given.

$$\sigma_x = \sigma_y = \sigma \qquad (2)$$

$$\sigma = CEP_{missile}/(0.589 \text{ x } 2)$$

Using the above relation, the coordinates of the aim-point are thus calculated.

$$x_{aim} = x_{aim\_user} + ran_x \sigma$$

$$y_{aim} = y_{aim\_user} + ran_y \sigma \qquad (3)$$

Here, ran_x and ran_y are random numbers.

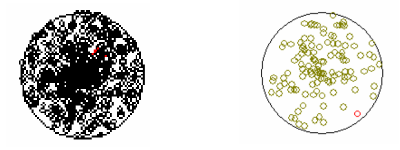
Around the impact point over a circular zone of lethal radius of the warhead, the fragment or bomblet positions (r and θ) are randomly generated. Each fragment or bomblet will be displayed as dots (Fig. 5).

$$r_{bomblet} = let_{bomb} \text{ x } ran$$

$$\theta_{bomblet} = 360 \text{ x } ran \qquad (4)$$

For displaying the incendiary warhead, over a circular zone of lethal radius, around randomly generated impact points, some smaller circular zone, indicating damaged area, is shown. This is done to differentiate among the various warhead types (Fig. 6(a)).

For the display of RDPS, a method similar to the pre-fragmented warhead and bomblet warhead has been adopted (Fig. 6(b)).



(a) (b)

Figure 5. (a) Prefragmented warhead; and (b) bomblet warhead.

For smart munition display, the user has an option to choose from random, uniform and geometric distributions. In case of random distribution a method similar to dumb munitions is followed. For uniform and geometric distribution the submunitions are spread either uniformly or a particular geometrical pattern is followed, respectively (Fig. 7).

Terminally guided submunitions are displayed in geometric pattern in a similar manner as smart munitions.

3.2 Damage Criteria

3.2.1 Pre-fragmented Warhead

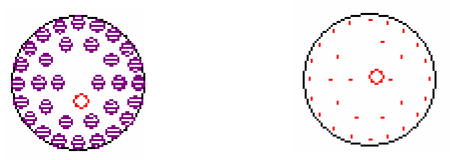
B-Class vehicles and men are the type of targets being considered for pre-fragmented warhead. Corresponding to every element, aim-point, number of missiles, type of target and the number of targets, the distance between the target and the missile impact point (d) is calculated. A condition is checked if

$$d < let_{pf} \qquad (5)$$

where, let_{pf} is the lethal radius of the prefragmented warhead. If this condition is satisfied, the number of men or vehicles, corresponding to the type of target destroyed, is calculated.

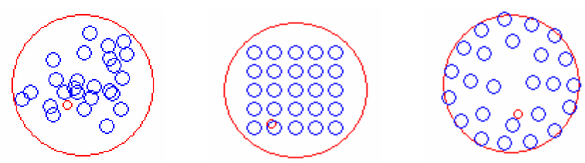
3.2.2 Bomblet Warhead

Bomblet warheads are meant to destroy B-Class vehicles. Corresponding to every element, aim point, number of missiles, type of target and the number of targets, condition (1) is checked. Further a count of number of vehicles destroyed is obtained by checking if the point of the bomblet impact lies within the limits of the vehicle boundaries and the lethal radius of each bomblet module.



(a) (b)

Figure 6. (a) Incendiary warhead and (b) RDPS warhead.



(a) (b) (c)

Figure 7. (a) Random distribution, (b) uniform distribution, and (c) geometric distribution.

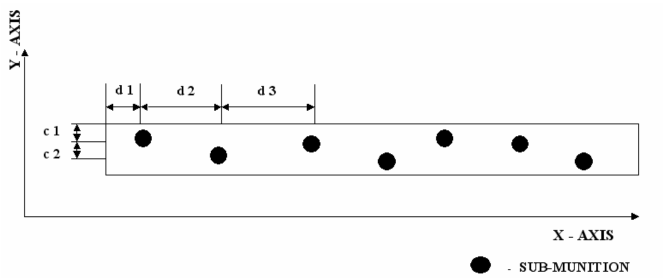


Figure 8. Runway denial penetration submunition.

3.2.3 Incendiary Warhead

The incendiary warhead impact point and the distribution of the sub-munitions are simulated using a random number. The whole area, which falls within the zone of the lethal radius of the warhead, is assumed destroyed.

3.2.4 Runway Denial Penetration Sub-munition

The RDPS warhead is meant for runway or bridge destruction. With respect to the impact point, the co-ordinates of each sub-munition are evaluated. Now, it is assumed that for an aircraft to take off, an area of 1000 m x 50 m is adequate. Hence, to check if the runway is destroyed, first the impact point of the sub-munitions are ordered (Fig. 8) from one end of the runway to the other as per their position on the *x*-axis, and then the distances, d1, d2, d3 and so on, between two adjacent impact points are checked. Their respective *y*-distances such as c1, c2 and so on, and the distance between the edges of the runway and the impact point of the sub-munition falling nearest to it are also checked. If these distances leave an area less than that required for aircraft take off, it is considered that the runway is destroyed.

