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SYNERGISTIC EFFECTS OF MULTIPLE COUNTERMEASURES AND THEIR IMPLICATIONS FOR TOSOM MODELING

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ABSTRACT (U)

(U)   The Threat Oriented Survivability Optimization Model (TOSOM) treats multiple countermeasures as independent operators without either synergistic or anti-synergistic effects.   This is accomplished simply by:

$$\text{Effectiveness}_{(CM\ total)} = 1 - ((1 - \text{Eff}_{(CM1)}) \times (1 - \text{Eff}_{(CM2)}) \times (1 - \text{Eff}_{(CM3)}) \times \ldots \times (1 - \text{Eff}_{(CMn)}))$$

While this methodology may be appropriate for some countermeasure combinations such as false target generator and Active Protection Systems, it is not for such combinations as a false target generator and smoke.

(U)   This paper will examine various synergistic/anti-synergistic countermeasure combinations and how they would possibly contribute to a non-optimal survivability suite.   The paper will also propose an intermediate step in the TOSOM modeling process to allow for the correction of some of these errors.

(U)   Introduction

(U)   Historically, the method for providing additional protection to a combat vehicle in the presence of a more lethal threat was to increase the thickness and/or composition of the armor. This method is no longer feasible due to the requirements for strategic/tactical transportability and the ability of the threat to target the vehicle from any axis. Thus, we have arrived at a point where traditional protection methods (i.e. armor) can no longer be used to increase the survivability of combat vehicles.

(U)   New approaches to increase combat vehicle survivability such as signature management, jammers, decoys and Active Protection Systems (APS) are being developed to "buy back" some

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of the survivability that was formerly provided by armor. While the operation of these countermeasures by themselves is relatively well understood, their use in combinations is less so.

(U)   The use of TOSOM in the modeling of countermeasure suites treats the multiple countermeasures as independent operators without either synergistic or anti-synergistic effects. The effectiveness of a multiple countermeasure suite is calculated thus:

$$\text{Effectiveness}_{(CM\ total)} = 1 - ((1 - \text{Eff}_{(CM1)}) \times (1 - \text{Eff}_{(CM2)}) \times (1 - \text{Eff}_{(CM3)}) \times \ldots \times (1 - \text{Eff}_{(CMn)}))$$

(U)   This paper will show that while this is true is some cases, it does not necessarily hold for all cases. This can have the effect of over- or understating the value of some combinations. The results of these errors and can be relatively minor is some cases but quite severe in others as will be shown in what follows.

(U)   Countermeasure Effectiveness Values

(U)   All of the countermeasure effectiveness in this paper are notional. They are for illustrative purposes only and do not represent any actual or proposed countermeasure.

(U)   Countermeasure Combination 1: MCD and APS

(U)   Let:

$\text{Eff}_{(MCD)} = 90\%$
$\text{Eff}_{(APS)} = 80\%$

(U)   Thus:

$$\text{Eff}_{(MCD + APS)} = 1 - ((1 - .90) \times (1 - .80)) = 98\%$$

(U)   This is the traditional TOSOM expected result. The MCD would defeat 90% of this threat and the APS would engage the remaining 10% for an overall effectiveness of 98%. This is possible because the two countermeasures are independent from each other and the normal MCD defeat range of an ATGM is sufficient to allow for an APS engagement should the MCD fail.

(U)   Countermeasure Combination 2: LATADS and APS

(U)   Let:

$\text{Eff}_{(LATADS)} = 80\%$
$\text{Eff}_{(APS)} = 80\%$

(U)   Thus:

$$\text{Eff}_{(\text{LATADS} + \text{APS})} = 1 - ((1 - .8) \times (1 - .8)) = 96\%$$

(U)   While this is the traditional TOSOM result, it can be incorrect. The critical issue is at what point is it necessary to commit to an APS launch and can the Laser Target Decoy System (LATADS) continue to function during an APS launch and flyout. The LATADS works by detecting the laser energy of a laser designator and projecting a similar pattern off the vehicle causing the threat to miss the vehicle. Because the LATADS traditionally places the decoy spot well within the engagement distance of an extended range APS, the launch decision has to be made prior to confirmation of a successful LATADS defeat.

(U)   As long as the LATADS can continue to function during the APS engagement, the TOSOM methodology applies. Either the APS will defeat the threat, at 80% effectiveness, or the LATADS will defeat the remaining 20% of the threat, at 80% effectiveness. However, should the LATADS be forced to cease operation prior to a successful defeat due to conflicts with the APS, and if there is insufficient time to reactive following an APS failure, then the effectiveness of the combined suite is not 96% but 80% (that of the APS).

(U)   Countermeasure Combination 3: LATADS and Smoke

(U)   Let:

$$\text{Eff}_{(\text{LATADS})} = 80\%$$
$$\text{Eff}_{(\text{Smoke})} = 50\%$$

(U)   Thus:

$$\text{Eff}_{(\text{LATADS} + \text{Smoke})} = 1 - ((1 - .80) \times (1 - .50)) = 90\%$$

(U)   In this case the traditional TOSOM result of 90% is in error. The application of smoke must be initiated as soon as the threat is detected to enable the smoke cloud to develop and the vehicle to maneuver out of the way of the threat. However, the very nature of the smoke cloud will render the LATADS ineffective. In order for the smoke cloud to be effective, it must obscure the vehicle in both the visual and presumably Infrared (IR) bands, this obscuration would prevent the threat laser from designating the vehicle and the LATADS from mimicking this onto the ground. The net result is that the effectiveness of this suite is not the 90% as calculated by TOSOM but the 50% effectiveness of the smoke alone.

