
AFVs KILLED PER SALVO

The high-resolution model (MADAM, used within the larger suite of models described in Appendix A) simulates in detail the process by which BAT submunitions search acoustically for target vehicles and then home in on them by infrared sensing. Each submunition and each Red vehicle is simulated individually. In PEM, by contrast, we assume a missile salvo kills a fixed fraction (FracKill) of the Red vehicles in the footprint, so long as the number of Red vehicles is relatively small and the limited number of submunitions does not become a factor. For a salvo of two TACMS missiles, we set FracKill = 0.41, which we scaled down to about 0.22 for a single missile to account for redundant targeting effects. Figure C.1 shows results from the DSB '98 simulations, overlaid with the aggregate relation we have used in PEM. The straight line used ignores some points on the right side of the figure because we concluded that those reflected unusual cases where AFVs in two or more aim areas were being lumped together artificially by the data-analysis procedure.

When too many AFVs are in the missile's footprint, the number of kills may be limited by the number of BAT submunitions (each TACMS/BAT carries 13 submunitions). To account for this, we truncated kills at a maximum value, MaxKills. Too few TACMS salvos in the DSB '98 simulations targeted large numbers of AFVs to allow us to confidently estimate the maximum kills per salvo, so we based the estimate on additional experiments with the high-resolution simulation. In these experiments we fired salvos of one and two TACMS at groups of target vehicles ranging from 1 to 36 vehicles per group. The vehicles were arranged in different configurations, as if they were traveling in single file or meeting at a crossroad or at a fork in a

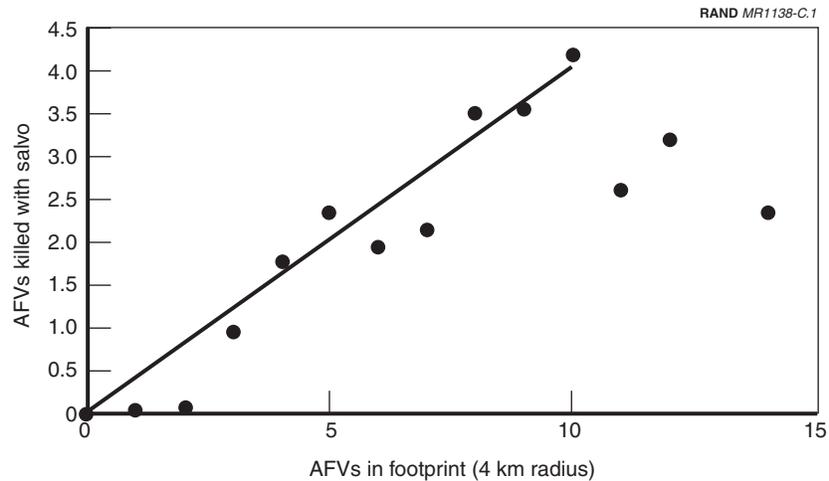


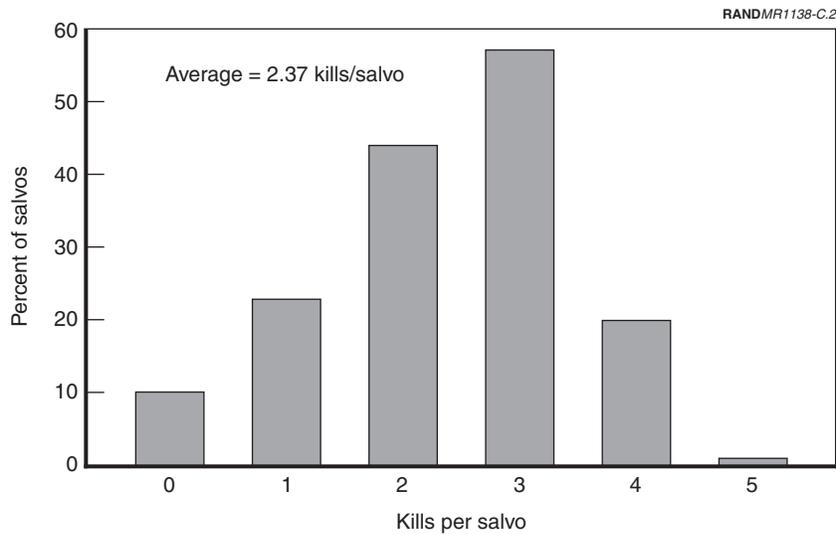
Figure C.1—Kills Versus Targets

road. A single TACMS/BAT missile killed roughly 5 target vehicles out of a group of 18, 6 out of 27, and 7 out of 36. Two missiles killed about twice the number of vehicles as one. We therefore truncated PEM's kill per salvo at $\text{MaxKills} = 6$ for a salvo of one missile. This implies a limit of 12 kills per salvo of two missiles for the conditions assumed (especially the acoustic environment).

The points in Figure C.1 are actually averages of many trials from the high-resolution model. The point with 5 AFVs in the footprint, for example, is the average of 155 trials. There is a considerable amount of variation in the number of AFVs killed per salvo, as shown in Figure C.2. To represent this variation, we make the parameter FracKill in PEM a random variable with a triangular distribution. Its minimum, mode, and maximum are (for a two-missile salvo) 0, 0.41, and 0.82, respectively.