3.2.5 Smart Munition

The detection range, height of operation, number of smart munitions, probability of detection, hit, and kill are given as user inputs. Each sub-munition describes an inward Archimedean spiral. The detection zone is calculated by considering the reduction in the radius, the initial angle of detection, the reduction in the sensing height and is given by the formula[8]:

$$det_{zone} = Z \ / \ \tan \ (\pi / 2 - \phi / 2) \qquad (6)$$

where, Z is the sensor height at any given time, and ϕ is the look angle of the sensor.

For a sample case of geometric distribution, the positions of the sub-munitions in the warhead are known wrt the warhead position. Corresponding to every element, aim point, number of missile, type of targets and number of targets, the distance between the missile impact point and the position of the target is calculated. Then the condition, if this distance falls within the zone of detection of smart munition, is checked.

A tank or vehicle that falls in the zone is considered destroyed, if the following conditions are satisfied.

$$R_1 < P_{det}, \quad R_2 < P_{hit}, \quad R_3 < P_{Kill}$$

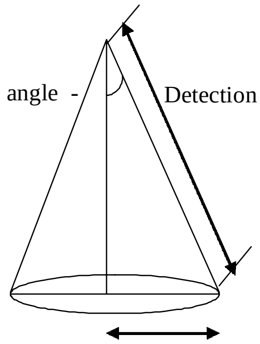


Figure 9. Smart munition sensing.

where R_1, R_2 and R_3 are random numbers and P_{det}, P_{hit}, and P_{kill} are the respective probabilities of detection, hit, and kill. If this condition is satisfied, depending on the type of target, the count of the number of targets destroyed is evaluated. The similar procedure is adopted for all other distribution patterns.

3.2.6 Terminally-guided Submunitions

Terminally guided submunitions are meant for destroying tanks. The height of operation, detection range, elevation and azimuth limit of detection, probability of detection, hit and kill are taken as input. It is assumed that after ejection of TGSMs from the mother missile, it drops vertically till height of operation i.e., 1500 m above sea level. The submunition is controlled to maneuver so as to take a 90° turn to become horizontal. A time of flight of 10 s has been considered for each TGSM (Fig. 10), once it becomes horizontal. The beam elevation angle of the seeker is 30°.

Figure 10 shows that the terminally-guided submunition, (i) drops from the mother missile, (ii) pulls the required latax to become horizontal, (iii) searches for the target during level-flight, and (iv) homes on to the target if found within the search range.

It travels until a sufficient kinetic energy is available to sustain flight. The TGSM is designed to travel at least for 10 s from the time of initiation of target detection. To define the search range, the missile impact point is taken as the reference. Minimum search range indicates the

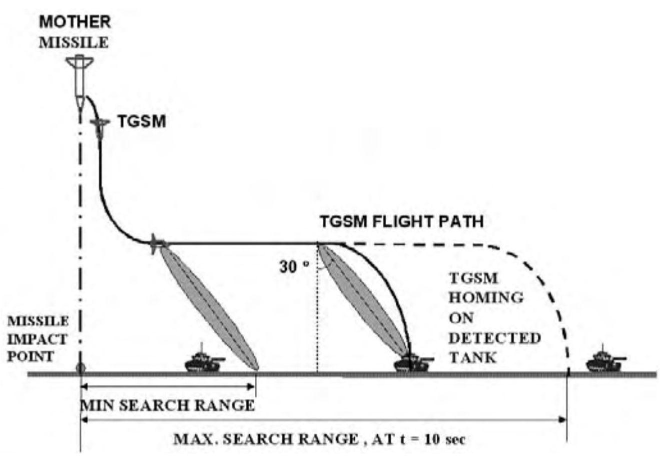


Figure 10. TGSM attack scenario.

distance between the impact point and the point from where the search initiates or the seeker gets activated. It is the blind zone of the seeker. The maximum search range indicates the maximum distance that the seeker can acquire targets referenced from the missile impact point. The difference between both these ranges gives the effective range, where the seeker remains active or the actual defending zone of the submunition.

The distance covered by the sub-munition at any time t is governed by the equation of motion as given below, where the cosine component of the average velocity has been considered.

$$r_{tgsm} = (V_{avg} \cos 45° \times t - 1/2 \times 15 \times t^2) \quad (7)$$

Two ways of deployment of the TGSM have been considered:

(a) **Omni-directional deployment**–The 16 submunitions are equally spaced in the mother missile to cover 360°. The missile is targeted at the center of the element and all the sub-munitions are ejected out in a star like manner, so as to cover the entire zone of target.