(U)   Countermeasure Combination 4: APS and Armor

(U)   Let:

$$\text{Eff}_{(\text{KE APS})} = 20\%$$
$$\text{Eff}_{(\text{Armor})} = 20\%.$$

(U)   Thus:
$$Eff_{(KE\ APS\ +\ Armor)} = 1 - ((1 - .20) \times (1 - .20)) = 36\%$$

(U)   In this example we postulate an armor appliqué for a thin-skinned vehicle. This appliqué is such that it is only 20% effective in stopping a KE penetrator. Likewise we envision a KE APS that defeats the KE penetrator by breaking the round into a number of smaller pieces. However, the fragments are of such size that upon striking the baseline vehicle, the KE APS is only 20% effective in protecting the vehicle. This results in a TOSOM effectiveness of 36%.

(U)   But the TOSOM result of 36% ignores the effect of the appliqué armor on those fragments. Let us examine this result from a slightly different perspective. Let us assume that the KE APS has an 80% probability of intercepting and breaking up the KE penetrator and that the appliqué armor has an equal probability of defeating those fragments.

(U)   Then:

$$Eff_{(KE\ APS\ @\ Round\ Defeat)} = 80\%$$
$$Eff_{(Armor\ @\ Fragment\ Defeat)} = 80\%$$

(U)   Thus:

$$Eff_{(KE\ APS\ +\ Armor)} = Eff_{(KE\ APS\ @\ Round\ Defeat)} \times Eff_{(Armor\ @\ Fragment\ Defeat)} = .80 \times .80 = 64\%$$

Plus the survivability contribution of the appliqué armor alone of the non-intercepted KE round:

$$Eff_{(Armor\ +\ KE\ APS\ Failure)} = (1 - Eff_{(KE\ APS\ @\ Round\ Defeat)}) \times Eff_{(Armor)}$$

$$Eff_{(Armor\ +\ KE\ APS\ Failure)} = (1 - (1 - .80)) \times .20 = 4\%$$

$$Eff_{(Total)} = 64\% + 4\% = 68\%$$

(U)   This is perhaps the clearest example of the synergistic effects of countermeasures that is discounted in TOSOM. The TOSOM calculated effectiveness of 36% is only 53% that of the synergistic value.

(U)   <u>Countermeasure Combination 5: APS and Signature Management</u>

(U)   Let:

$$Eff_{(APS)} = 80\%$$
$$Eff_{(Signature\ Management)} = 80\%$$

(U)   Thus:

$$Eff_{(APS\ +\ Signature\ Management)} = 1 - ((1 - .80) \times (1 - .80)) = 96\%$$

(U)   This is another case in which the TOSOM result is not necessarily correct. In this example we are protecting a vehicle against a faller type threat such as a SADARM. The effectiveness value for the signature management treatment is predicated on a fully signature management treated vehicle, which implies that the APS is either signature management treated or that it is covered and must be raised to firing position thus negating the signature management. For this example, we will assume that the APS launcher is stowed under the signature management treatment.

(U)   The long standoff range of the faller threat means that the decision to raise the APS must be made early in the engagement before the threat is within shooting distance or to rely entirely on the signature management. In this case the effectiveness of the suite is only that the APS, 80% not the 96% that TOSOM would calculate. If, however, the APS could be signature management treated to the same level as the vehicle and the APS radar would not betray the vehicle, then TOSOM would provide the correct answer.

(U)   Possible Solutions

(U)   Two possible solutions to the synergy/anti-synergy problem are bundling and post process editing. An admitted drawback to both methods is the requirement that the analyst know what countermeasure combinations will generate synergy/anti-synergy effects and what the magnitude of this result will be.

(U)   Bundling

(U)   Bundling is the creation of a limited (hopefully) set of countermeasure suites that have synergistic/anti-synergistic effects. From the above examples this might be bundling APS and Armor as one countermeasure and perhaps LATADS and smoke as another.

(U)   Post Process Editing

(U)   This would entail editing the TOSOM output file prior to processing the results with the Analytical Hierarchical Process (APH) module or importing into either a spreadsheet or database. This is already done in limited fashion in some analyses to eliminate the double costing of some sensors that are originally allocated as for a stand alone countermeasure but would be shared for a multiple suite.

(U)   Conclusion

(U)   It has been demonstrated that various countermeasure combinations can generate either synergistic or anti-synergistic effects. This can have the effect of over- or understating the value of some combinations. The results of these errors and can be relatively minor is some cases but quite severe in others.

(U)   This is not to question the value of TOSOM. It is intended as a decision support tool in order to winnow down the large number of countermeasure combinations that are either physically incompatible or of marginal utility. Simply inputting data and blindly following the

output is not an option. As with any other model, this is no substitute for a good analyst and thorough review of both the input and output of the model.