DISCUSSION

For salvos with three to ten AFVs in the footprint, there is a reasonably good match between kills per salvo calculated from PEM's and



**Figure C.2—Variation in Kills per Salvo
(Includes Only Salvos with 5 AFVs in Footprint)**

kills per salvo from the high-resolution simulation. But when the number of AFVs in the footprint is either very small (one or two) or larger than ten, PEM appears to estimate significantly more kills per salvo than the high-resolution model.

Consider first the points in Figure C.1 with only one or two AFVs in the footprint. In the DSB '98 simulations, almost no AFVs were killed in these trials. However, we also conducted some experiments with the high-resolution model in which a single AFV was killed by a single TACMS with probability 0.87, even when the missile's aim point was as much as six kilometers distant from the AFV. On the face of it, the high-resolution model is contradicting itself! However, a second experiment showed that when background noise was present, BAT could no longer pick up a target group of vehicles from as far away. Perhaps when the target group contains only one or two AFVs, it produces too little noise to stand out from the background except when BAT's aim point is very close to the target group. Whether this explanation resolves the apparent contradiction awaits further investigation.

Consider next the points in Figure C.1 with more than ten AFVs in the footprint. These show considerably fewer kills per salvo than the high-resolution experiments on which MaxKills is based. Our tentative explanation is that the configuration of vehicles in these large groups confuses BAT. We have observed this phenomenon in previous studies, and while we haven't been able to characterize the confusing configurations definitively, we know they generally occur when Red columns meet at crossroads. In the DSB '98 cases, Red's march doctrine precluded AFVs in the same column from concentrating, so large concentrations of AFVs occurred only at crossroads where two Red columns could come together.

One may ask whether PEM's kills-per-salvo function should be modified to take account of this phenomenon. We do not think this is necessary when considering dispersed Red march formations, for large concentrations of target vehicles will be rare. We speculate that it will not be very important when considering more compact Red formations, for most large concentrations of target vehicles will not occur at crossroads. We hope to investigate this phenomenon further, however.

Finally, consider the points in Figure C.1 with three to ten AFVs in the footprint. The PEM relation fits these points extremely well, though not perfectly. For example, it is disconcerting that more AFVs are killed per salvo when there are five AFVs in the footprint than when there are six or seven.

This is systematic and not due simply to random variation. Each point in Figure C.1 is the average of many tens or hundreds of salvos. While the random variation in kills per individual salvo is large, the random variation on the average of a hundred salvos is much lower.

One possible explanation is that in the DSB '98 simulations, different salvos targeted different mixes of the four types of AFVs (RADAXX, RAPC1F, RAPCXF, and RTANKF), each of which had its own vulnerability to TACMS/BAT. Moreover, early in the simulations, AFV packets could overlap packets of other kinds. Thus many vehicle types might be in the footprint of a single salvo of TACMS missiles. Table C.1 lists the 13 types of vehicles found in the DSB '98 simulations, along with the number of each type in the simulations, its

Table C.1
Numbers and Kill Fractions of Red Vehicles

Vehicle Type	Number	Kill Fraction	Exposure Odds
RADAT	12	0.057	1.03
RADAXX**	4	0.146	1.72
RAPC1F**	35	0.123	1.34
RAPCXF**	32	0.318	0.97
RHELRL	36	0.000	0.10
RLCVA	12	0.059	2.00
RLCVAA	27	0.264	0.28
RLCVM	12	0.010	2.00
RLTATK	7	—	0.00
RMCMV	21	0.000	1.40
RMCVGM	12	0.000	0.01
RTANKF**	33	0.250	1.05
RTRK3	300	0.009	1.08

** AFVs.

likelihood of being in the footprint of a salvo of TACMS missiles, and a measure of its vulnerability to TACMS with BAT.

The kill fraction of a vehicle type is the ratio of the number of kills of that type in all the simulated cases to the actual number of exposures. Since the kill fractions of different types of AFVs ranged from 0.123 to 0.318, the maximum error from using the weighted average kill fraction is about 50 percent. The actual error will be less, however, if all AFV packets have about the same proportions of the high kill fraction vehicles (RAPCXF and RTANKF) versus low (RADAXX and RAPC1F). In fact, most AFV packets contained 70 percent or more vehicles with the higher kill fractions. In only 1 AFV packet out of 13 were fewer than half the vehicles either RAPCXF or RTANKF.

The exposure odds for a vehicle type is the ratio of the actual number of appearances of that vehicle type in footprints of simulated TACMS salvos to its pro rata share of the total number of appearances of all vehicles. While all types of AFVs received their pro rata share of exposures or somewhat more, other types of vehicles were equally likely to be exposed, and they often appeared in footprints that also contained AFVs. This was especially likely early in the scenario, before the three different kinds of packets (see Appendix B) had

separated. We speculate that BAT might first be attracted into the neighborhood by the noise of AFVs, but the submunitions could be “distracted” by non-AFV vehicles during their IR detection stage.