(b) **Directional deployment**–The target area's dimensions are fixed and depending on its width, a conical zone of distribution is defined. The submunitions are made to travel in a suitable angle so as to cover a chosen region on the target area. This has been considered to:
   (a) improve the probability of detection of a tank, and
   (b) neutralise the effect of the blind zone, as this can be eliminated by suitably specifying the aim-point. In omni-directional deployment this cannot be done. The blind zone has to be taken care of by deploying more missiles.

This zone is then searched for any tanks or guns. If the seeker has detected any tank the TGSM homes on to it. It is assumed that if a target is detected, it is hit and killed. A tank is killed if

$$R_1 < P_{det}, \quad R_2 < P_{hit}, \quad R_3 < P_{Kill}$$

where R_1, R_2, and R_3 are random numbers and P_{det}, P_{hit}, and P_{kill} are the respective probabilities of detection, hit and kill.

4. CASE STUDY

4.1 Runway

The RDPS missile destruction performance has been analysed by considering a single stretch of runway of length 4 km and width 100 m in a target area of 6 km × 5 km. Eight aim-points separated by some distance have been selected and one missile is aimed at each aim-point. For a 99 per cent confidence level, the code is executed and the results are displayed (Fig. 11).

The RDPS damage assessment is modelled, by checking the runway between the spatial distributions of the submunitons, for any usable strip of dimension 1000 m X 50 m. When any such space is identified, the software immediately gives a message to the user telling 'runway has not been destroyed' otherwise, it says 'runway has been destroyed'. The display gives an idea of the space that has not been encountered by any sub-munition. The user input would then be required to change the aim points, or the number of missiles accordingly, for the next iteration of damage assessment evaluation.

The result of 534 runs show that the necessary and sufficient condition for the destruction of runway has been satisfied using eight RDPS missiles. There is no accessible strip in the runway for an aircraft take off (Fig 11).

4.2 Terminally-guided Submunition

A target area of 6 km × 5 km and an element area of 4.7 km × 4.7 km has been considered. It is assumed that

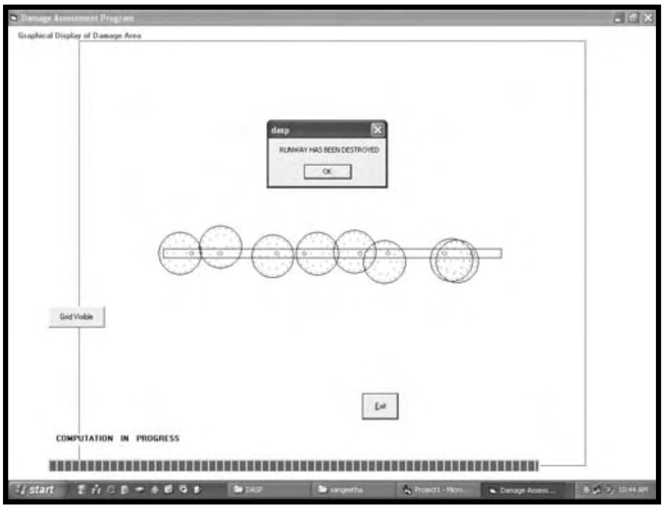


Figure. 11 RDPS screenshot from DASP.

121 tanks are distributed in two different patterns over the element. Three aim-points have been considered and one missile is fired at each aim-point.

The above two deployment options have been tested with
(i) Various dimensions of target areas
(ii) Number of targets
(iii) Different kinds of distribution

The damage in the corresponding cases has been compared.

Four cases have been considered to compare the damage capability of the two deployment options for terminally guided submunitions. The two deployment options have been checked, by distributing, 121 tanks in the target area, in both uniform and random manner.

The results show that the directional deployment is more effective as the damage caused is 1.5 times greater than that of the omni-directional deployment for a uniform distribution of vehicles. In case of random distribution of vehicles the ratio of the damage percentage of directional deployment and omni-directional deployment is 1.67. Thus considering random distribution as an optimum assumption, the directional deployment is seen to have a better damage capability.

The plot corresponding to the directional deployment

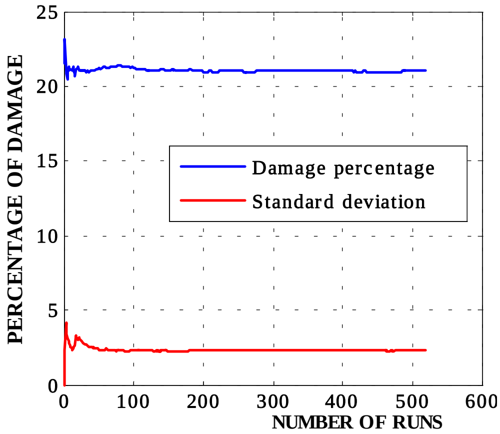


Figure 12. (a) Directional, uniform distribution.

option with a uniform vehicle distribution is given in Fig. 12(a).

The plot gives the mean (μ) percentage of tanks damaged and the dispersion (standard deviation- σ) about the mean and $\mu + 3\sigma$ value is maximum damage that can be caused. This gives an idea of the total efficiency of the number of missiles used to neutralise the tanks in the given target area. Table 1 summarises the percentage of damage for the different combinations deployment options and the vehicle distribution.

Table 1. Percentage of damage

Deployment pattern / vehicle distribution	Percentage of damage $\mu + 3\sigma$	
	Uniform	**Random**
Directional	32 %	29 %
Omni-directional	24 %	18 %

4.3 Tank Concentration

The case of an armoured brigade deployment in concentration area of 9 km × 9 km, studied by Gupta[8], *et al*. has been considered with suitable inter-tank distances of 300 m, 400 m and 500 m, respectively and studied in this software. A total of six rockets with 9M55K1 warheads each containing five MOTIF-3M submunitions[9] are considered. The search zone is taken as 60 m radius circular zone. This is derived from the area coverage characteristics of the system. They are aimed at the squadron centres. A uniform distribution of vehicles and tanks are taken. The damage achieved is plotted against the inter-tank distances and the results compared.

The target area of 9 km × 9 km has been simulated in the software (Fig.13). A uniform distribution of 15 tanks is considered in each formation, totally amounting to 180 tanks. The simulation shows that the result corresponding to different inter-tank distances is in agreement by the results produced by Gupta[8], *et al*.

The probability of detection, hit and kill are taken as 0.65, 0.8, and 1, respectively.

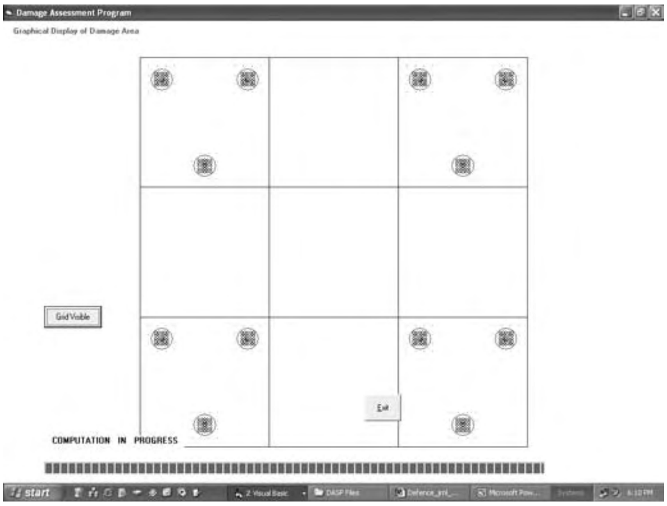


Figure 13. 9 km x 9 km armoured brigade.

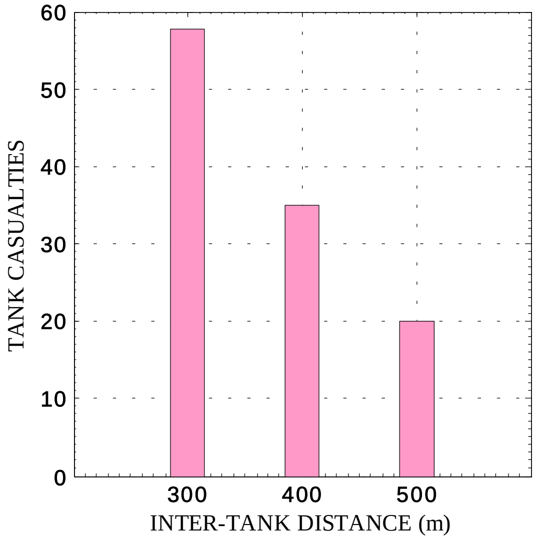


Figure 14. Inter-tank distances versus tank casualties.

The 1-σ value of the tanks destroyed is calculated. The plot of the tank casualties against the inter-tank distances is generated (Fig. 14).

5. CONCLUSION

The damage assessment software program is used to assess damage in a target area when different missiles with different kinds of warheads are deployed. It gives an overview of the damage inflicted on the target area. This application software has been tested with various cases of targets and warheads and the results have been discussed. The 'directional' deployment of the terminally-guided sub-munitions is recommended owing to its better detection and kill capability. The program has also been validated with a reference test- case and it proves to be an effective war-planning tool to efficiently utilise the missile inventory.

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